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TABLES

Table 2.1 INVENTORY OF HYDROPOWER PROJECT (1/3)

Project/River Basin	River Name	Stage	Catch. Area (sq.km)	Annual Average Runoff (cms)	Main Features: Power Generation: Type	Installed Capacity (MW)	Energy (GWh/a)	Effect. Head (m)	Dam and Reservoir: Height (m)	Type	Reservoir Vol.: Net (MCM)	Gross (MCM)	Const. Cost (mil.US$)	Price Level (Year)	Cost/ KW (US$/ KW)	Cost/ KWh (Cent/ KWh)
I. Existing project																
a) Narayani/Gandaki																
1. Trisuli	Trisuli		4,640	-	ROR	21.0	-	-	-	C	-	-				
2. Gandak	Narayani		-	-	-	15.0	-	-	-	C	-	-				
3. Devighat	Trisuli		-	-	-	14.1	-	-	-	C	-	-				
4. Marsyangdi	Marsyangdi		3,850	209.0	ROR	69.0	45.4	91.5	38.0	C	-	3.9				
5. Phewa	Phewa lake		120	9.2	D/R	0.8	1-2	71.5	15.5	F&C	14.7	53.0				
6. Adhikhola	Adhikhola		-	-	-	5.1	-	-	-	-	-	-				
b) Sun Kosi																
1. Panauli	Sun Kosi		82	-	ROR	2.4	6.7	62.0	2.5	EF/C		0.5				
2. Sunkosi	Sun Kosi		-	-	ROR	10.1	-	-	-	C	-	-				
c) Bagmati																
1. Kulekhani No.1	Kulekhani		156	3.9	D/R	60.0	201.6	550.0	107.0	RF	73.3	85.3				
2. Kulekhani No.2	Kulekhani/ E.Rapti		180	5.0	ROR	32.0	117.9	278.0	14.5	C	-	-				
II. Under planning or proposed																
a) Narayani/Gandaki																
1. Upper Kali Gandaki No.1	Kali Gandaki	M/P	3,070	50.0	ROR	100.0	-	800.0	10.0	C	-	-	104.0	1979	1,040	-
2. Upper Kali Gandaki No.2	Kali Gandaki	M/P	3,170	52.0	ROR	70.0	-	535.0	10.0	C	-	-	94.0	1979	1,343	-
3. Budhi Gandaki	Budhi Gandaki	Pre F/S	5,370	195.0	D/R	600.0	2,765.0	185.0	225.0	RF	2,755.0	3,320.0	739.0	1983	1,232	2.5
4. Upper Budhi Gandaki	Budhi Gandaki	M/P	3,840	110.0	ROR	130.0	-	415.0	10.0	C	-	-	143.0	1979	1,100	-
5. Upper Trisuli	Trisuli	M/P	3,550	120.0	ROR	300.0	-	800.0	15.0	C	-	-	255.0	1979	850	-
6. Trisulganga	Trisulganga	M/P	16,260	710.0	D/R	1,500.0	-	185.0	230.0	E/RF	4,300.0	11,000.0	977.0	1979	651	-
7. Mugling	Trisulganga	M/P	11,600	480.0	ROR	90.0	-	70.0	90.0	C	-	-	111.0	1979	1,233	-
8. Kali Gandaki No.1	Kali Gandaki	M/P	9,150	410.0	D/R	1,600.0	8,950.0	314.0	260.0	RF	5,200.0	6,900.0	1,105.0	1979	691	1.1
9. Kali Gandaki No.2	Kali Gandaki	Pre F/S	11,374	490.0	D/R	660.0	5,575.0	128.3	117.0	C	3,450.0	5,200.0	772.0	1985	1,170	1.3
10. Sapta Gandaki	Narayani	F/S	31,100	1,500.0	ROR	225.0	1,609.0	42.3	60.0	RF	8.5	450.0	544.0	1982	2,418	3.1
11. Kali Gandaki A	Kali Gandaki	F/S	7,100	310.0	ROR	90.0	385.0	95.0	12.0	C	1.0	2.2	110.0	1978	1,222	2.6
12. Adhikhola No.1	Adhikhola	M/P	420	29.0	D/R	180.0	-	410.0	130.0	C	800.0	930.0	187.0	1979	1,039	-
13. Seti Gandaki No.1	Seti	M/P	2,740	190.0	D/R	320.0	-	139.0	165.0	-	2,150.0	4,000.0	372.0	1979	1,163	-
14. Seti Gandaki No.2 with Seti No.1	Seti	M/P	2,960	200.0	D/R	160.0	-	63.0	85.0	E/RF	2,150.0	4,000.0	157.0	1979	981	-
15. Upper Marsyandi	Marsyandi	M/P	1,880	65.0	ROR	95.0	-	590.0	9.0	C	-	-	111.0	1979	1,168	-
16. Langtang	Langtang	M/P	250	9.0	D/R	175.0	-	1,585.0	130.0	E/RF	100.0	180.0	325.0	1979	1,857	-

Note:
- Stage: M/P : Master plan, P/S: Preliminary study, F/S: feasibility study, Pre F/S: Pre-feasibility study
- Type : ROR : Run-of-river, D/R : Dam and reservoir
- Dam type : RF : Rockfill, EF : Earthfill, C : Concrete gravity, S/M : Stone masonry, A/F : Asphalt facing, G/F Gravel-Fill
- Cost/kw is derived by dividing construction cost with installed capacity.
- Cost/kwh is estimated by using discount rate of 10 % and project life of 50 years.

Table 2.1 INVENTORY OF HYDROPOWER PROJECT (2/3)

Project/River Basin	River Name	Stage	Catch. Area (sq.km)	Annual Average Runoff (cms)	Main Features: Power Generation: Type	Installed Capacity (MW)	Energy (GWh/a)	Effect. Head (m)	Dam and Reservoir: Height (m)	Type	Reservoir Vol.: Net (MCM)	Gross (MCM)	Const. Cost (mil.US$)	Price Level (Year)	Cost/KW (US$/KW)	Cost/KWh (Cent/KWh)
b) Sun Kosi																
1. Arun No.1	Arun	M/P	32,998	405.0	ROR	146.0	1,166.0	109.0	20.0	C	-	-	277.0	1985	1,897	2.2
2. Arun No.2	Arun	M/P	32,881	398.0	ROR	239.0	1,967.0	196.0	18.0	C	-	-	292.0	1985	1,222	1.4
3. Arun No.3	Arun	D/D	29,310	365.0	ROR	402.0	2,960.3	288.0	65.0	C	2.0	6.5	268.0	1987	667	0.8
4. Upper Arun	Arun	F/S	26,000	280.0	ROR	300-350	2600-3000	465.0	12.0	C	-	-	396.0	1985	1,320	1.4
5. Sun Kosi No.1	Sun Kosi	M/P	16,200	657.0	D/R	1,357.0	4,640.0	119.8	147.0	C	1,500.0	40.0	1,033.0	1987	761	2.0
6. Sun Kosi No.2	Sun Kosi	M/P	10,396	547.0	D/R	1,110.0	4,760.0	130.7	166.0	C	4,370.0	3,040.0	1,027.0	1985	925	2.0
7. Sun Kosi No.3	Sun Kosi	M/P	5,520	280.0	D/R	536.0	2,070.0	116.3	140.0	C	1,220.0	550.0	582.0	1985	1,086	2.6
8. Sun Kosi high dam	Sun Kosi	F/S	61,000	1,633.0	D/R	3,489.0	16,810.0	170.5	239.0	C	4,420.0	8,500.0	2,721.0	1985	780	1.5
9. Tama Kosi No.2	Tama Kosi	M/P	3,010	168.0	ROR	196.0	1,013.0	176.0	20.0	C	-	-	245.0	1985	1,250	2.2
10. Tamakoshi No.3	Tama Kosi	M/P	2,753	154.0	ROR	123.0	603.0	107.9	60.0	C	-	-	206.0	1985	1,675	3.1
11. Mulghat	Tamur	F/S	5,640	324.0	ROR	68.4	424.6	49.0	68.0	C	63.5	67.5	135.0	1980	1,974	2.9
12. Tamur No.1	Tamur	M/P	5,085	308.0	D/R	696.0	2,750.0	131.6	153.0	C	760.0	1,890.0	846.0	1985	1,216	2.8
13. Bhote Koshi No.1	Bhote Kosi	M/P	2,320	74.0	ROR	64.0	444.0	239.8	24.0	C	-	-	89.0	1985	1,391	1.8
14. Bhote Koshi No.2	Bhote Kosi	M/P	2,170	69.2	ROR	69.0	480.0	274.0	20.0	C	-	-	93.0	1985	1,348	1.8
15. Dudh Kosi No.1	Dudh Kosi	M/P	4,100	227.0	ROR	228.0	978.0	96.6	104.0	C	-	-	449.0	1985	1,969	4.2
16. Kimti Khola No.1	Kimti Khola	Pre F/S	359	31.0	ROR	60.0	408.9	647.7	25.5	S/M	0.6	-	107.0	1988	1,783	2.4
c) Karnali																
1. Karnali (Chisapani)	Karnali	F/S	43,679	1,389.0	D/R	10,800.0 (3600.0)	20,842.0	185.0	270.0	G/F	12,000.0	16,000.0	6,396.0	1989	592	2.8
2. Upper Karnali	Karnali	Pre F/S	20,120	518.0	ROR	230.0	1,665.0	141.0	49.0	C	3.1	7.5	365.0	1989	1,587	2.0
3. West Seti	West Seti	F/S	4,250	170.0	D/R	283.0	2,087.0	280.0	187.0	RF	1,288.0	1,560.0	356.0	1986	1,258	1.6
4. Thapna	Bheri	P/S	11,090	390.0	D/R	500.0	2,980.0	160.0	-	-	2,010.0	-	528.0	1973	1,056	1.6
5. Surkhet	Bheri	P/S	11,780	415.4	D/R	600.0	3,570.0	160.0	-	-	2,700.0	-	509.0	1973	848	1.3
6. Lakarpata	Bheri	P/S	20,970	532.7	D/R	1,200.0	7,110.0	320.0	197.0	C	1,860.0	2,600.0	502.0	1973	418	0.6
7. Jabitan, Ramni, Samla, Poliparni	Karnali	P/S	2,740	69.4	ROR	124.0	960.0	-	-	-	-	-	131.7	1973	1,062	1.3
8. Bhanakot	Karnali	P/S	19,130	485.2	D/R	810.0	4,800.0	320.0	200.0	RF	-	-	615.0	1973	759	1.2
9. Bheri-Babai Div.	Bheri	P/S	-	-	ROR	200-300	-	-	150.0	RF	-	-	200-275	1980		
d) Bagmati																
1. Bagmati	Bagmati	M/P	2,700	177.0	D/R	140.0	540.0	97.0	117.0	F	2,320.0	3,220.0	243.0	1981	1,736	4.1
2. Kulekhani No.3	Kelekhani/ E.Rapti	F/S	188	7.2	ROR	22.0	59.0	105.7	45.0	C	0.4	0.7	43.0	1988	1,955	6.7
e) Kankai																
1. Kankai	Kankai	M/P	1,190	49.0	D/R	38.0	194.0	59.0	85.0	A/F	1,080.0	1,480.0	89.0	1978	2,342	4.2
2. Maikhola Loop	Kankai	P/S	670	30.3	D/R	13.0	57.0	109.0	65.0	RF	28.0	46.0	26.0	1973	2,000	4.2

Note:
- Stage: M/P : Master plan, P/S: Preliminary study, F/S: feasibility study, Pre F/S: Pre-feasibility study
- Type : ROR : Run-of-river, D/R : Dam and reservoir
- Dam type : RF : Rockfill, EF : Earthfill, C : Concrete gravity, S/M : Stone masonry, A/F : Asphalt facing, G/F Gravel-Fill
- Cost/kw is derived by dividing construction cost with installed capacity.
- Cost/kwh is estimated by using discount rate of 10 % and project life of 50 years.

Table 2.1 INVENTORY OF HYDROPOWER PROJECT (3/3)

Project/River Basin	River Name	Stage	Catch. Area (sq.km)	Annual Average Runoff (cms)	Main Features: Type	Power Generation: Installed Capacity (MW)	Power Generation: Energy (GWh/a)	Effect. Head (m)	Dam and Reservoir: Height (m)	Dam and Reservoir: Type	Reservoir Vol.: Net (MCM)	Reservoir Vol.: Gross (MCM)	Const. Cost (mil.US$)	Price Level (Year)	Cost/KW (US$/KW)	Cost/KWh (Cent/KWh)
e) Kankai																
1. Kankai	Kankai	M/P	1,190	49.0	D/R	38.0	194.0	59.0	85.0	A/F	1,080.0	1,480.0	89.0	1978	2,342	4.2
2. Maikhola Loop	Kankai	P/S	670	30.3	D/R	13.0	57.0	109.0	65.0	RF	28.0	46.0	26.0	1973	2,000	4.2
f) West Rapti																
1. West Rapti	West Rapti	Pre F/S	3,680	120.0	D/R	250-300	400-1000	140.0	90-100	EF	-	3,000.0	50-70	1976	233	0.6
2. Jhimruk (Piuthan)	Jhimruk Khola	F/S	645	25.3	ROR	10.0	70.9	180.0	3.4	S/M	0.1	-	15.0	1986	1,500	1.9
g) Mahakari																
1. Pancheshwar	Mahakari	F/S	12,100	550.0	D/R	1,000.0	-	-	232.0	C	5,200.0	6,800.0	1,438.0	1983	1,438	-
		Updating study of F/S in 1971 is being carried out by Pancheswar Consortium.														
h) Kamala																
1. Kamala	Kamala	P/S	1,530	44.4	D/R	30.0	116.0	32.0	51.0	G/F	493.0	713.0	9.6	1973	320	0.8
i) Babai																
1. Sarda	Sarda Khola	P/S	860	14.3	D/R	49.0	249.0	250.0	85.0	RF	220.0	260.0	61.5	1973	1,255	2.3

Note:
- Stage: M/P : Master plan, P/S: Preliminary study, F/S: feasibility study, Pre F/S: Pre-feasibility study
- Type : ROR : Run-of-river, D/R : Dam and reservoir
- Dam type : RF : Rockfill, EF : Earthfill, C : Concrete gravity, S/M : Stone masonry, A/F : Asphalt facing, G/F Gravel-Fill
- Cost/kw is derived by dividing construction cost with installed capacity.
- Cost/kwh is estimated by using discount rate of 10 % and project life of 50 years.

Table 2.2 INVENTORY OF IRRIGATION PROJECT (1/2)

Project	Water Source	Stage	Type	Net Command Area (ha)	Main Features: Intake: Height (m)	Crest Length (m)	Max. Intake Discharge (cms)	Irrigation Canal: Main (km)	Second. (km)	Const. Cost (mil.Rs)	Cost/ha (1000 x Rs/ha)	EIRR (%)
I. Surface water irrigation												
a) Existing Scheme												
1. Kankai	Kankai		ROR	8,000	W:1.85	126.0	10.2	37.0	24.9			
2. Kosi (West Canal)	Sapta Kosi		ROR	34,500	W	1,149.0	210.0	112.7				
3. Sunsari-Morang	Sapta Kosi/ GW(81 DTW)		ROR	66,000	F	-	45.3	53.0	299.0			
4. Kamala	Kamala		ROR	25,000	W:2.4	650.0	16.0	62.0	138.0			
5. Hardinath	Hardinath		ROR	2,000	D:80.6	-	2.0	16.0	7.5			
6. Manusmara	Southern Terai		ROR	5,800	W	40.0	6.4	17.8	39.0			
7. Jhaj	Southern Terai		ROR	1,500	F	-	4.3	16.0	32.6			
8. Narayani Stages I, II, III	Narayani		ROR	40,100	Gandaki Barrage		71.0	94.0	471.0			
9. Sirsia Dudhora	Bherai		ROR	1,200	F	-	3.3	2.1	12.7			
10. Chitwan	Trisuli		ROR	11,200	F	-	11.0	54.6	90.0			
11. West Gandak	Narayani		ROR	13,400	Gandaki Barrage		8.3	25.8	28.0			
12. Banganga	Banganga		ROR	6,500	W	200.0	8.5	4.6	25.0			
13. Pathraiya	Pathraiya		ROR	2,133	W:about 3.0	54.9	2.8	9.9	30.0			
14. Mahakali Stage I	Mahakali		ROR	5,000	Sarda Barrage in India		28.3	13.0	60.0			
15. Mohana	Mohana		ROR	3,500	W:1.0	212.0	8.0	1.9	25.5			
16. Khutia Stage I	Khutia		ROR	1,500	W:3.0	175.0	about 5.0	5.0	16.5			
18. Bagmati Phase I	Bagmati		ROR	30,000	W	404.0	112.6	37.0	176.0			
19. Rato	Southern Terai	F/S	ROR	3,200	W:1.2	200.0	6.0	16.2	22.0			
b) Under planning or proposed												
1. Kankai Multipurpose	Kankai	F/S	D/R	67,000	W:1.85	126.0	-	37.0	198.0	7,204.0	107	13.7
2. Eastern Terai	Southern Terai/ GW(90DTW)	F/S	ROR/GW	7,000	F	-	-	-	-	520.7	74	13.3
3. Sunkosi-Kamala Diversion	Sapta Kosi/ Kamala	M/P	D/R	175,000	Kurule intake:48.6 Kamala dam : 51.0		72.0 57.0	152.5		15,365.0	103	12.3
4. Kamala Multipurpose	Kamara	P/S	D/R	96,000	D:51.0	-	90.7	73.7	294.7	6,321.0	95	13.6
5. Bagmati Mutipurpose	Bagmati	F/S	D/R	120,000	W	404.0	112.6	562.0	1,140.0	14,490.0	121	11.3
6. Bagmati Phase II	Bagmati	F/S	ROR	120,000	W	400.0	112.6		154.7	606.8	16	17.8
7. East Rapti	E.Rapti	D/D	ROR	9,500	W:2.6	370.0	14.3	24.0	81.0	720.3	76	18.0
8. Marshawar Lift	Southern Terai	F/S	ROR by pump	5,600	P	-	6.5	49.0	200.0	147.7	26	33.3
9. West Rapti Multipurpose	W.Rapti	P/S	D/R	76,070	D:90-100	-	-			4,095.0	74	16.1
10. Sikta	W.Rapti	F/S	ROR	36,070	W:14.0	330.0	52.0	36.0	75.7	3,163.0	88	5.2
11. Bheri-Babai Diversion	Bheri-Babai	P/S	ROR	40,000	Bheri diversion dam		35.0			6,938.0	79	18.4
12. Babai	Babai	D/D	ROR	13,500	W:4.0	270.0	11.8	23.0	90.0	925.3	69	8.3
13. Geruwa Island	Karnali	F/S	ROR	15,000	F	-	-	91.0	24.3	-	-	-
14. Jamuar Nala	Karnali	F/S	ROR	13,600	-	-		-	-	-	-	-
15. Karnali Multipurpose	Karnali	F/S	D/R	190,950	D:270.0	-	322.0	134.0		14,853.0	78	12.7
16. Khutia Stage II	Southern Terai	F/S	ROR	2,500	W:3.0	175.0	about 8.0	2.5	3.2	132.7	88	3.4
17. Mahakali Stage II	Mahakali	F/S	ROR	6,800	Sarda Barrage		28.3	-	-	615.7	91	17.9

Note :
- Irrigation schemes with net irrigation area more than 1000 ha are included in the above inventory.
- ROR : run-of-river, D/R : dam and reservoir, GW:groundwater, W:weir, F: free intake, D:dam
- Stage: M/P:master plan, F/S: feasibility study, P/S: preliminary study, R: reconnaissance, D/D : detailed design
- Column with symbol of "-" means data not collected.
- Features of dam and reservoir for multipurpose schemes are shown in the inventory of hydropower schemes.

Table 2.2 INVENTORY OF IRRIGATION PROJECT (2/2)

Project	Stage	Type	Main Features: Irrigation Area (ha)	Main Features: Nos. of Tube Well	Main Features: Pump Capacity (cm/hr)	Const. Cost (mil.US$)	Cost/ha (US$/ha)	EIRR (%)
II. Groundwater irrigation								
a) Existing schemes								
1. Narayani TW		DTW	2,700	29	-			
2. Bhairawa-Lumbini TW Stages I and II		DTW	12,000	102	200-300			
3. Kailali-Kanchanpur		STW/DTW	7,100	233	-			
4. Sagarmata		STW	19,800	2,340	-			
5. Sarlahi, Saptari, Mahottari		DTW	2,065	16	-			
b) Under planning or proposed								
1. Bhairawa-Lumbini TW Stage III	F/S	DTW	7,875	73	200-300	564.7	66	22.4

Note :
- Irrigation schemes with net irrigation area more than 1000 ha are included in the above inventory.
- DTW: deep tube well, STW: shallow tube well
- Stage: F/S: feasibility study
- Column with symbol of "-" means data not collected.
- Features of dam and reservoir for multipurpose schemes are shown in the inventory of hydropower schemes.

Table 2.3 INVENTORY OF WATER SUPPLY PROJECT

Project	Water Source	Supply Capacity (1000 person) by 2001	Present (1986)	Incremental	Prpject Cost (mil.Rs)
I. Urban water supply					
1. Dipayal	SW	20	9	11	38.3
2. Mahendra N	GW	55	12	43	75.2
3. Dhangadi	GW	54	11	43	58.2
4. Birendra N	SW	59	9	50	169.4
5. Tribhuvan	SW	52	9	43	89.6
6. Nepalganj	GW	107	36	71	89.4
7. Pokhara	SW	161	127	34	195.2
8. Tansen	P-SW	42	10	32	78.2
9. Taulihawa	GW	49	10	39	33.3
10. Butwal	GW-SW	103	30	73	56.9
11. Bhairawa	GW	123	31	92	94.6
12. Kathomandu	GW-SW	729	500	229	1,141.3
13. Lalitpur	included in Kathmandu system				
14. Bhanktapur	GW-SW	62	31	31	36.5
15. Hetauda	GW-SW	125	19	106	79.7
16. Banepa	GW	22	12	10	33.3
17. Bharatpur	GW-SW	59	15	44	81.1
18. Birganj	GW	514	50	464	373.0
19. Kalaiya	GW	46	12	34	27.2
20. Janakapur	GW	212	17	195	155.9
21. Jaleswar	GW	58	12	46	37.1
22. Dhankuta	SW	19	9	10	46.0
23. Ilam	SW	18	5	13	47.6
24. Lahan	GW	85	11	74	79.9
25. Dharan	GW-SW	180	50	130	90.6
26. Rajbiraj	GW	59	15	44	58.4
27. Biratnagar	GW	371	83	288	232.9
28. Damak	GW	121	7	114	167.9
29. Bhadrapur	GW	74	35	39	50.9
Total		3,579	1,177	2,402	3,717.6
II. Rural water supply schemes					
1. Shllow TW					
Far Western	GW	1,086	158	928	15.3
Middle Western	GW	642	187	455	7.5
Western	GW	1,301	101	1,200	19.8
Central	GW	2,337	479	1,858	30.7
Eastern	GW	2,803	45	2,758	45.5
Total		8,169	970	7,199	118.8
2. Piped System					
Far Western		1,346	104	1,242	511.0
Middle Western		2,164	271	1,893	703.0
Western		2,668	628	2,040	666.0
Central		2,764	822	1,942	612.0
Eastern		2,165	366	1,799	770.0
Total		11,107	2,192	8,916	3,262.0

Note : GW : Groundwater, SW : Surface water
Price level : 1986

Source : Water Supply and sanitation Sector Study, 1986, UNDP/World Bank

Table 2.4 LIST OF MAJOR NATURAL HAZARDS IN NEPAL

Year	Description
1934	- Earthquake in Bihar and Nepal
1964	- Glacial lake burst and flooding in the Arun river
1968	- Rockslide on 5th March and blocking of the Burhi Gandaki river, a second landslip on 17th July and a third one on 1st August which caused the flood with the peak flood discharge of 5,210 m^3/s
1969	- Flood in the Gandaki river basin
1971	- Flood in the Gandaki river basin
1974	- Rockslide and damming of the Ankhu Khola at Labu bensi and washing out of Arughat Bazar town
1977	- Glacial lake burst and flooding in the Tamur river
1980	- Bhajhang earthquake
1980	- Glacial lake burst and flooding in the Tamur river
1981	- Glacial lake burst in head region of the Bhote Kosi
1981	- Glacial lake burst and flooding in the Barun Khola
1981	- Flooding in the Tinau river in the Terai plain
1985	- Glacial lake burst of Dig Cho and washing out of Namche hydropower station
1986	- Rockslide and flash flood in the Gandaki Khola on 30th June
1987	- Flood in the Sun Kosi river and damage to the Sun Kosi hydropower station
1987	- Flood in the eastern Terai

Source : Natural Hazards and Man Made Impacts in the Nepal Himalaya

Table 2.5 DAMAGE RECORDS DUE TO NATURAL DISASTER IN FISCAL YEAR 1985/1986 (1/2)

River Basin	District	Damages						
		Human		Live-stock (nos)	Houses (nos.)	Crops (ha)	Loss of Property (US$)	Bridges
		Death (Person)	Injury (Person)					
1. Mahakali	Darchula	1	4		6		834	
	Baitadi				3			
	Dadeldhura				4		2,084	2
2. Karnali	Humula							
	Mug							
	Dolpa	4		1	1		750	
	Jumla	2	1					
	Kalikot							
	Bajura	1	2		2			1
	Bajhan							
	Doti							
	Achham				10		5,625	
	Dailekh	2	2		1			
	Jajarkot				17			
	Rukum			10	7		17,988	
	Surkhet		3		10	850	10,320	
3. Southern Border No	Kanchanpur			67	41		3,238	
	Kailali			21	6			
4. Babai	Bardiya				15			
	Salyan	7	5	2			5,354	
5. Southern Border No	Bake							
6. West Rapti	Pyuthan				44		4,250	
	Rolpa							
	Dan Deukhun	1		12			44,000	
7. Southern Border No	Kapilbastu							
	Rupandehi							
8. Narayani/Gandaki	Mustan	1			539		291,667	
	Manan					14		
	Gorkha	4	2		1			
	Dhadin	30	55	59	46		208	
	Rasuwa	3		6	4		833	
	Nuwakot	56		231	66	3,859	284,573	
	Chitwan	1			1		333,333	
	Lamjun				1			
	Tanahu	4						
	Nawarparasi				4			
	Kaski							
	Syanja	2	9	9	65		35,517	
	Palpa	2	2					
	Myagdi	2		16	3		41,667	
	Parbat				1			
	Baglun			22	179	838	16,667	
	Gulmi	1		31	96	1,418	27,875	1
	Argghakhacl	1		16		3,473	279,004	

Source : Home Ministry HMG, Nepal, record of 1985/1986

Table 2.5 DAMAGE RECORDS DUE TO NATURAL DISASTER IN FISCAL YEAR 1985/1986 (2/2)

River Basin	District	Damages						
		Human		Live-stock	Houses	Crops	Loss of Property	Bridges
		Death (Person)	Injury (Person)	(nos)	(nos.)	(ha)	(US$)	
9. Southern Border No	Parsa	6		531	1,913	42,371	1,522,083	
	Bara			1	90		9,792	
10. Bagmati	Bhaktapur				9		280	
	Makawanpur				30			
	Lalitpur	2			4		3,125	
	K.Palanchok		3	4			5,000	
	Sinddhuli	3		19				
	Khatmandu		1	8				
11. Southern Border No	Sarlahi			164	18			
	Mahotari				15		4,048	
12. Kamala	Dhanusa	7	1					
	Siraha							
13. Southern Border No	Saptari							
14. Sapt Kosi	Sindhupalch(	118	24	616	68		922,917	7
	Dolakha	9	2		3		2,500	
	Solukhumbu	2			5		24,219	
	S.wasabha	23	1		9		6,250	7
	Taplejun							
	Ramechhap	7			2		833	
	Okhaldhunga							
	Khotan							
	Udayapur							
	Bhojpur	2	3	4	1		752	
	Dhankuta	8				6,000		
	Terhathum				2		8,528	
	Pachthar				1		46,042	
15. Southern Border No	Sunsari				213			
	Saptari							
	Morang		2	3	16	90		
16. Kankai	Ilam				2			
17. Southern Border No	Jhapa	1						
Total		313	122	1,853	3,574	58,913	3,962,156	18

Source : Home Ministry HMG, Nepal, record of 1985/1986

Table 2.6 IDENTIFIED FLOOD PROBLEM AREAS IN TERAI

Village	District	River in Terai	Area No. in Source
(1) Eastern Development Region			
1. Lagadi, Langadiyani	Siraha	Gagan	4
2. Govindpur, Lalpatti	Sapatari	Khando	5
3. Tilathi	Sapatari	Khando	6
4. Sahebganjanj	Sunsari	Burhi and Kaisali	7
5. Majhore	Morang	Lohindra	8
6. Bahundangi, Jamir, Kakarvitta	Jhapa	Mechi	9 & 20
7. Belhi, Tharhi, Balan	Saptari/Siraha	Balang	17
8. Bairawa	Saptari	Drainage congestion by Kosi river	19
(2) Central Development Region			
9. Gaur Bazaar, Gaur	Rautahat	Bagmati/Lalbakiya	1
10. Raghunathpur, Balra, Hathiyol	Sarlahi/Mahottari	Manusmara	2
11. Phulbaria, Musharia, Mukhiapatti	Dhanusha	Kamala	3(a) & 3(b)
12. Inarwa	Parsa	Uriaiya	15
13. Amarpatti	Parsa	-	18
14. Raghunathpur	Mahottari	Maraha	30
(3) Western Development Region			
15. Rangpur, Tulsipur, Bijuwa	Kapilbastu	Siswa, Marethi, Bajaha and Siswa Sagar	11
16. Suata	Nawalparasi	Narayani	10
17. near Surajpur Powerhouse	Nawalparasi	Gandaki Western Main Canal	28
18. Jamuni	Dhanusha	Jamuni	16
19. Karaulia, Heradawa, Semari, Itahawa	Kapilvastu	Banbanga	21
20. Pakhilhawa	Bhairawa	Danda	22
21. Bhiali		Ghagar	23
22. Parthahewa, Pajarbatti	Rupandehi	Rohini Nadi	24
23. Bhujehawa, Sankharpur, Kurthawal	Nawalparasi	Jharai	25
(4) Mid-western Development region			
24. Nepalgunj	Banke	West Rapti	13
25. Rajapur, Gulariya	Bardia	Karnali and Saryu	27 & 29
26. Dang Koilabash	Dang	Gurangena	12
(5) Far Western Development Region			
27. Chaugurdi, Dhansingh	Kailali	Karnali	26
28. Darchula	Darchula	Mahakali	14
29. Jogbura	Kanchanpur	Maraha Khola	31

Source : Itemwise Minutes of Standing Committee between Nepal and India on Inundation Problems, 1991

Table 2.7 LIST OF WATER LEVEL AND RAINFALL STATIONS OF NEPAL-INDIA FLOOD FORECASTING PROJECT

No.	Station	River	Existing Equipment	Equipment to be provided
I.	Water Level and Rainfall Gauge			
(1)	Karnali River Basin			
	1. Benighat	Karnali	G, D	SG, OR, SRG, W
	2. Bangga	Seti	SG, D, OR	SRG, W
	3. Jamu	Bheri	SG, D, OR	SRG, W
	4. Raskot	Karnali	OR	SG, OR, SRG, W
(2)	West Rapti			
	5. Jalkundi	Jalkundi	SG, D	OR, SRG, W
	6. Bhalubang	Bhalubang	SG, D	OR, SRG, W
(3)	Gandaki			
	7. Narayan Ghat	Narayani	SG, D	OR, SRG, W
	8. Ansing	Kali Gandaki	-	SG, D, OR, SRG, W
(4)	Bagmati			
	9. Pandhera Dobhan	Bagmati	SG, D	OR, SRG, W
	10. Hariharpur Gharhi	Bagmati	OR	SG, D, SRG, W
	11. Batra	Bagmati	-	SG, D, OR, SRG, W
	12. Patherkot	Bagmati	OR	SG, D, SRG, W
(5)	Kamala			
	13. Chisapani	Kamala	OR	SG, D, SRG, W
(6)	Kosi			
	14. Pachuwar Ghat	Sun Kosi	SG, D	OR, SRG, W
	15. Toksel Ghar	Sun Kosi	G	SG, D, OR, SRG, W
	16. Rabuwa Bazar	Dudh Kosi	SG, D	OR, SRG, W
	17. Turki Ghat	Arun	SG, D	OR, SRG, W
	18. Majhitar or	Tamur	G, D	SG, OR, SRG, W
	Angba Ghat			SG, D, OR, SRG, W
(6)	Others			
	19. Pipra	Parman	-	SG, D, OR, SRG, W
	20. Mainachuli	Kankai	SG, D	OR, SRG, W
II.	Rainfall Gauge			
(1)	West rapti			
	1. Kusum		OR	SRG, W
	2. Bhairahawa		OR, W	SRG
(2)	Gandaki			
	3. Pokara		OR, W	SRG
	4. Simra		OR, W	SRG
	5. Belwa-Girwari		OR	SRG, W
	6. Musikot		OR	SRG, W
	7. Gorkha		OR	SRG, W
	8. Nuwakot		OR	SRG, W
	9. Beni		OR	SRG, W
	10. Arughat Bazar		OR	SRG, W
(3)	Kosi			
	11. Okhaldhunga		OR, W	SRG
	12. Taplejung		OR, W	SRG
	13. Dhankuta		OR, W	SRG
	14. Sidhuli Garhi		OR	SRG, W
	15. Lhumthung		OR	SRG, W
	16. Udaipur Garhi		OR	SRG, W
	17. Chaurikharka		OR	SRG, W
	18. Jiri		OR	SRG, W
	19. Num		OR	SRG, W
	20. Kathmandu		OR, SRG, W	-
	21. Ramoli-Bairia		OR	SRG, W
	22. Nijgarh		OR	SRG, W
	23. Barahakshetra		-	OR, SRG, W
(4)	Others			
	24. Harancha		OR	SRG, W
	25. Ilam		OR	SRG,W

Note : (1) D : Discharge Station, G : Staff Gauge, OR : Ordinary Rain Gauge,
SG : Automatic Water Level Recorder, SRG : Self Recording Rain Gauge
W : Wireless Set

(2) Locations of station from No. 10 to 12 and 19 of Item I. are tentative.

FIGURES

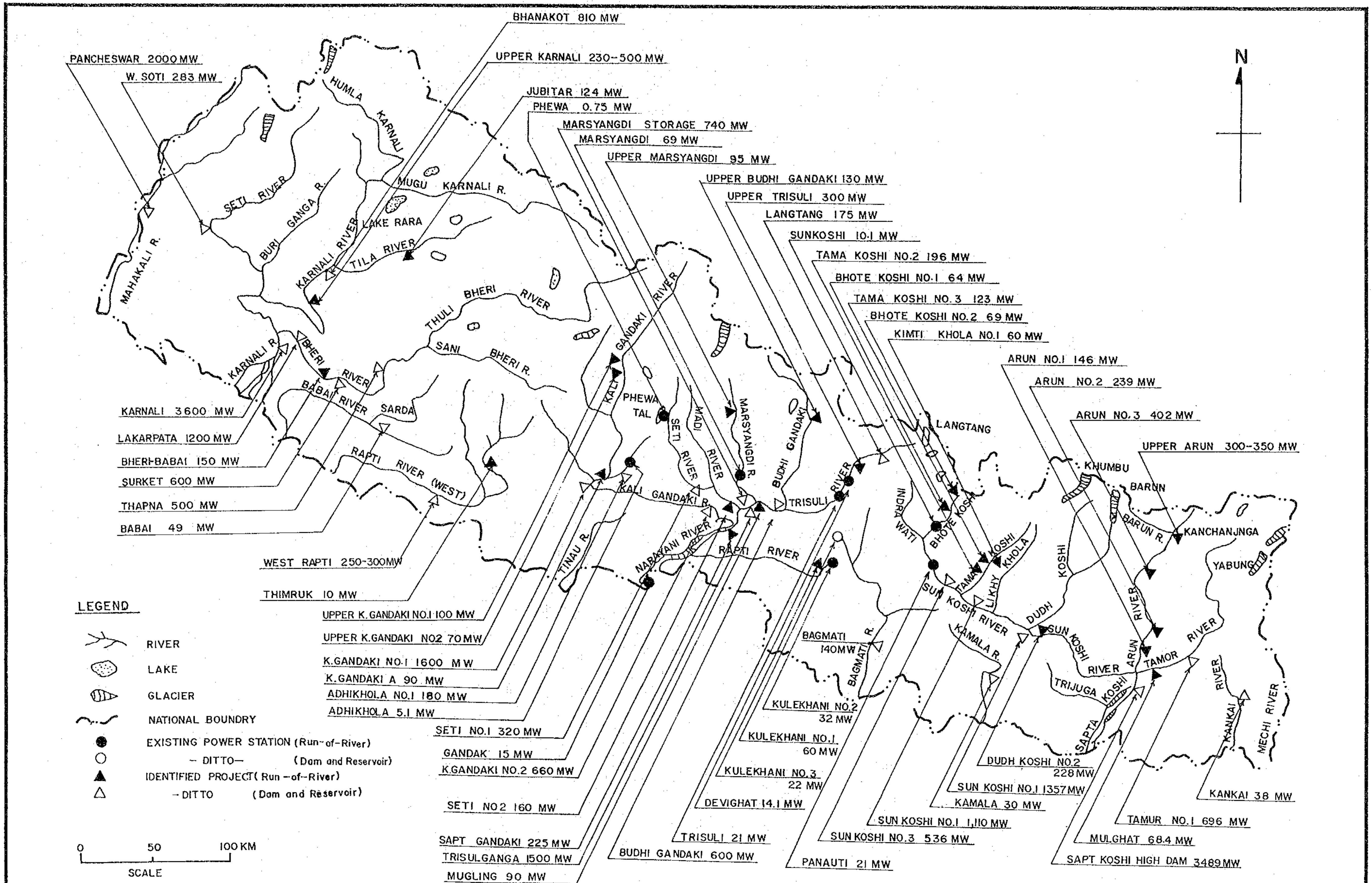
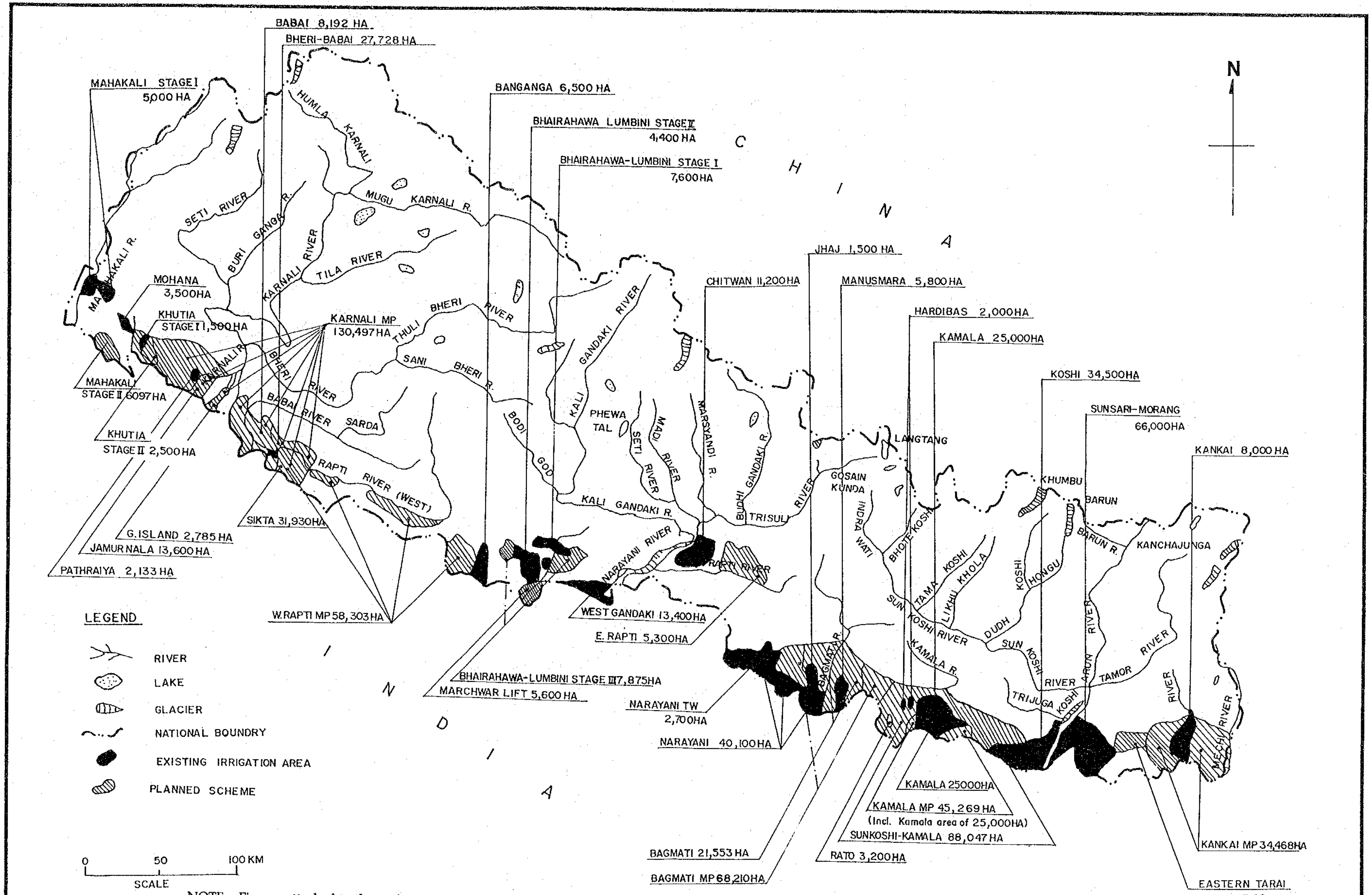


Fig. 2.1 LOCATION MAP OF HYDROPOWER DEVELOPMENT PROJECTS



NOTE : Figures attached to the project name indicates net irrigation area for the existing irrigation area and planed project.
irrigation schemes with a net irrigation area more than 1,000 ha area indicated in the figure.

Fig. 2.2 LOCATION MAP OF IRRIGATION DEVELOPMENT PROJECTS

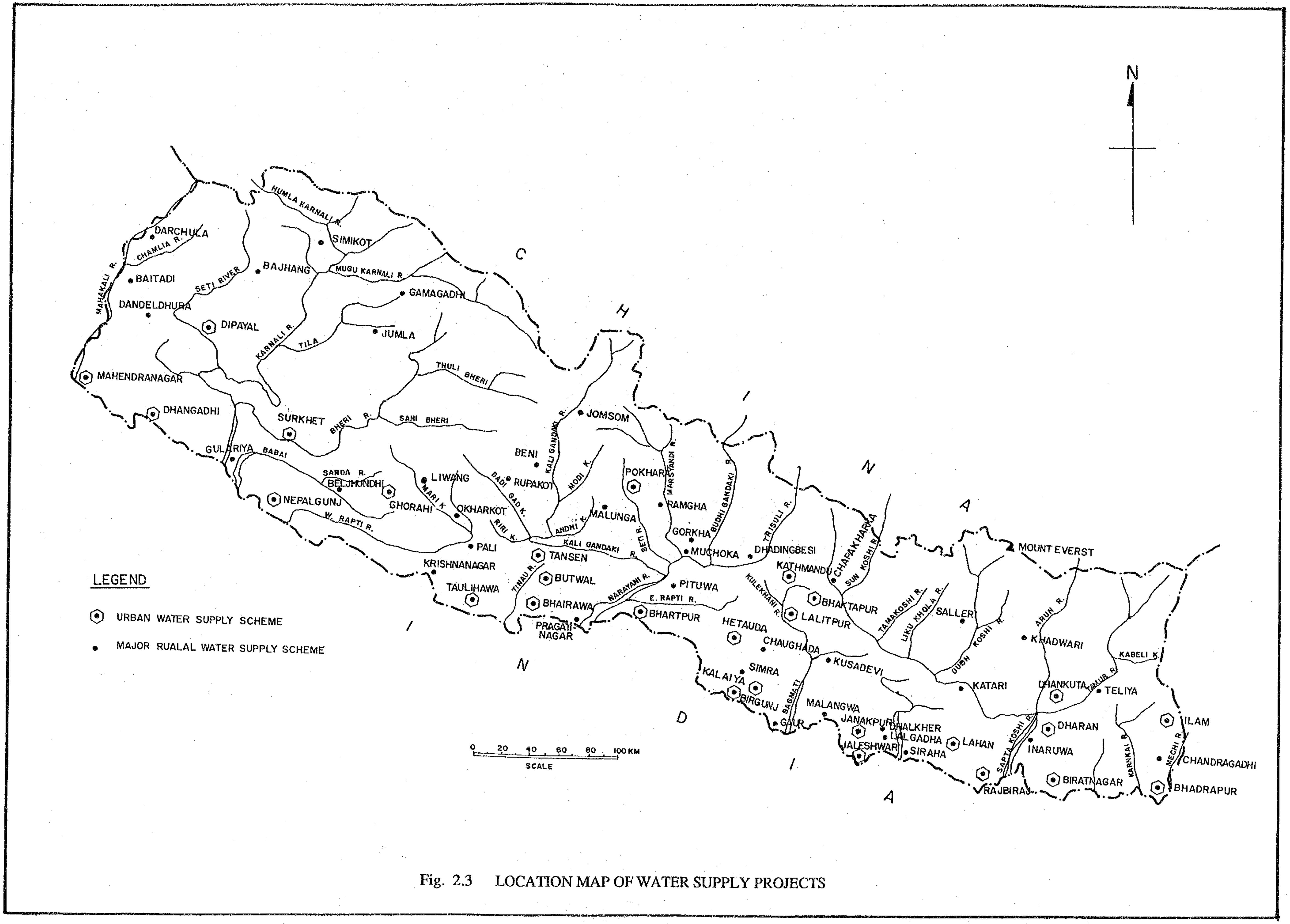


Fig. 2.3 LOCATION MAP OF WATER SUPPLY PROJECTS

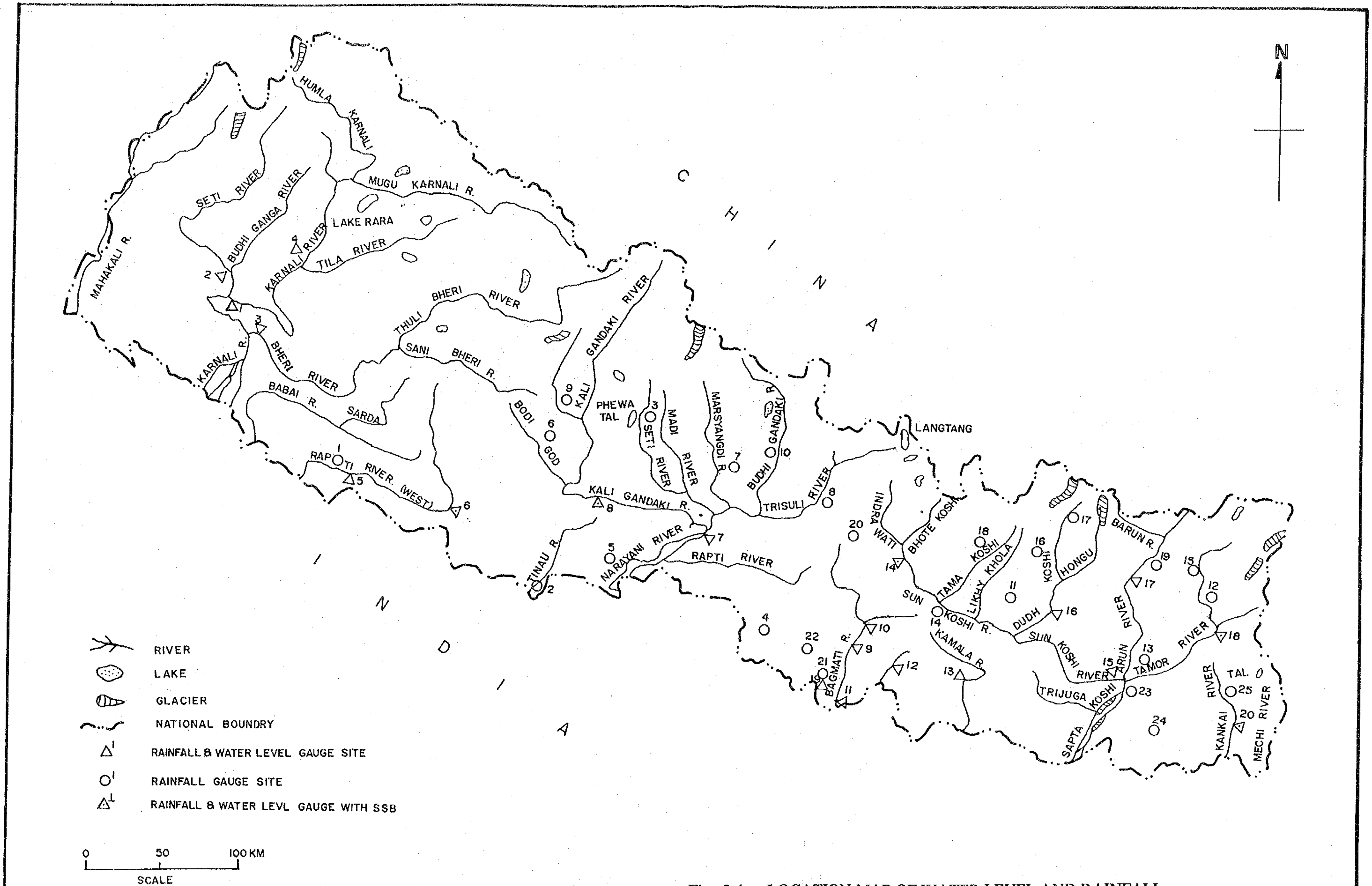
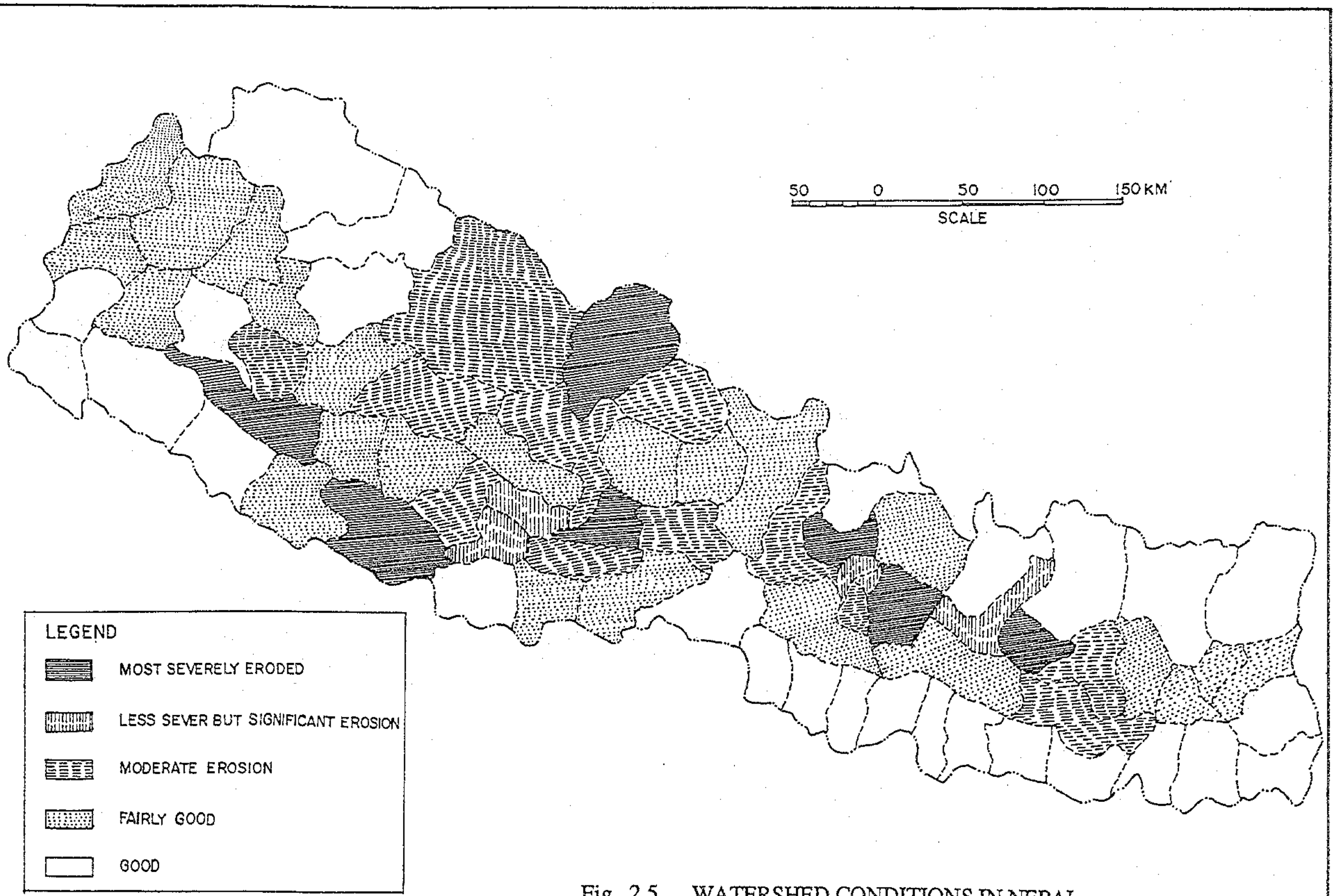


Fig. 2.4 LOCATION MAP OF WATER LEVEL AND RAINFALL STATION OF NEPAL - INDIA FLOOD FORECASTING PROJECT

Remark: The Gauging Stations are Numbered as Listed in Table 2.7.



Source : Field Document No.9 (NEP/08/029)

Fig. 2.5 WATERSHED CONDITIONS IN NEPAL

ANNEX E

OBSERVATION SYSTEM

NATIONWIDE HYDRO-METEOROLOGICAL DATA MANAGEMENT PROJECT

ANNEX E OBSERVATION SYSTEM

CONTENTS

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background

Nepal has an area of 147,181 km^2. The river basins of the Koshi, the Gandaki and the Karnali which are the tributaries of the Ganges river cover more than 60 percent of the whole country. The water resources of these rivers is one of the most important natural resources for the economic development of the country. On the contrary, neighboring countries of India and Bangladesh in the downstream reaches as well as Nepal suffer from heavy flood damage in the rainy season every year.

In view of such circumstances, His Majesty's Government of Nepal HMG)had put stress on realization of river control and water resources development in preceded five-year plans of national development. Rectification and intensification of existing hydro-meteorological observation networks has accordingly become the most urgent requirement to the HMG.

Measures so as to rearrange existing data and to reinforce a part of existing hydro-meteorological observation instrument have then taken by the HMG with the cooperation of the UNDP since 1982 up to 1987. An establishment of the Department of Hydrology and Meteorology (DHM) was realized in 1987 responding to the preceding measures.

An assistance to further improvement and reinforcement of the said observation and data management system was requested to the Government of Japan by the HMG. In response to this request, the Japan International Cooperation Agency (JICA) made a preliminary investigation for it in September, 1990. A scope of works for the assistance was agreed between the HMG and the JICA. In accordance with this scope of works, this study was proceeded in March 1991.

The objectives of the Study are as follows:

1) To formulate improvement and extension plans for nationwide hydro-meteorological data management system comprising:

    (a) hydro-meteorological observation network system and

    (b) data management system.

2) To undertake the transfer of technology to the HMG personnel and counterparts by the experts of the JICA Study Team in the course of the Study.

1.2 Objectives of the Study

Duration of the study will be for 29 months in total from March 1991 to July 1993. The study will be made dividing into two phases as follows:

(i) Phase I : Study on Long Term Programme (for 19 months from March 1991 to September 1992)

(ii) Phase II : Study on Immediate Programme (for 10 months from October 1992 to July 1993)

(1) Long term programme

Reviewing the current conditions of the hydro-meteorological observation and data management systems and finding existing problems in relation to their systems, more effective and practicable plans so s to rectify and or supplement the existing their observation networks and management are formulated in the studies of the Long Term Programme. The Target Year for the Long Term Programme is set up in the year 2005.

Transfer of technology is made through actual operation of a model observation system and any of likely problems to exist or to be possible are found through managing of the system and data.

(2) Immediate programme

For the project with high priority selected in the Long Term programme, the Immediate Programme of hydro-meteorological observation and management system will be formulated.

1.3 Items of the Study in Each Phase

Items of the study on Observation System in each Phase are summarized as follows:

(1) The First Field Investigation (from early June to end of September, 1991)

1) Collection and review of the existing data, materials and information

2) Investigation and review of the existing hydro-meteorological observation system

3) Preliminary study on the Long-Term Programme

4) Study on model observation system

(2) The First Home Work (from middle of October to end of December, 1991)

1) Basic study on the Long-Term Programme

2) Planning of model observation system

(3) The Second Field Investigation (from middle of February to end of March, 1992)

1) Supplemental field investigation for the formulation of the Long-Term Programme

2) Establishment of model observation system by constructing observation stations and installing instruments planned and designed in the preceding stages

3) Restudy on operation and maintenance method and procedure of the model observation system

(4) The Third Field Investigation (from middle of May to end of June, 1992)

1) Observation with the Model System and monitoring of the system

2) Study on problems of executing of model observation system and improve operation and maintenance of the system

(5) The Second Home Works (from middle of July to end of October, 1992)

1) Formulation of the Long-Term Programme

2) Selection of the Immediate Programme

(6) The Fourth Field Investigation (from early October to end of November, 1992)

1) Supplemental data collection for the Immediate Programme

2) Observation with the model system and monitoring of the system

3) Preparation of operation and maintenance manual for the Model Observation System

(7) The Third Home Works (from middle of January to middle of February, 1992)

1) Formulation of the Immediate Programme

(8) The Fifth Field Investigation (from beginning of June to middle of June, 1993)

1) Explanation and discussion on the Draft Final Report

1.4 Work Schedule and Reporting

The general work schedule of the study and reports is tabulated below:

Study Stage	Work Period	Submitted Report
First Field Investigation	End of May to beginning of Oct. 1991	Progress Report (1)
First Home Works	Middle of Oct. to end of Dec. 1991	Interim Report (1)
Second Field Investigation	Beginning of Jan. to end of Mar. 1992	Progress Report (2)
Third Field Investigation	Middle of May to middle of July 1992	—
Second Home Works	Beginning of July to middle of Sept. 1992	Interim Report (2)
Fourth Field Investigation	Beginning of Oct. to end of Dec. 1992	Progress Report (3)
Third Home Works	Beginning of Jan. to end of Mar. 1993	Draft Final Report
Fifth Field investigation	Beginning of June to middle of June 1993	Final Report

Work schedule is shown in Fig. 1.1.

2. NATURAL CONDITION IN NEPAL

2.1 Topography

Nepal is a mountainous country stretched over 147,181 km^2. The country shares a common boundary with India on the east, south and west. Its northern boundary is with the Tibetan Region of China. The country lies between latitudes 26°22' and 30°27' north and longitudes 80°04' and 88°12' east with the length of about 870 km on an average from east to west and width of 130 to 260 km from south to north.

The topographic features of Nepal are so persistent along the length of the country that cross sections do not differ radically. Nepal is usually divided into five topographical regions from south to north as illustrated in Fig. 2.1 which are Terai, Siwalik Ranges, Middle Mountains, High Mountains and High Himalaya. These five physiographic divisions are running nearly in parallel bands from north-west to south-east.

Every region has a distinct geological characteristics. The main characteristics of each region are tabulated below.

Physiographic Region	Elevation	Geology
1. Terai zone	60 m - 300 m	Quaternary alluvium
2. Siwaliks zone	200 m - 1500 m	Tertiary sand stone, Silt Stone, Shale and Conglomerates.
3. Middle Mountains zone	800 m - 2400 m Relief 1500 m with isolated peaks to 2700 m.	Phyllite, quartzite, Lime-stone and islands of granites.
4. High Mountain zone	2200 m - 4000 m High relief 3000 m from valley floor to ridge	Gneiss, quartzite, and mica schists
5. High Himalaya	4000 m +	Gneiss, schist, limestone and Tethys sediments.

Source: Land Resource Mapping Project, Geology Report, 1986.

2.2 Climate

In Nepal, there are five major climatological zones: subtropical, warm temperature, cool temperature, alpine, and arctic.

The climate of the Terai and the Siwalik is subtropical. Rainfall concentrates in the monsoon months. Winter temperatures are mild. The climate in the Middle Mountains is warm temperature. In winter there is occasional snow in the highest areas.

The climate in the High Mountains is cool temperature. Snow occurs in the winter months and persists on the mountain tops throughout the winter. Alpine climate appears in the higher mountain regions with low temperature in summer and an extremely frosty condition in winter. Arctic climate is above snow line where there is perpetual frost.

The annual mean precipitation is around 1,530 mm in Nepal. The seasonal variation of rainfall in Nepal is attributable to the south-east monsoon during the months of June to September. More than 75% of rainfall occurs during this period. It is of longer duration in eastern Nepal than in the western area.

Heaviest rainfall is recorded along the southern margin of the Great Himalaya Range reaching 5,000 mm yearly and along the southern foot of the Siwaliks or the Mahabharat Ranges. Drier conditions prevail in the lee of these regions. Thus alternate bends of comparatively moist and dry conditions occur parallel to the mountain ranges.

Rains occur in winter in Nepal. They originating in the Mediterranean region are significant especially in the western Nepal.

2.3 River and River Basin

All the rivers in Nepal finally come out of the southern border to India. The division of basic unit was made as listed as follows:

Basin No.	Name of River Basin
I	Mahakali river system
II	Southern border river group No.1
III	Karnali river system
IV	Babai river system
V	Southern border river group No.2
VI	Rapti river system
VII	Southern border river group No.3
VIII	Narayani/Gandaki river system
IX	Southern border river group No.4
X	Bagmati river system
XI	Southern border river group No.5
XII	Kamala river system
XIII	Southern border river group No.6
XIV	Sun Koshi river system
XV	Southern border river group No.7
XVI	Kankai river system
XVII	Southern border river group No.8

The map of river and river basins in Nepal is shown in Fig. 2.2 and the drainage areas are shown in Table 2.1.

2.4 Communication and Transportation

Climate and topography of Nepal are under very unfavorable conditions for inland transportation. Although railways and ropeways are now being operated within some limited areas by the Nepal Transport Corporation, the major transport depends on roads, and a part of the road transport is supplemented by air-craft for the tourist transport.

Communications are very important for Nepal where road transport is not adequate, and in view of significance in the social and economic development of the country, special attention of the Government has been given to the development of this sector since the first five years plan.

The major communications medium of Nepal is telecommunication and postal services. But the number of medium is very little considering a population size amounting to about 18.5 million in 1991.

3. HISTORY AND ORGANIZATION OF DHM

3.1 History of Hydro-Meteorological Service in Nepal

(1) Hydrological Services

The history of hydrology in Nepal can be divided into the following periods:

<u>Prior to 1960</u> Very little had been done in the field of hydrology in Nepal prior to 1960. The Swiss mission had obtained some data in Rosi Khola at Panauti, and Government of India had collected some data at a proposed power site at Trisuli and at three sites in the Koshi river basin for the Koshi project.

<u>1961</u> The systematic collection of hydrological data in Karnali basin was started in 1961 by the UN Special Fund for the feasibility study of power project. Hydrological Investigation Project, a joint venture between HMG/N and USAID-mission, began in 1961. This project was designed to establish a nation-wide hydrological data collection system with centralised agency to collect, compile, and publish data produced by the network.

<u>1962-1965</u> The Hydrological Investigation Project was implemented in May 1962. Hydrology Survey Section, which was established under the Department of Electricity designed a nation-wide hydrological data collection system under the supervision of two technical advisors from U.S. Geological Survey. thirty regular stream gauging stations and more than twenty partial stream gauging stations were established during 1962-65. The Hydrology Service Section grew up into Hydrological Survey Department in 1965.

<u>1966</u> Hydrological Survey Department was renamed as Department of Hydrology and Meteorology in 1966.

<u>1967</u> Surface water records of Nepal through December 1965 was compiled and published in February 1967 which was the first publication of basic information on rivers in Nepal.

1968 All the hydrological and meteorological programmes and activities were handed by the Department of Hydrology and Meteorology in 1968. During 1962 to 1968 a priority network of river stations was established on the major rivers possessing structures such as cable way, stilling wells and sediment sampling facilities, then the network expanded 120 stations until 1968.

1969 Ground Water Investigation project was started under the joint agreement between HMG/N and USAID/N.

1972 Department of Irrigation, Hydrology and Meteorology (DHM) was organized with hydrological field offices in Biratnagar, Kathmandu, Pokhara and Nepalgunj in financial year 1972.

1981-84 Four regional training courses for hydrology technicians were organized in Kathmandu under the joint sponsorship of HMG/N and UNESCO from 1981 to 1984.

1983 UNDP project on development of operational hydrology was started in 1983 and implemented until 1988.

1984 Nepal-India Flood Forecasting Project was started.

1987 Snow and Glacier Hydrology was initiated with the technical assistance of GTZ and German volunteer service started their activities.

1988 The Department of Irrigation, Hydrology and Meteorology was recognized into Department of Irrigation (DOI) and Department of Hydrology and Meteorology (DHM).

1990 The Regional Office for hydrology at Nepalgunj was combined with one for meteorology at Biratnagar. In 1991, the Regional Office at Chisapani was moved to Dhangadhi.

(2) Meteorological Services

Prior to 1964 — In 1921, the first rainfall station was established at Indian Embassy in Kathmandu, following this Station Four Climatological stations and about a hundred precipitation stations were established and operated in Nepal by India Meteorological Department.

The Indian Meteorological Department (IMD) operated and administered a network of precipitation and climatological stations in Nepal.

1965 — The Nepal Meteorological Service (NMS) was created in 1965 with technical assistance form the United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO).

1966 — The Hydrological Survey Department took over the responsibility for meteorological data collection from India Meteorological Department and was renamed as Department of Hydrology & Meteorology in 1966.

HMG/N started to establish Meteorological stations. The first Climatological records in the year 1966 was published on 1st October, 1968.

1970 — A weather satellite reception station was established with the aid from the United States of America through the WMO Voluntary Assistance Programme (VAP).

1974-1978 — WMO project on Expansion of Meteorological Services (NEP/73/003) was started in December 1974 and terminated in December 1978.

1982-1987 — WMO/UNDP project on Agrometeorology and Instrument Maintenance (NEP/78/019) was started in 1982 and terminated in 1987. The number of effective agrometeorological stations has been increased from 20 to 32 and the instrument workshop was established.

3.2 Present Organization of DHM

There are twenty one Ministries under the Office of the Prime Minister in the Government. The Ministry of Water Resources has the sole responsibility for planning, implementation and management of water resources development. The Department of Hydrology and Meteorology (DHM) is one of the Departments under the Ministry of Water Resources.

The DHM is responsible to fulfill the role of observation, management, analysis and dissemination of hydrological and meteorological data including forecasting and the other information.

The DHM consists of three (3) Divisions, five (5) Regional Offices and two (2) Sections as shown in Fig. 3.1. These Divisions are Hydrology, Meteorology and Weather Forecasting, and Climatology Divisions. All the Divisions are located in the Central Office at Babarmahal except for Meteorology and Weather Forecasting Division at Kathmandu airport. Two Sections are Administration and Accounts, and Other Technical Services in the Central Office. Regional Offices are Eastern, Central, Western, Mid Western and Far Western Regional Offices. The Eastern Regional Office has a hydrological office and a meteorological office separately, the former is located at Dharan and the latter at Dhankuta. The Central, Western, Mid Western and Far Western Regional Offices, in which both the hydrological section and the meteorological section are combined, are situated in Kathmandu, Pokhara, Birendranagar and Dhangadhi respectively.

The organization of the Central Office of the DHM was modified in January 1992 by adding three Units, which are Data Processing Unit, Training Unit and Network Unit.

3.3 Work Item of DHM

Meteorological and hydrological data in Nepal are observed, collected, processed, stored and disseminated mainly by the DHM.

The functions of the Divisions, Sections and the Regional Offices are described below:

1) Hydrology Division

- Report preparation and publication of study and analysis of different hydrological aspects:

  Periodical collection, evaluation and analysis of hydrological data of the water resources including the rivers within the boundary of the country.

- Development of different types of hydrological models including analysis of regional hydrology for long-term development and implementation of water resources.

- Study of basic models which are necessary for flood forecasting.
- Study of environmental imbalance survey of glaciers in Himalayan region.

2) Climatology Division

- Study, analyses and preparation of reports of different climatological aspects:

  Publication of report and analyzed data,

  Preparation of the special reports, which will be useful for agriculture, water resources, transportation, health, tourism and planning etc.,

  Classification of the country into different climatological regions.

- Provide necessary services to agriculture:

  Make available the climatological informations including forecasts to farmers, which are necessary for planning their long-term programmes,

  Make alert about the bad effects of weather in agriculture.

- Long-term study of climate and prepare informations about the previous and possible changes of climate and their effects in environment.

3) Meteorology and Weather Forecasting Division

- Weather forecasting:

  Provide weather forecasts and necessary information about weather to civil aviation, tourism, mountaineering and public sectors,

  Periodical study of climate and information to the people about the possible bad weather.

- Storm and flood warning.
- Establishment of observation centres and making arrangement of information about weather from abroad.

4) Other Technical Services Section

- Construction, operation and maintenance of observation centres.

  Instrument maintenance of observation centres.

- Data collection processing and management of computer.
- Chemical laboratory:

  Sediment analysis,

Chemical analysis of water and analysis of river pollution,

Analysis of air pollution and data collection of different environmental aspects.

- Training and cooperation with WMO, SAARC countries and other countries.

5) Administrative and Accounts Section

- Administration for staff and internal and public administration.
- Preparation and use of office budget.
- Auditing.
- Supervision of financial administration and preservation of office property.

6) Regional Offices

- Establishment of observation centres, their operation and maintenance and minor maintenance, and minor maintenance of instruments.
- Data collection and primary processing.
- Data collection for study of different environmental aspects.
- Connection with centre.

Three Units in Central Office of DHM was added in January 1992, these units are described below:

1) Data Processing Unit

Two (2) Hydrologists and one (1) Meteorologist in charge were assigned in this Unit and they started data checking, and instructions to the Regional Offices on data correction and processing.

2) Training Unit

This Unit aims at planning and executing their own training and education programme as well as coordinating the programme managed by the other agencies. The trainings for newly employed staffs and junior staffs of the Regional Office were executed in February and June 1992.

3) Network Unit

This Unit is responsible for investigating the present condition of observation stations and storing the station description.

4. PRECEDING AND ONGOING PROJECTS RELATED TO DHM

4.1 Development of Operational Hydrology Services (UNDP)

UNDP funded project - Development of Operational Hydrology Services started in June 1982 with the objective to develop and strengthen the institutional capability of the HMG in hydrological services. The executing agency of this project was the World Meteorological Organization (WMO) and the project was completed in December 1987.

The following seven outputs were incorporated in the project:

Output 1: Reliable operation of river gauging and sediment sampling stations with proper and timely collected data.

Output 2: Storage of hydrological data files on computer compatible support.

Output 3: Establishment of statistical summaries and estimates based on data files.

Output 4: Print out of year books containing daily values of river states and discharges, extremes, monthly and yearly averages, data on sediment transport and water temperature.

Output 5: Supply quasi-realtime operational information.

Output 6: A team of qualified and motivated professional hydrologists, hydrological technicians and assistants.

Output 7: Hydrological equipment workshop facilities.

The activities on Output 1, 6 and 7 related to observation system are described below:

(1) The activities on Output 1

The activities under this output as follows:

1) Complete repair where required on 25 stations at:

St No.	River	Location
240	Karnali	Asara Ghat
250	Karnali	Benighat
260	Seti	Bang
262	Thuli Gad	Khanayatal
270	Bheri	Jamu
280	Karnali	Chisapani
290	Babai	Bargadha
350	Rapti	Bagasoti Gaon
390	Tinau Khola	Butwal
410	Kali Gandaki	Satibeni
415	Andhi Khola	Dumrichaur
439.8	Marsyangdi	Gopling Ghat
445	Burhi Gandaki	Arughat
446.8	Phalandhu Khola	Betrawati
448	Tadi Khola	Tadipul Balkot
465	Manohari Khola	Manohara
505	Bagmati	Sundarijal
550.1	Bagmati	Sampkhel
536.2	Bishnumati	Budhanilkantha
589	Bagmati	Pandheradovan
610	Bhote Kosi	Barabino
620	Balephi Khola	Jalbire
630	Sun Kosi	Pachuwar Ghat
647	Tamakosi	Busti
795	Kankai	Mainachuli

2) Prepare detailed description of 35 stations.

3) Install seven rainfall and three river stations in the Bagmati river basin.

4) Strengthen the sediment data collection programme including establishment of two sediment laboratories in the Western and Eastern Regional Offices.

5) Improve the operational condition of stations recommending to increase the number of discharge measurement and to provide continuous maintenance.

6) Improve facilities at nine stations with priority status where rating curves merit this work including rehabilitation/ construction of recorder houses and cableways.

(2) The activities on Output 6

The activities under this output as follows:

1) Strengthening the responsibilities of the Regional Offices with good communication to the Central Office.

2) A technical training programme in the form of fellowships and group trainings.

(3) The activities on Output 7

The activities under this output as follows:

1) Order machinery and tools for the central workshop and set of tools for each field offices.

2) Order spare parts for water level recorder, sounding real and current meters.

3) On-the-job training in teaching the surveying levels and calibrating the current meter by using TT current meter in irrigation channel.

4) More comprehensive calibration for eleven (11) current meters in Bangkok.

The project concluded by emphasizing lack of motivation of the staff and the office floor space, difficult field condition such as access, damage of gauges due to flood and sediment, insufficiency of budget and management.

Among 25 stations repaired by the UNDP project, six stations are closed, washed away or troubled due to flood and sedimentation and detailed description of stations prepared by the UNDP has not been updated after.

4.2 German Development Services

Learnt during the study in the First Field Investigation is that the German Volunteer Services (GVS) has provided the DHM with assistance to improve and strengthen technical and managerial works of the Department since 1986. Four (4) German water resources engineers assigned to do the tasks are being stationed at four (4) offices named the Central, Eastern, Western and Mid-Western Regional Offices, respectively.

Their performance and services are maintained within scope of river hydrology. Their main works and activities are:

1) Guidance of hydrological observation including discharge measurement,

2) Guidance of inspection and maintenance of hydrological observation stations and equipments,

3) Guidance of data processing including hydrological data entry into the computer and development of discharge rating curve,

4) Assistance to plan training program for the DHM's junior engineers,

5) Recommendation on future plans of the DHM for water quality observation,

6) Installation of four pressure type water level gauges shown in Fig. 4.1 and so forth.

As set forth in the above, the work programme and activities being carried out by the GVS's engincers consequently overlap and duplicate to some extent with the work of the Study Team. Their activities are at all times programmed and performed, consequent upon the prior consent of the DHM, to meet immediate needs.

Whatever the hydrological outcome such as data, materials, information and so forth resulted from, both the studies of the Study Team and the GVS's engineers are reciprocally interchanged and incorporated in each study so as to develop their subsequent studies and plan formulation.

The Long-Term objective of setting up the water quality laboratory is to produce a water quality index map of Nepal that indicates the chemical, biological and microbiological parameters, and demonstrates the rate of increase of pollution. The short term objective is to do the chemical examination of river water by analysing Ph-value, Conductivity, Temperature, BOD, Dissolved Oxygen, Hardness, Ammonia, Nitrate, Nitrite, Ortho Phosphate and Chloride.

To fulfil the short term objective, water sampling and chemical analysis will be made. Eight points in the Kathmandu Valley and six stations of the Snow and Glacier Hydrology Project in the Himalayan regions are selected to take water sample. By measuring all parameters at different stations a chemical water quality index is to be calculated. All the works will be carried out by the present DHM manpower. The short term programme will give the first experiences to the DHM, based on which further planning can be made.

The GVS was renamed to German Development Services (GDS) at the end of 1991.

4.3 Snow and Glacier Hydrology Project

The Snow and Glacier Hydrology Project was initiated in 1987 with the technical assistance of the German Technical Agency (GTZ) on the request of the HMG.

The objective of this pilot project is to organize a Snow and Glacier Hydrology Unit within the DHM and to establish six hydro-meteorological stations in the snow and glacier regions of the Nepal Himalaya to collect data relevant for water resources planning.

So far, the following six (6) hydro-meteorological stations have established since mid 1987 and operated:

- Kyangjing (upper Langtang valley)
- Dingboche (Imja Khola valley in the Khumbu Everest)
- Machapuchare Base Camp (named Annapurna station, in the Modi Khola valley)
- Makaru (upper Arun Basin)
- Hurikot (upper Bheri Basin, Jagdula Khola)
- Simikot (upper Karnali Basin)

and following seven (7) observation items are measured in these stations:

- Temperature
- Relative humidity
- Precipitation
- Wind speed and direction
- Global radiation
- Water gauge height
- River discharge (by tracer technique)

Despite a strict standard, station operation and maintenance is extreme difficult in the snow and glacier regions of Nepal Himalaya. Some of main reasons is why:

1) Durability of some instruments against severe conditions in altitudes of around 4,000 m and above is not sure.

2) Measurement of solid precipitation is difficult.

3) Freezing of the pressure gauge sensor and insufficient batter capacity.

4) Physical and other psychological strain for the field staff and the Kathmandu based staff who has to visit each station routinely 4 times per year.

5) Personnel with sufficient scientific or technical background can't be employed at the situations under the present salary structure.

6) Occurrence of avalanche disasters, glacier lake out burst.

These six stations extend widely over the snow and glacier regions and are considered to represent the spetial differences of snow and glacier hydrological conditions in Nepal.

Location Map is shown in Fig. 4.1.

A workshop on objective oriented project planning was held in March 1992 in Kathmandu and the following analyses were made to frame next phase of the Snow and Glacier Hydrology Project scheduled to last for 3 years from 1993 to 1995:

1) Analysis of problems on the existing project,
2) Analysis of objectives for next phase,
3) Project planning with schedule, and
4) Sharing of responsibility for project implementation.

The overall goal to which the project contributes is to improve management of water resources in the Himalayan area of Nepal. The purpose is set to support efficient planning and operation of water resources projects by providing processed hydro-meteorological data in that area.

1) operation and maintenance of observation stations under the project,
2) training of the counterpart personnel,
3) runoff simulation of snow and glacier melt,
4) processing and publication of hydro-meteorological data,
5) establishment of communication to end-users and cooperation with other institutions,
6) routine calibration of gauging stations and sediment measurement, and
7) efficient management of the Snow and Glacier Hydrology Unit in the DHM.

4.4 Nepal-India Flood Forecasting Project

The Nepal-India Flood Forecasting Project, which was initiated in 1984, aims to provide real-time hydro-meteorological data to India for flood forecasting purpose. This plan provides 20 water level and 45 rainfall gauges with wireless communication facility (SSB) supplied by the Indian Government. Locations and equipments to be supplied are shown in Fig. 4.2 and Table 4.1.

Among these stations proposed to be established, the following are in operation at present, though the operation period is from June to October in a year for flood forecasting purpose:

1) 9 water level gauging stations with raingauges at:

- No. 795	Mainachuli	(Kankai river)
- No. 589	Pandhera Dobhan	(Bagmati river)
- No. 598	Chisapani	(Kamala river)
- No. 665	Tokselghat	(Sunkoshi river)
- No. 684	Majhitar	(Tamur river)
- No. 450	Narayanghat	(Narayani river)
- No. 350	Bhalubang	(Rapti river)
- No. 604.5	Turkeghat	(Arun river)
- No. 630	Pachuwarghat	(Sunkoshi river)

2) 7 raingauging stations at:

- No. 1030	Kathmandu	(Aeronautical)
- No. 804	Pokhara	(Aeronautical)
- No. 909	Simara	(Aeronautical)
- No. 705	Bhairahawa	(Aeronautical)
- No. 1206	Okhaldhunga	(Synoptic)
- No. 1307	Dhankuta	(Synoptic)
- No. 1405	Taplejung	(Synoptic)

Water level, discharge and rainfall data observed at the above stations are transmitted by SSB to Patna, India through the DHM Central Office in Kathmandu. At present, the real-time data at four water level gauging stations are not able to be transmitted to Kathmandu due to some technical problem of wireless equipment. The SSB transmitting time is 11:00 and 14:00 between stations and Kathmandu, and 12:00-12:30 between Kathmandu and Patna. Though the DHM Central Office sends all the available real-time data to Patna, India receives data of 10 stations including 7 raingauging stations and 3 water level gauging stations in Narayanghat, Pandhera Dobhan and Chisapani (Kamala).

According to the information from the DHM in June 1993, two water level stations, Batra in the Bagmati river and Pipra in the Parman river, have been cancelled in the Project.

4.5 Hydro-meteorological Observation by Other Agencies

Some hydrological stations have been established for the purpose of projects under the Department of Irrigation (DOI), the Nepal Electricity Authority (NEA) and the Department of Water Supply and Sewerage (DWSS) in collaboration with the DHM. In most cases, the data observed at these stations are available in the DHM, though the number of the stations is not so much and recording period is short because of the purpose. On the other hand, the data recorded at stations established with no relation to the DHM are analysed and stored by them and have not been sent to the DHM.

5. PRESENT CONDITION OF OBSERVATION SYSTEM

5.1 Observation

5.1.1 Precipitation Observation

(1) General

Prior to the year of 1964, the Indian Meteorological Department operated an observation network which consisted of 4 climatological and about a hundred precipitation stations in Nepal. In 1965, the Nepal Meteorological Service (NMS) was established with technical assistance from the UNDP and the WMO. After that, a number of the WMO projects have assisted the NMS in establishing its own network of meteorological stations which consists of Precipitation, Climatological, Agrometeorology, Synoptic, Aeronautical ones, and in developing station inspection, and maintenance program, forecasting unit at Kathmandu airport, radio telecommunication and so on. Training both on-the-job and through fellowship abroad and initiating publication of data were also provided by many WMO projects.

At present, 252 meteorological stations are operational in the whole Nepal and its density is around 580 km^2/gauge in average. However this density seems to be insufficient judging from assessment of rainfall distribution patterns in such a mountainous area, for instance a norm for minimum network recommended by the WMO between 100 km^2 and 250 km^2/gauge in such area. The principal reasons for this scarce distribution of stations are the difficult access to many portions in the High Mountain area, the difficult finding of adequate-trained person as observer, the shortage of trained personnel and budget and so on.

(2) Precipitation Network

Total 252 meteorological stations except for 14 model rainfall observation stations are in operation under the management of the DHM as of August 1991.

The meteorological network consists of Aeronautical, Synoptic, Agrometeorological, Climatological and Precipitation stations. The number of each type of station is as follows:

Type of Station	Number of Station
Aero/Synoptic stations	14
Agrometeorological stations	24
Climatological stations	65
Precipitation stations	149
Total	252

General observation items of each type of stations are shown in Table 5.1.

The existing network of the meteorological stations is insufficient in rainfall gauge density comparing with a norm of the WMO which proposes the density of 100 km^2 to 250 km^2/gauge in mountainous area, and biased having greatest density in the Central part, especially, Kathmandu Valley, and next in the Eastern part, and most sparse in the northern mountainous area in the Western part. The list of the meteorological stations is given in Table 5.2 and the locations are shown in Fig. 5.1 to 5.3. No snow measurement is performed at present except for six stations under the Snow and Glacier Hydrology Project.

Distribution of meteorological stations by altitude is as follows. The highest station is Paigutan (Climatology) in Central at EL. 4,091 m.

Altitude (m)	Number of Stations		Altitude (m)	Number of Stations	
< 100 m	10	(4.0%)	1,500 - 2,000 m	43	(17.1%)
100 - 300 m	57	(22.6%)	2,000 - 2,500 m	18	(7.1%)
300 - 500 m	15	(6.0%)	2,500 - 3,000 m	10	(4.0%)
500 - 1,000 m	34	(13.5%)	3,000 - 4,000 m	10	(4.0%)
1,000 - 1,500 m	54	(21.4%)	> 4,000 m	1	(0.4%)
			Total	252	

Among 252 stations, 14 stations are equipped with rain recorder and continuous rainfall observation is available, though the number is insufficient judging from the requirement for nationwide development plan of water resources and a norm of the WMO which recommends 10% of total stations at a minimum.

(3) Observation Instrument

All of precipitation stations are equipped with an ordinary rainfall gauge. Out of total 252 meteorological stations, only 14 recording rainfall gauges, around 6% of the total number, are installed at 13 synoptic/aeronautical and one agrometeorological stations.

U.S. standard 8 inch precipitation gauge is in common use as an ordinary raingauge in Nepal, which consists of an over flow can, a measuring tube, an 8 inch diameter collector and three legged support, and is 1 m high. As a recording rainfall gauge, weighing-type and float with syphon-type ones are used with drum chart type recorder. Recording charts are one-day or one-week long type.

Recording raingauges are installed at following stations:

	Code Number	Name of Station	Type of Station	Type of Instrument (Manufacture)	Type of Chart
1.	0104	Dadeldhura	Synop.	Weighting type (Belfort, USA)	1 week
2.	0219	Dhangadi	Synop.	Float and syphoning (Casella, ENG)	1 day
3.	0303	Jumla	Synop.	Accumulating type (Israel)	
4.	0406	Surkhet	Synop.	Weighing type (Belfort, USA)	1 week
5.	0515	Ghorai	Synop.	Float and siphon (Fuess, GER)	1 day
6.	0705	Bhairahawa	Aero.	Weighing type (Belfort, USA)	1 week
7.	0804	Pokhara	Aero.	Weighing type (Belfort, USA)	1 week
8.	0909	Simara	Aero.	Natural siphon (Casella IMD)	1 day
9.	1030	Kathmandu	Aero.	Natural siphon (Casella, IMD)	1 day
10.	1206	Okhaldhunga	Synop.	Natural siphon (Casella, IMD)	1 day
11.	1304	Pakhribas	Aegro.	Float and siphon (Casella, ENG)	1 day
12.	1307	Dhankuta	Synop.	Weighing type (Belfort, USA)	1 week
13.	1319	Biratnagar	Aero.	Float and siphon (Fuess, GER)	1 day
14.	1405	Taplejung	Synop.	Weighing type (Belfort, USA)	1 week

Drum type recording charts of recording raingauge is available to print in Kathmandu, however, quality of printing, cutting and paper is inferior condition.

(4) Observation Staff

The Aeronautical and Synoptic stations are operated and maintained by stationed staffs of the DHM. In the other meteorological stations such as Agrometeorological, climatological and Precipitation stations, part-time observers appointed by the DHM take observation.

Part-time observers' qualification is mostly under SLC (School Leaving Certificate) and their technical level on observation is relatively low due to insufficient training.

(5) Observation Method

Existing observation Manual entitled "Nepal Meteorological Service Manual of Observation" was made by WMO Adviser and UN volunteer on June 1978, but this Manual has not revised, so some portion are different from present condition. This Manual covers following items of observation on Precipitation, Temperature, Humidity, Evaporation, Wind velocity, Wind direction, Solar radiation and so on.

1) Techniques and Procedures of observer
2) Procedures in Recording and Reporting
3) Data Evaluation Guidelines for Auto Graphic Records
4) Principles of Operation, Exposure, Installation and Maintenance of Meteorological Instruments
5) Standard Operating Procedures for Tele-communication

Precipitation observation are carried out as following:

1) Synoptic/Aeronautical/Climatological Station

    twice a day: 8:45 AM and 17:45 PM

    Empty the bottle once a day after observation at 8:45.

2) Precipitation Station

    once a day: 8:45 AM

Two types of recording raingauge, which are weighing-type and float and siphon-type, are in operation and recording charts are changed every day or every week.

There are no adequate snow data, only occasional snow depth observations by a graduated ruler are carried out. The water equivalent of snow is measured by using the ordinary raingauge. Water equivalent snow is measured by melting snow to pour hot water measured before and into a measuring tube. Total equivalent of snow is obtained by reducing added hot water.

5.1.2 Hydrological Observation

(1) General

The systematic collection of hydrological data was started in the Karnali basin in 1961 by the UN Special Fund for the feasibility study of power project.

During the years of 1962 to 1968 a priority network of river stations was established by the USAID project on the major rivers possessing structures such as cable ways, stilling wells, and sediment sampling facilities. The network expanded to 120 stations until 1968. Among them 38 of the most important stations were published with data form. After completion of the USAID project, the network had expanded to a maximum total of more than three hundred stations which consists of regular stream gauging stations and partial record ones. Subsequently in 1988, all partial stations and some regular stations were closed due to difficulties in operation and maintenance and from the view point of its priority. At present totally 136 river gauging stations are in operation. However, the DHM faces problems on network, operation and maintenance of observation stations, data management and so on.

Hydrometric stations are divided in regular stations and partial stations. Definition of each types of Hydrometric Station is basically as follows:

1) Regular stream gauging station

Regular stations provided regular discharge record and devided 2 classes.

(a) Primary or Priority Type of Station

- Long term installation and operation for indefinite periods of time.
- Data for these stations are used to study trends and changes in flow patterns on a long range basis.

(b) Secondary Type of Station

- Basically short term installations for correlation studies to the Primary type of station.

2) Partial Record Station

Partial record stations provide intermittent low flow discharge records and miscellaneous stations provide only some discharge measurements according to the special needs for supplementing data from other types of stations.

(a) Low-Flow Partial Record Station

- Only low-flow discharge measurement and gauge staff reading for the purpose of the low-flow potentiality.

(b) Miscellaneous Sites

- No gauge staff and only low-flow discharge measurement for the purpose of the low-flow potentiality.

At present no partial stations are operational, and among totally 136 river gauging stations, 48 stations are selected as Primary ones. Most of these primary stations were established at USAID Project in the 1960's with a view to provide suitable data for the major hydropower, irrigation and water supply schemes.

Type of Station	Number of Station	Installed Instrument		
		Cable Way	Automatic Recorder	Sediment Sampling
Primary Station	48	40	24	18
Secondary Station	88	44	10	0
Total	136	84	34	18

(2) Hydrometric Network

A total of 136 water level gauging stations are in operation under the management of the DHM as of August 1991 except for Model Observation. The list of the stations is given in Table 5.3 and the locations are shown in Fig. 5.4. The existing network of hydrometric stations has the greatest density in the middle hills, and is more sparse near the northern and southern borders. The numbers of stations are 13, 31, 25, 38, and 29 in the Far Western, Mid Western, Western, Central and Eastern Region, respectively. Though the average gauge distribution density, around 1,100 km^2/gauge, is nearly sufficient comparing with the WMO Norm which shows 300 km^2 to 1,000 km^2/gauge, biased gauge distribution should be corrected from the viewpoint of the hydrological requirement and water usage/control projects.

The water level gauging stations are categorized in terms of installed instruments as follows:

	Installed Instrument				
	Staff Gauge	Automatic Recorder	Cable Way	Sediment Sampling	Number of Stations
1	A	A	A	A	17
2	A	A	A	–	15
3	A	A	–	A	1
4	A	A	–	–	1
5	A	–	A	–	53
6	A	–	–	–	49
Total	136	84	34	18	136

The automatic recorders are installed at 34 stations and suspended sediment sampling is carried out in 18 stations, of which the appropriateness should be examined. There is no nationwide observation system of water quality. Network of sediment stations is shown in Fig. 5.5.

There are about 6,000 rivers in Nepal and three major river system, Saptakosi River in the East, Narayani/Gandaki, Karnali in the Central and Western respectively.

Following table shows number of hydrometric stations in each River Basin:

Name of of River Basin	Basin Area (km^2)	Number of Stations	Installed Instrument		
			Cable Way	Automatic Recorder	Sediment Sampling
1. Mahakali River	5,317	3	1	2	
2. Karnali River	43,227	24	7	19	4
3. Babai River	3,252	6	2	3	1
4. West Rapti River	6,215	8	2	7	2
5. Narayani River	31,726	35	9	26	5
6. Bagmati River	3,618	12	3	2	1
7. Saptakoshi River	27,863	34	5	17	3
8. Kankai River	1,317	5	2	4	1
9. Mechi River	1,316	0	0	0	0
10. Others (Terai)	23,330	9	3	3	1
Total	147,181	136	84	34	18

There are five Regions, Far Western, Mid Western, Western, Central and Eastern Regionals, in Nepal. DHM has five regional offices in each region and each regional office is responsible for operation and maintenance of stations.

Number of hydrometric stations in charge of each Regional office gives in following table:

Name of Region	Area (km^2)	Number of Station	Installed Instrument		
			Cable Way	Automatic Recorder	Sediment Sampling
Far-Western	28,456	13	10	6	3
Mid-Western	27,410	31	21	7	4
Western	29,398	25	21	5	3
Central	42,378	38	19	10	3
Eastern	19,539	29	12	6	5
Total	147,181	136	84	34	18

(3) Observation Instrument

1) Recording Water Level Gauge

The number of recording water level gauging stations is 34 which is 25% of among the total 136 stations. Float-type gauge installed in a stilling well is in common use. However, a lot of gauge wells is suffering from sedimentation in monsoon season and scouring of the riverbed in dry season. On the contrary, the pressure-type gauge has an advantage to be able to be removed easily when sediment deposits or riverbed is scoured. In consideration of this condition, the first pressure-type gauge was installed in Chepe Khola in the Western Region in November 1990 in collaboration with the German Development Service. At present, four pressure-type gauges are operated and monitored under different geological, sedimental, climate and polluted rivers conditions as follows:

No. 299.99	Bheri Nadi/Samaiji Ghar (Mid. W.)	June, 1991
No. 440	Chepe Khala/Garam Besi (Western)	Nov., 1990
No. 550.05	Bagmati River/Khokana (Central)	June, 191
No. 690	Tamur River/Mulghat (Eastern)	April, 1991

In advance of DHM installations of pressure-type gauge, this type already introduced in North Mountain Area where elevation is higher than about 3,000 m by Snow and Glacier Project in 1987. (See Fig. 4.1)

Following manufacturer's instruments are used:

Float-type	Stevens type recorder A71 Leupold & Stevens Instrument INC. USA
Pressure-type	SEBA Vertical water level recorder ALPHA-5 SEBA Hydrometric INC., Germany

Float-type recording gauge employs one-year strip recording chart and pressure-type one does one month drum recording chart in dry season and daily or one week drum recording chart in monsoon season.

2) Gauge Well Facilities

Generally, the gauge well is masonry concrete structure with some reinforcement bar or reinforced concrete, which is equipped with two or more intake pipes and an opening for inspection and clearing of sediment.

As measures for clearing blockade of the well by sediment, removal of silt from the well is carried out usually twice a year before and after monsoon by manpower or pump and the flushing facilities are provided in some gauge wells, but no effective means have been found yet except for continuous removal by manpower.

Occasionally, flood, avalanche and Glacier break destroy gauging wells severely.

3) Cable facilities

Eighty four (84) observation stations are equipped with cableway facilities for discharge measurements. Most cableways are provided with manual single-drum winch which is manufactured in Nepal. In Far-Western and Mid-Western Region, a lot of puller operation is still used without a winch. Only two stations at No. 150 Pancheshwor/Mahakali (NEA operates this station) and No. 280 Karnali/Chisapani are equipped with manual double winch cable ways applied for bank operating system. Because most cable ways are not maintained well winch and cable became rusty, and traction cables became loose and so on.

4) Current-meter

At present all of discharge measurements are carried out by current-metering method. The number of the current meter is 24 in total and insufficient. Price current meter, which consists of six conical cups rotating about a vertical axis and counting devices, is always used in discharge measurements. Advantage of this current meter is that it is normally very sturdy and easily maintained, but it is more prone to errors in metering turbulent flow. There are some propeller-type current meters provided in some projects, but they are hardly used now.

Following manufacture's instrument is always used:

Price current-meter, Teledyne Gurley, USA

Mode 622, Operation range 0.2 to 23 Ft./sec.

(4) Observation Staff

In hydrometric stations, gauge readers, sediment sample collectors, winch operators, and bottle runners who carry sediment sampling bottles to the laboratory are employed by the DHM as part-time observers/workers.

Duties of Field technicians in the Regional Office are discharge measurement, levelling and river cross section survey, field inspection and mirror maintenance activities.

In a Hydrology station at Chisapani, staffs of the DHM observe river water level, discharge and sediment continuously with cooperation of NEA Karnali Multi Purpose Project.

Qualification of the part-time observers and technical staffs is not well due to insufficient training.

(5) Observation Method

Observations of hydrometric stations consist of:

1) daily manual water level gauge reading,

2) recording water level gauge observation,

3) discharge measurement,

4) sediment sampling and

5) surveying of river cross section and levelling.

All the stations are equipped with staff gauges. The staff gauge reading is executed three times at 8:00, 12:00 and 16:00 every day by part-time observers. The recording charts are changed every day, week, three months or year depending on recorder type and frequency of field investigation.

In all sites discharge measurements are done by employing a current meter from a cable way or a bridge deck and by wading rod when river discharge takes low water level at some stations.

Method of discharge measurement follows United States Geological Service (USGS) Standard. Partly, Hydrological Observation with illustrations in Hindu language published by Central Board of Irrigation and power in India is used. This Manual is translated Hydrological Observation explained in picture, Ministry of Construction, Japan. Outline of discharge measurement method is as follows:

(a) The number of vertical section are determined as follows:

The discharge between any sections does not exceed 10% of the total discharge. In practice normally some 20-30 verticals are required.

(b) The number and depth of the measuring points in one vertical section is determined by using two-point and one-point method according to the depth of a river.

Water depth (D)	Number of Flow Measurement in Vertical	Depths of Measurement
< 1 m	1	0.6 D
> 1 m	2	0.2 D, 0.8 D

(c) Discharge measurement is done only in one runs.

(d) Vertical correction had been introduced by former project but now few vertical angle is measured. The use of heavier sounding weight to minimize vertical angle is difficult in existing manual single winch system in high velocity flow.

In Nepal, the heavy rains of the monsoon occur from middle of June to end of October and begin in the eastern parts.

Department recommended a minimum of 5 discharge measurements every year, at the beginning of monsoon (June, July), at the middle of monsoon (August) at the end of monsoon (Oct., Sep.) in middle flood (Dec., Jan.) and in low flood.

However actually Discharge measurements are carried out averagely 3 to 4 times every year, high flood measurement between August and October, Middle flood measurement between December and February and low flood measurement between April and June by Technicians.

Because of shortage of budget, insufficient staffs and equipments, remoteness and difficult accessibility in monsoon, frequency of discharge measurements including flood measurements are scarce. Besides, river cross section survey is also few due to lack of staff and budget in spite of challenge river bed condition.

Suspended load sediment sampling is executed applying depth integrated method in all stations except for station No. 150 Pancheshwor/Mahakari and No. 280 Chisapani/Karnali which uses point integrated method. Usually, part-time observers take one sample in the middle of the river from the cable car, or sometimes near the bank by wading rod. Sampling is done once at 8:00 or 12:00 every day no special observation to flood caries out.

At No. 280 station, during monsoon staffs assigned Kalnali Multi Purpose Project from NEA and DHM carry out frequent sediment measurements. In normal condition, when river stage is not raising up, sampling is done in intervals of 2 hours from 6:00 to 18:00. When river stage is raising up, sampling is done in shorter intervals of 1 hour or half hour during 24 hours.

In all sediment station no velocity measurement and no grain size analysis for sediment transportation study is done.

5.2 Sediment and Water Quality Analysis

5.2.1 Sediment Analysis

One chemical laboratory is in the Central Office in Kathmandu and four sediment laboratories are in Far-Western (Chisapani), Mid Western (Dang), Western (Pokhara) and Eastern Regional Office (Dharan). There is one tracer laboratory in the Central Office under the Snow and Glacier Hydrology Project, which evaluates discharge of rivers by tracer technique.

In each laboratories suspended sediment concentration is analysed by weighing the dried residue by using filter or evaporation method. Their instruments are one or two electric ovens and big and small scale balances. One silt analyst and one lab boy carry out analysis. In Central Department three Chemists, two Assistant Chemists and two Lab boys carry out sediment and tracer analysis for snow and Glacier Hydrology Project.

During our field investigation, two laboratories in Dang and Dharan, were not operational due to malfunction of equipments. The space of each laboratory is insufficient. Analysis staff does not have enough knowledge due to lack of training. There is no analysis manual which is requisite for proper analysis.

No gradation analysis of suspended sediment load and no analysis of bed material load is made at present, which will be needed for sediment transportation study.

The major instrument equipped in each Laboratory are given in Table 5.4

5.2.2 Water Quality Analysis

Water contamination due to the untreated sewage and industrial waster water discharge into the river is pulling down the water quality and damaging the aquatic environment in some areas in Nepal. Some Reports state that some zones of the Bagmati River are polluted and the self depuration capability is badly damaged. However, there is still no systematic water quality analysis.

In response to the request of the DHM, the German Development Services (GDS) prepared a proposal in July 1992 to set up a water quality laboratory in the DHM in two years between 1992 and 1994. An environmental engineer from the GDS has started her work after submittal of the above proposal to support the setup in technical matters of the water quality laboratory. The laboratory has been established in the DHM in early 1993.

The long term objective of setting up the water quality laboratory is to produce a water quality index map of Nepal that indicates the chemical, biological and microbiological parameters, and demonstrates the rate of increase of pollution. The short term objective is to do the chemical examination of river water by analysing Ph-value, Conductivity, Temperature, BOD, Dissolved Oxygen, Hardness, Ammonia, Nitrate, Nitrite, Ortho Phosphate and Chloride.

To fulfil the short term objective, water sampling and chemical analysis will be made. Thirty points in the Kathmandu Valley are selected to take water sample. By measuring all parameters at different stations a chemical water quality index is to be calculated. All the works will be carried out by the present DHM manpower. The short term programme will give the first experiences to the DHM, based on which further planning can be made.

This GDS study is based on an issue Water Quality Study Programmes, July 1991, by Environment & Public Health Organization and DISVION International Cooperation.

5.3 Establishment, Inspection and Maintenance of Facility

5.3.1 Inspection and Maintenance in Regional Office

(1) Meteorological Station

Field technicians, called Hydro-Meteorological Assistant and Field Assistant should carry out works of both Meteorology and Hydrology in spite of their background and experience.

Field inspection of precipitation stations is carried out once or twice a year by technicians of the Regional Office without overall schedule. Inspection Form for the meteorological stations was prepared by the WMO in 1974. Following items should be inspected according to this form and minor repair is carried out. However, no revision has done.

1) condition of site

2) observer's performance of duties

3) administration condition

4) instrument condition

5) remarks and necessary action

Inspection and calibration of instruments at the synoptic stations are carried out by mechanics of Meteorological instrument workshop in the Central Office because there is no work shop in each Regional office.

(2) Hydrometric Station

Field inspection of Hydrometric stations is carried out in an average two or three times a year. During this field investigation, the technicians of the Regional Office are supposed to take record of and report the condition of the station and its equipment. Field inspection, discharge measurement, data collection, payment of salary for observers and training of observer are done when site visit.

Item to be checked are as follows:

1) condition of equipments and facilities (staff gauge, cable way and gauge house)

2) observer's performance duties

3) data book

4) if necessary, required construction details

5) works done in the field and

6) minor maintenance have to be done in the field.

After return to the office, if necessary, they make an estimate of cost for repair and maintenance works of the station and equipment based on their report and their report is examined by Regional Chief and Hydrologist. If required works are beyond the budget proposal is to be submitted to the Department. Supposing estimate is approved, the technicians carry out required maintenance or repair works.

Maintenance/repair works cover stretching and marking cable, foot bridge construction, anchor block constructions, winch repair and gage well clearance and so on. These works are done by hiring local people and some of special works are ordered to local workshop. Therefore technicians are required to be capable for construction work.

Inspection form is provided but there is no inspection and maintenance manual. Junior technicians are trained by experienced staffs on the job training during the time of field job. Inspection and maintenance is not conducted sufficiently due to lack of proper training and manuals.

For both of meteorological and hydrometric stations, station and instrument inventories are incomplete and not updated. Record of inspection, adjustment, calibration and repair is also insufficient. These are very important information to maintain and improve observation system.

5.3.2 Inspection and Maintenance in Central Office

There are two individual instrument workshops, Hydrological and Meteorological one in Central Office, but there are no workshop in each Regional Office and they have only simple tools.

The instrument workshop provides laboratory room, office room, mechanical workshop, and section for mechanical repair and storage of meteorological instruments.

The staff of the Meteorological Instrument Workshop deals with all the meteorological instruments, but nobody has background of mechanic and electric.

One of their job is annual field investigation of 14 synoptic and aeronautical stations and regular certification examinations of meteorological instruments. Examinations of minimum thermometer, barometer, thermograph, are taken every 2 years and examinations of ordinary and maximum thermometer are taken every 5 years.

Until UNDP/WMO project, Hydrological instrument workshop was a small one which was intermittently operational as assigned to the single staff, then machinery and tools were provided for workshop by them. An instrument mechanic was recruited and on-the-job training was given under guidance of the associate UNDP expert.

Two staffs, one instrument mechanic and one junior Hydro-meteorological assistant who are trained during UNDP/WMO project, are engaged.

Operation condition of both laboratory is not good due to lack of spare parts and training. There is no calibration facility for the current meter in Nepal, so most current meters have been used without calibration.

The major instruments equipped in workshop are given in Table 5.5.

5.4 Training and Education

The qualifications of the Hydrologists and Meteorologists are in general high, equivalent to an university degree, and they have opportunities to participate in technical refreshing programmes offered by the WMO, UNDP, UNESCO and other agencies or supporting projects. The senior Hydro-Meteorological Assistants are experienced and have good technical knowledge transferred from the past USAID, UNDP, WMO, UNESCO and other supporting projects.

However, young junior Hydro-Meteorological Assistants and Field Assistants graduated at School Leaving Certificate and Under School Leaving Certificate grades have difficulties to have such opportunities because their ability of language is insufficient. So it is necessary to prepare alternate technical training programmes for them. Just in 1990, the DHM in collaboration with the GDS started their own training programme on hydro-meteorology for them in Pokhara. One training programme for the technical staff was executed from October 1991 for a period of three (3) months.

The field works are usually taught by on-the-job training by experienced technicians. For gauge readers, at the time of establishment or new employment a short guidance for observation is carried out and occasional spot instructions are given during inspection, if necessary. Their guidance is all verbal instruction.

There are four German Development Service Workers in the Mid-Western, Western, Central and Eastern Region. One of their activities is to train DHM technicians through field works such as survey, discharge measurements, establishment and maintenance of water level gauging station and data processing.

5.5 Organization and Staff

The Department of Hydrology and Meteorology has five Regional Offices in Eastern Region (Dhankuta/Dharan), Central Region (Kathmandu), Western Region (Pokhara), Mid-Western Region (Surkhet) and Far-Western Region (Dhangadhi) and five Divisions/Sections of Hydrology Division, Climatology Division, Meteorology and Weather Forecasting Division, Other Technical Services and Administration and Accounts.

The Regional Offices are responsible for operating and maintaining all the hydrological and meteorological stations and processing data preliminary.

At present, technicians in the Regional Offices consist of 3 Senior Hydrologists, 2 Senior Meteorologists, 5 Hydrologists, 3 Meteorologists, 29 senior Hydro-Meteorological Assistants, 28 junior Hydro-Meteorological Assistants, 26 Field Assistants and 3 Silt Analyst and total number is 102. Among them 32 technicians belong to 13 synoptic stations.

There exist 30 vacant seats of personnel including 23 by junior Hydro-Meteorological Assistants (7 of them are in Synoptic stations). The shortage of technicians is also very real problem.

A gauge reader, collector, winch operator, and runner who carries sediment sampling bottles to the laboratory in hydrometric stations and observers in meteorologicla stations and are employed as part-time observers. Staffs 5 of aero/synoptic stations belong to the DHM.

Occupation of part-time observer is mostly agriculture, business like small shop owner and employee. His/her qualification is mostly under SLC (School Leaving Certificate) and experience is mostly 10 to 20 years.

Number of staffs in the present Central and Regional Offices is summarized in Table 5.5 and 5.6.

6. MODEL SYSTEM

6.1 Purpose of Model System

(1) Purpose of Model System

The Model System of the hydro-meteorological observation and data management was planned and established, and has been operated for the purposes of:

1) attempting several ways of observation, data collection and data management in the Model System and to help to formulate more practicable Long Term Programme by taking account of the results of the above attempts,

2) transferring technology through planning, establishment and operation of the Model system,

3) strengthening the existing observation and data management systems by installing new gauges and new management systems including new computer facilities introduced in the Central Office and Regional Offices in the Model System, and

4) accumulating reliable observation data by operating the Model System for a long term and using them for detailed meteorological and hydrological studies of the basin.

6.2 Work Schedule of Model System

The following study and field work on Model Observation System were carried out:

(a)	Observation network design	:	First Field Investigation (End of May to beginning of Oct. 1991)
(b)	Field investigation for site selection	:	ditto
(c)	Design of gauging station and selection of observation instruments	:	First Home work (Middle of Oct. to end of Dec. 1991)
(d)	Construction (Establishment) of gauging station	:	Second Field Investigation (Beginning of Jan. to middle of Mar. 1992)
(e)	Operation of the Model System	:	Second, Third and Fourth Field Investigation (Beginning of Jan. to middle of Dec. 1992)

Work schedule on Model Observation System is given in Fig. 6.1.

6.3 Selection of Model Basin

The Model Basins, in which model observation networks where established, were selected through two screenings, the first and second screenings among all the river basins in Nepal. Two Model Basins, Kali Gandaki river and Jamuni river basins were finally chosen from two river groups originating from the Himalaya mountains and the Mahabharat mountains/Siwalik zone, respectively. These groups show different hydrological characteristics. The Kali Gandaki river basin was finally chosen as one of the Model Basins taking account of:

1) Wide variation of rainfall amount such as heaviest one in Nepal at the foot of the Annapurna mountains and arid in the Mustang area,

2) The Kali Gandaki A hydropower project, located just downstream of the basin which is one of the top priority hydropower projects in Nepal.

3) Existence of only a few small scale hydropower plans in the basin such as Andhi Khola powerhouse comparing with many river structures in the Seti Gandaki river basin.

4) Operation of a station of the Snow and Glacier Hydrology Project in the basin.

The second screening for river basins originating from the Mahabharat mountains/Siwalik zone was carried out to select one Model Basin from small river basins in the Terai plain. Jamuni river basin was finally chosen as one of the Model Basin due to the following reasons:

1) No raingauge and no water level gauge was installed at the planing stage in the Jamuni river.

2) Few river structures exist except for the Gandaki Eastern Canal in the Jamuni river basin, which enables easy observation and modeling.

3) Jamuni river is easily accessible to Kathmandu, which enables easy operation and maintenance.

General map of two Model Basins, the Kali Gandaki river and Jamuni river basins, are given in Fig. 6.2 and Fig. 6.3. Rainfall characteristics of these basins are illustrated in Fig. 6.4 and Fig. 6.5.

6.4 Study on Model Observation System

6.4.1 Observation Item

Observation items for the Model System were determined to be the same as items in the Long Term Programme except for water quality analysis. The Items are

1) Daily/hourly Rainfall
2) Daily/hourly Water level
3) River discharge measurement
4) Suspended sediment load

The discharge measurement activity includes those by using floats and measuring surface water profile reading staff gauges.

6.4.2 Gauge Distribution

Principally, observation station should be so located that the data will be useful in developing meteorological and hydrological studies, for instance, study on point and a real rainfall relationship, study on density of hourly rainfall observation etc. The significant characteristics such as topography, elevation, slope and land use and pattern of rainfall should be considered for network study.

Kali Gandaki River basin (basin area 7110 km^2)

The existing observation network had 22 rainfall gauging station s and 7 water level gauging stations in the Kali Gandaki River basin. There is only one recording water level gauge in Setibeni and no recording rainfall gauge.

Twelve (12) new recording raingauges were installed at Yaragau, Samargau, Dhagarjong, Baghara, Muna, Kuhun, Bega, Doban, Sallyan, Pamdur, Sirkon, and Tisedi as shown in Fig. 6.2. These gauges are distributed considering phenomena of monsoon, uniformity and density of distribution, and steady operation. Total rainfall gauging stations become 34 in number and density of the raingauge distribution is around 210 km^2/gauge on an average.

Three (3) new recording water level gauges were installed at Tapopani, Kalleri and Setibeni as shown in Fig. 6.2. Total water level gauging stations become 10 in number.

1) Precipitation Network

12 new rainfall gauging stations are chosen at Yaragau, Samargau, Sanda, Baghara, Muna, Kuhun, Bega, Khuldi, Sallyan, Pamdur, Sirkon, and Tisedi as shown in Fig. 6.2 considering the following:

(a) The south east monsoon conveys humid air mass from Bengal Bay and induces heavy rainfall in the southern area of the Annapurna and Dhaulagiri mountains. The drier air mass passes through the Mustang area.

(b) Attention is paid to uniform distribution of raingauge including the existing and the new ones.

(c) Total number of raingauges becomes 34 in this basin after this installation. Density of the raingauge distribution is, then, around 210 km^2/gauge on an average. This density is considered to lead to approximate a real rainfall and yield some information for observation network design judging from the study on point and areal rainfall relationship based on the record.

(d) The southern part of this basin is a rather high rainfall zone as seen in Fig. 6.4. The raingauge distribution is, thus biased to arrange densely in this southern part with 120 km^2/gauge to catch variation of rainfall.

(e) The recording raingauges to be established should be located in the villages where.observers are available.

2) Hydrometric Network

3 new water level gauging stations are chosen at Tatopani, Modibeni and Setibeni in Fig. 6.2 considering the following:

(a) Tatopani is considered to be a changing point of runoff because the upstream area of Tatopani receives low rainfall and the downstream higher.

(b) Modibeni is one of the significant points in terms of river management where one big tributary, Modi river joins the main course. A recording water level gauge is proposed to be installed upstream of the confluence due to site condition.

(c) In Setibeni, there is one recording water level gauge. This gauge suffers from sedimentation in the well and also scouring of riverbed, and the recording is interrupted sometimes. On the other hand, this site is an important one from the view points of not only river management but also of planning of the prospective Kali Gandaki A hydropower Project. Thus, a gauge is to be added to obtain continuous data.

Jamuni River basin (basin area 110 km^2)

Two (2) new recording raingauges at Kolbhi and Chyuntaha and one (1) new recording water level gauge at Chyuntaha were installed as shown in Fig. 6.3 considering the following:

a) The Gandak Eastern Canal is running across the Thali, Tiar and Jamuni rivers in the Thali river basin. During flood, this canal blocks flood flow in the rivers and backwater appears in the upstream of the canal. The selected site is located much upstream of the canal and not affected by this backwater. The Jamuni river has the biggest catchment area among the above three rivers.

b) The selected site is near the village of Chyuntaha, and observation and maintenance shall be easier.

6.4.3 Observation Instruments

(1) Selection of Instruments

1) Recording Raingauge

In the Model System, all the raingauges to be installed are of continuous recording type in order to get not only hourly rainfall data but also some information on required density of hourly rainfall observation. This recording raingauge should be accompanied with an ordinary raingauge.

Tipping bucket-type, Weighing-type and Float with syphons-type recording raingauge are in common use and also in DHM weighing type and float with syphones-type raingauge are operational. Characteristics of each recording gauge are shown in Table 6.1.

Selection of recording raingauge is done in consideration of:

(a) Some raingauging stations are to be established in about 3,000 to 4,000 m in northern part of Kaligandaki. The weighing-type is the only available and relatively satisfactory recording one which measures snowfall directly by the water equivalent snow. Float-type and Tipping bucket-type are impracticable in measuring snowfall without a heating device which induces excessive evaporation losses.

(b) Maintenance of weighing-type raingauge is easy, also mechanism is simple.

(c) Weighing-type raingauge has long operational experiences in DHM.

(d) Tipping-bucket type are recommended to be installed in combination with a data logger because the other type of gauges in combination with a data logger are complicated mechanism and difficult to maintain.

Therefore, the weighing-type raingauges are selected in 13 gauging stations and 1 tipping-bucket-type raingauge in combination with a data logger is selected in Pamdur.

The recording chart must be one week drum recording type since observers are forced to inspect the gauge at the time of paper changing and durm type chart is available in Nepal.

2) Recording water level gauge

All the water level gauges also are of continuous recording type in order to obtain continuous data and to assess hydrological characteristics. Staff gauges are needed to install adjacent to respective the recording gauge.

The type of instruments should be selected in consideration of geography around observation station, easiness of operation and maintenance, required accuracy, accessibility to site, available power supply, economical respect, existing instruments, operational condition and so on.

In Nepal, most of water level gauges are float-type, however most gauge wells confront following problems:

(a) In spite of regular clearance of gauge well before and after monsoon and installation of flushing arrangement, frequent blockade of intake pipe happens and recording charts become useless.

(b) In hilly area scouring of rive bed makes gauge well malfunctional therefore costly new gauges have been reconstructed.

(c) In Terai River, not only fluctuation of river bed but also change of water course occur frequently.

(d) Some big floods have destroyed and damaged gauge well severely.

In view of these situation, some pressure-type gauges, which are in common use as well as float-type were introduced in 1990 and 1991 in collaboration with German Volunteer Service, considering above-mentioned situation.

Advantages and disadvantages of three common types of water level gauge are summarized in Table.6.2. In this table the ultrasonic-type is most preferable because of no problems on sedimentation and scouring of river bed. However, selection of this type is reserved from the view point of accuracy, maintenance and power supply.

Kali Gandaki River basin

The pressure-type water level gauges are selected judging from the following points:

(a) Kali Gandaki has big sediment flow and high variation of river bed level

(b) Existing observation well at Seti beni is suffering from sedimentation and scouring of river bed and sometimes the recording is interrupted.

(c) Accessibility is not good for installation.

Two pressure gauges at Setibeni and Tatopani employ chart recording devices and one at Kalleri is connected with a data logger. Drum type one week recording chart is to be used due to the same reasons as explained in the weighing-type raingauge.

Proper training of operation, repair and maintenance are prime condition to keep in good operation.

Jamuni River basin

The float-type water level gauge is recommended. Instead of an existing concrete well for float-type gauge, the outer steel pipe for the float is to be adopted, which is vertically movable and adjustable to river bed fluctuations. This method may lead to one of the solutions of sedimentation and scouring problems.

Drum-type weekly recording chart also is to be used .

3) Current Meter

Conventional current-meters are two general types, the cup type (price-meter) with the vertical shaft and the propeller type with horizontal shaft.

The advantages of the price-type current meter is easy operation and maintenance because this type is mechanically simple and very sturdy. But if the current flow is not parallel to the flow axis or turbulent, overestimated stream velocity will be indicated due to rotation by vertical currents or upstream velocity component.

On the other hand, propeller type current meter is suited to the river with turbulent and shifting streams because of less sensitive than price-type one to velocity component not to parallel to the meter axis.

In Nepal the price-type current meter has been extensively used by the staffs of the DHM for a long time and propeller-type ones are used rarely.

The propeller-type current meter is recommended to measure river discharge at Modibeni, Tatopani in Kali Gandaki basin and Chyuntaha in Jamuni river, because this type is preferable to use for the turbulent flow and to connect with the double winch cable way. The price-type current meter is chosen to measure river discharge at Seti beni, since the existing cable way is well operational.

The pigmy price type is necessary to measure low flow discharge at Chyuntaha in Jamuni River in dry season.

4) Cable way

At Kalleri, Tatopani in Kali Gandaki and Chyuntaha in Jamuni River, the double winch system to be applied for the bank operation is recommended because of safety of discharge measurements and easy operation with the heavy weight of the current meter even under the high flow velocity condition.

5) Data logger

Two data loggers connected with pressure-type water level gauge at Kalleri and Tipping bucket-type raingauge at Pamdur are to be introduced in order to develop prompt and correct data processing. Condition of operation and maintenance should to be monitored, then its suitability in future stage will be judged.

(2) Summary of Instruments

14 sets of recording raingauges and ordinary ones, 4 sets of recording water level gauges and staff gauges, 5 sets of current meters and 3 sets of cable ways were introduced in the Model System as followings. Summary of instrument of the Model System is shown in Table 6.3 and

1) Recording raingauge

(a)	Weighing-type recording raingauge	13 sets
(b)	Tipping bucket-type recording raingauge with a data logger (at Pamdur)	1 set
(c)	Ordinary (Manual) Raingauge	14 sets

2) Recording water level gauge

(a)	Pressure-type recording water level gauge with horizontal recorder at Tatopani and Setibeni	2 sets

(b)	Pressure-type recording water level gauge with a data logger at Kalleri	1 set
(c)	Float-type recording water level gauge at Chyuntaha	1 set
(d)	Staff gauges	L.S.

3) Current meter

(a)	Price-type current meter for Setibeni	1 set
(b)	Pigmy price-type current meter for Chyuntaha	1 set
(c)	Propeller-type current meter for Tatopani, Kalleri and Chyuntaha	3 sets

4) Cable way installation

(a)	Double winch cable way applied for bank operating system at Tatopani, Kalleri and Chyuntaha	3 sets
(b)	Sounding real applied for price current meter for Setibeni	1 set

6.4.4 Observation Procedure

Procedures and methods are provided for the observation in the Model System as follows and detailed in the Manual of Installation, Operation, Inspection and Maintenance for Instruments and Gauging Stations:

(1) Ordinary raingauge

The time of observation is 8:45 in the morning every day. The gauge is emptied after measuring water content. A graduated measuring cylinder and a graduated dip rod are in common use for manual rainfall observation. In case that there is less than 0.1 mm water in the inner tube, rainfall record amounts 'T' (traces). In case that there is no water, record rainfall marks 0.0 mm.

(2) Weighing type recording raingauge

Charts are to be changed once a week at 9:00 every Monday.

(3) Staff gauge

Staff gauge reading is to be done three times a day at 8:00, 12:00 and 16:00.

(4) Recording water level gauge

Recording charts are to be changed at 9:00 in every Monday morning after reading staff gauge.

(5) Discharge measurement by current metering

It is recommended that the number of verticals in a cross section is such that the interval between any two verticals should not be greater than 1/20 of the total width and the discharge per section does not exceed 10% of the total discharge. The two-point method is used where the velocity distribution is normal and depth is greater than about 60 cm. The one-point method is used for shallower depth. A normal measuring time is in the order of 40 to 70 seconds.

(6) Discharge measurement by float

The measurement with float is made at the time of high water level, when the measurement with current meter will meet the difficulty. The river velocity will be obtained form the time required for the float passing through between two cross sections predetermined. The cross sectional areas must be measured after the flood has subsided.

(7) Discharge measurement by slope-are method

This measurement method is one of the most common type of indirect measurement. Discharge is computed on the basis of uniform/non uniform flow equation involving channel characteristics, water surface profiles and a roughness coefficient, etc.

(8) Observation and Maintenance Manual

For the purpose of accurate and continuous observation of hydro-meteorological phenomena, operation and maintenance manuals of existing and model observation instruments and facilities were prepared for observers and technical staffs of the DHM, respectively. The operation and maintenance manuals for observation contain:

<u>Observers Manual</u>

1) Manual of Ordinary Raingauge for Observers

2) Manual of Recording Raingauge for Observers

3) Manual of Staff Gauge Reading for Observers

4) Manual of Recording Water Level Gauge for Observers

Technical Staffs Manual

5) Manual of Installation, Operation, Inspection, and Maintenance for Instruments and Gauging Stations

In the observers manuals, fundamental actions being made by observers are illustrated including observation procedures, observation and recording methods, inspection items and methods, matters to care and note, and actions for emergency. The technical staffs manual states detail of instruments, and procedures and methods of installation, observation, inspection and maintenance of stations with instruments for precipitation observation, water level observation, discharge measurement sediment observation and data transfer/primary processing.

All the manuals mentioned above are attached in Manuals of Final Report.

6.4.5 Establishment of Model Stations

(1) Field Investigation for Site Selection

According to observation network study based on existing data such as topographic condition, hydro-meteorological condition and so forth. Field investigation was carried out from Mid of August to Mid of September in 1991 in the First Field Investigation. Following considerations were taken into account.

Much care to the site selection for the rainfall gauging station has to be paid on the effect of the wind. A suitable site for the rainfall gauging station is on the level ground, where the airflow across the gauge is horizontal and tree and other obstacles can serve as an effective windbreak. But surrounding obstacles are so close that they reduce the measurement of the gauge. A qualified observers and security of the observation station are essential for reliable observation.

Meanwhile, suitable site for the water level gauging station should be selected in order to obtain optimum stage discharge relations considering as follows:

(a) A straight reach of the river such that flow has a nearly uniform distribution of velocity.

(b) Smooth flow, small flow velocity.

(c) No back water from tributaries or structures.

(d) The river bed and bank are stable.

(e) The river flow is a consolidated stream.

(f) Good administrative condition.

- Easy accessibility
- Proximity of site to a local observer
- Good Security
- Qualified Observer

(2) Civil Construction and Installation Works

The contract agreement for each Lot was signed on December 8., 1991 and Civil Construction work started. Subsequent to the civil construction works, raingauges, water level gauges and cable way facilities were installed during Second Field Investigation.

6.5 Operation of Model Observation System

6.5.1 Operational Condition of Model Observation System

(1) Rainfall Observation

Fourteen (14) new recording raingauges which consist of, thirteen (13) weighing-type recording gauges with weekly drum chart recorder and one (1) tipping bucket-type recording gauge with data logger, were installed at following stations accompanied with an ordinary raingauge.

No.	Station Name	River Basin	Type of Recorder	Recodtype
0623	Yaragau	Kali Gandaki	Weighing-type	Drum weekly chart
0624	Samargau	"	"	"
0625	Dhagarjung	"	"	"
0626	Bega	"	"	"
0627	Kuhun	"	"	"
0628	Muna	"	"	"
0629	Baghara	"	"	"
0630	Sirkon	"	"	"
0828	Kuldi dovan	"	"	"
0829	Sallyan	"	"	"
0830	Pamdur	"	Tipping bucket-type	data logger
0831	Tisedi	"	Weighing type	Drum weekly chart
0923	Kolbhi	Jamuni River	"	"
0924	Chyuntaha	"	"	"

Status of raingauge and Recording charts of automatic raingauges which were received as of June, 1993 are given in Table 6.4.

Almost the recording raingauges are working. However some weighing-type recording gauges are not operated completely mainly due to inappropriate initial adjustment, misoperation by observers and insufficient training and inspection.

All of weighing-type recording gauges were already re-calibrated or repaired at the end of 1992. Though one data logger with the tipping bucket-type raingauge at Pamdur was operated with good data recording, data stored in data logger could not be retrieved in March, 1992.

Operational condition of each raingauge station as of June, 1993 is summarized as follows:

Yaragau	:	Working but to be improved - Inappropriate initial adjustment of an instrument - Insufficient training and inspection - Incomplete adjustment of time setting and zero adjustment
Samargau	:	Working but to be improved - Same as the above
Dhakarjung	:	Working but to be improved - Same as the above
Bega	:	Working but to be improved - A recording raingauge was not working due to inappropriate initial adjustment from middle of June to end of November, 1992. - Insufficient training and inspection - Incomplete adjustment of setting and zero adjustment
Kuhun	:	Working but to be improved - Inappropriate initial adjustment of an instrument - Insufficient training and inspection - Incomplete adjustment of time setting and zero adjustment
Muna	:	Working but to be improved - A recording raingauge was damaged by the observer and was out of order until middle of December 1992. - Insufficient training and inspection - Incomplete adjustment of setting and zero adjustment
Baghara	:	Working but to be improved - Same as the condition at Yaragau
Sirkang	:	Operated well and to be monitored - Insufficient training and inspection
Kuldi Dovan	:	Operated relatively well, but no data were sent by the observer from middle of December, 1992.
Salyan	:	Operated completely well.
Pamdur	:	Data logger was stopped due to some troubles from March, 1992. It was operated with good data recording until March, 1992.
Tisedi	:	Operated completely well

Kolbhi : Operated completely well

Chyuntaha : Operated completely well
- Inappropriate installation and initial adjustment of instruments.

In spite of the above mentioned inadequate operation in some stations, prompt repair or calibration was not conducted.

The weighing type raingauges were affected by vibration of heavy wind and evaporation and weighing mechanical and transmission parts of this raingauge is very sensitive to friction and levelling, so periodical check and maintenance are necessary.

Proper observation of ordinary raingauges was not carried out at some stations showing extraordinary values.

Almost all the recording cards of ordinary raingauges were sent from the observers completely except Kuldi Dovan and most of recording charts were gathered completely except some stations.

(2) Water Level Observation

Four (4) new recording water level gauges, which are three (3) pressure-type recording gauges and one float type recording gauge, were installed at following stations accompanied with staff gauge.

No.	Station Name	River Basin	Type of Recorder
403.5	Tatopani	Kali Gandaki	Pressure-type gauge with weekly drum chart recorder
406	Kalleri	Kali Gandaki	Pressure-type gauge with data logger
410	Setibeni	Kali Gandaki	Pressure-type gauge with weekly drum chart recorder
595	Chyuntaha	Jamuni River	Float-type gauge with weekly drum chart recorder

Status of recording charts of automatic water level recorder which were received as of June, 1993 are given in Table 6.5.

Except at Chyuntaha station in Jamuni River, where the steel gauge well does not work due to shift of river course to the opposite bank and a lot of sand deposits around well during low water level from middle of April, 1993 to present, all the recording water level are operated well at present time.

One data logger with pressure sensor at Kalleri is operated with good data recording.

Operational condition of each water level gauge station as of June, 1993 is summarized as follows:

Tatopani : Operated well

- The installed pressure sensor was washed away due to attack of big boulders in August 1992, then a new one was installed in May 1993.
- Inappropriate installation of recording gauge due to insufficient joint treatment of sensor cable in May, 1993.

Kalleri : Operated completely well

- Minor correction of factor for pressure sensor

Setibeni : Operated relatively well

- Some peaks of water level were not plotted correctly in August, 1992.

Chyuntaha : The steel gauge well does not work due to shift of river course and a lot of sand deposits around well from middle of April, 1993.

- The gauge well did not work due to the above mentioned condition for a few weeks in August, 1992.

Despite the above accidents or troubles, no immediate repair or rehabilitation works were conducted. Tatopani station was recovered.

At the beginning of observation, proper observation of staff gauge reading was not carried out at some stations in which extraordinary data were included and incomplete adjustment of time setting and zero adjustment were conducted at most stations.

Records of staff gauge reading and recording charts of automatic water level gauge are collected in the Regional offices completely.

(3) Discharge Measurement

Three (3) bank operating cable ways with double-drum winch and propeller-type current meter were installed at Tatopani, Kalleri (Kali Gandaki) and Chyuntaha (Jamuni River). During flood, this cable way is safe and easy to handle a heavy weight.

When the measurement with current meter will meet the difficulties during high flood, discharge measurement by float method and slope-area method are useful. Three (3) staff gauge sections including standard staff gauge were installed at Setibeni (Kali Gandaki) for the purpose of above-mentioned float method and slope-area method.

Field measurements during the study period were conducted as shown in Table 6.6.

Following findings are found through field activities:

a) At Tatopani in upstream of Kali Gandaki, which is a steep and rocky river in high mountains, propeller type current meter was damaged due to attack against big boulders during a measurement in rapid and turbulent flow. A steel protector for a propeller was adopted to avoid damage of current meter.

b) During high flood, float method and slope area method are useful.

c) Bank operating cable way with double-drum winch is safe during high flood measurement and easy for handling heavy weight.

(4) Suspended Sediment Sampling

There are two general kinds of sampling method: a point integrated sampling and depth integrated sampling. A point integrating sampling with velocity measurement is most accurate because the suspended sediment concentration is affected by the flow velocity.

At Setibeni (Kali Gandaki) to investigate distribution of suspended sediment concentration in accordance with water depth i.e. flow velocity, range sampling method using depth integrated samples, which is made in the method of sampling from water surface to specified depth, was carried out.

Three (3) sampling sections were taken for more accurate sediment observation.

(5) Inspection and Maintenance of Facilities and Instruments

Inspection is the most basic item for maintenance and is important to know current condition of instruments and facilities as well as observer's activities. Periodic inspection by well-trained technicians is essential for maintaining the observation systems in good condition. Also daily/weekly inspection by part-time observers is very important for keeping good condition of the station.

Adjustment/Calibration for the equipment which shows a measured value exceeding a standard value and immediate repairs for any faults of equipments and facilities are required for satisfactory observation system.

6.5.2 Evaluation of Model Observation System and Proposal of Long Term Programme

One of the important purposes of the Model observation system is to make more practical Long Term Programme by taking account of the results of Model observation operation.

Through monitoring of the Model observation system, the following are found:

(1) Observation instruments for precipitation

a) The weighing type raingauge is usable in snowfall area though careful and appropriate adjustment/calibration is required.

b) The weighing type raingauge is affected by vibration of heavy wind and evaporation.

c) The tipping bucket type raingauge is recommendable from viewpoints of stable operation and easy connection with data logger.

d) The data logger is applicable and efficient for reliable data recording, however the logger should have monitoring function against misoperation by a operator and unexpected troubles.

(2) Observation instruments for water level

a) The pressure sensor should be installed with careful site selection and designing of strong protection.

b) The adjustable steel pipe well at Cyuntaha in Terai Plane was available following riverbed fluctuation but impossible following river flow change.

c) The data logger is applicable and efficient for reliable data recording, however the logger should have monitoring function against misoperation by a operator and troubles.

(3) Observation instruments for river discharge

a) The bank operating double-drum winch cable way is recommendable to be applied for safe and smooth discharge measurement.

b) The float method and the slope area method are also effective for flood measurement.

(4) Sediment Sampling

a) Following items should be considered in proper sampling:

- Discharge measurement at the same time
- Selection of point/depth integrated sampling
- Appropriate sampling sections
- Frequent flood sampling

(5) Operation and maintenance

a) Proper and regular adjustment/calibration by technicians is essential for weighing-type raingauge to operate with good condition.

b) The daily inspection and continuous maintenance are important for raingauges as well as water level gauges by part-time observers.

c) The operation and maintenance manuals should be modified and updated.

d) Immediate repair of the station is required to minimize missing data.

(6) Training

a) Adequate training is necessary for part-time observers to operate recording raingauges and water level gauges accurately.

b) Adequate training of adjustment/calibration of raingauges and water level gauge, operation of data logger, inspection of stations and so on is requisite for field technicians.

On the basis of these findings, proposals of the Long Term Programme are given in Table 6.7.

6.5.3 Field Training

In the Model System, the transfer of technology given to counterpart by the expert of the Study Team is carried out through on-the-job training.

Items of on-the-job training of Model System operation are as follows:

(a) Discharge measurement using double drum winch cable way applied for bank operating system with the propeller-type current meter

(b) Flood measurement such as float method and slope area method

(c) Suspended sediment sampling

(d) Operation, Calibration and Adjustment of instruments

(e) Inspection of instrument and facilities

(f) Data transfer and processing of Data logger

Field activities with DHM counterpart during our field investigation are given in Table 6.8.

7. LONG TERM PROGRAMME

7.1 Purpose of Long Term Programme

The Long Term Programme, improvement and reinforcement plan of the existing hydro-meteorological observation and data management systems, is examined and formulated for the purpose of:

1) Observing and managing long term hydro-meteorological data which are useful for and ensure analysis of nationwide hydrological characteristics, evaluation of national water resources, planning of the water resources development projects including flood control and watershed management, and management of river water, and

2) Especially, offering long term and reliable data to the planning and designing of the priority water resources development

The Long Term Programme, however, does not include observation and management systems of the following items, which is decided by considering the purpose to concentrate on improvement of fundamental activity and target year of the Programme:

1) Observation and data management system for meteorological parameters such as solar and wind energy,

2) Observation and data management system for snow and glacier including preparation of inventory of glacier lakes,

3) Limnological observation such as water level, sedimentation and water quality of lakes, and

4) Observation and data management system of real-time rainfall and water level data during floods for flood control purpose.

Though these items are excluded in the Long Term Programme, these should be reviewed and examined by the other projects on the earliest occasion.

7.2 Target Year of Long Term Programme

The target year of the Long Term Programme is set up in the year of 2005, since the year of 2005 is not distant future which enables realistic and practicable planning and the period of 13 years from the completion of the Study to the year of 2005 is proper length to realize the Programme.

In order to approach to and accomplish the target of the Long Term Programme steadily and completely, implementation of the Programme is divided into three stages as stated below.

(1) First Stage: target year of 1995

The first stage concentrates to improve quality of the hydro-meteorological data by strengthening the existing hydro-meteorological observation and data management system without big expansion. This strengthening work includes elevation of observation accuracy by manual preparation and staff training, selection of important stations and intensive observation, reinforcement of data processing activity by introducing computers and manuals with staff training and improvement of monitoring system of all the activity. This stage will be formulated as the Immediate Programme.

(2) Second Stage: target year of 2000

The second stage is highlighted as "Observation System Expansion Stage" and targets to expand the hydro-meteorological observation network to the interim scale and to introduce new observation items such as sediment and water quality.

(3) Third Stage: target year of 2005

The third stage is the final stage of the Long Term Programme and aims to complete the observation network to the minimum required one and to improve the system of data dissemination to the users to publish the observed data within the next year.