HIS MAJESTY'S GOVERNMENT OF NEPAL
MINISTRY OF WATER RESOURCES
DEPARTMENT OF HYDROLOGY AND METEOROLOGY

THE STUDY ON NATIONWIDE HYDRO-METEOROLOGICAL DATA MANAGEMENT PROJECT

FINAL REPORT

MAIN REPORT

August 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO, JAPAN

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The cost estimate was based on February 1993 price level and expressed in NRs. according to the exchange rate of US$1.00 = Nepali Rupees 46.4315 = Japanese Yen 121.05 as of February 15, 1993.

PREFACE

In response to a request from the Government of the Kingdom of Nepal, the Government of Japan decided to conduct a study on Nationwide Hydro-meteorological Data Management Project in the Kingdom of Nepal and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Nepal a study team headed by Mr. Masaru Koshiba, Nippon Koei Co., Ltd., five times between May 1991 and June 1993.

The team held discussions with the officials concerned of the Government of Nepal, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Nepal for their close cooperation extended to the team.

August 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

August 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

We are pleased to submit herewith to you the Final Report of "the Study on Nationwide Hydro-meteorological Data Management Project" in Nepal. This Report has been furnished for His Majesty's Government of Nepal as a guideline to lead the existing hydro-meteorological observation and data management systems to more satisfactory and competent ones, based on the study which had been conducted during a period from March 1991 to July 1993 in accordance with the agreement of both the Governments of Japan and Nepal.

The Report comprises five (5) volumes consisting of the Summary, Main Report, Annexes, Manuals and Data Book. Main outputs presented in the Report are the Long Term Programme and the Immediate Programme. The former Programme aims to establish firm and reliable systems of hydro-meteorological observation and those data management. A target year of this Programme is set at 2005. The latter Programme proposes to improve on quality and accuracy of those data by strengthening the systems urgently within the target year of 1995. The Report mentions also design, construction and operation of the Model System established during the study period.

Improvement of the present observation facilities and data management systems is inevitably required to obtain the reliable data for planning and designing of development schemes such as hydropower, water supply, irrigation, flood control, watershed management and so forth, economically and viably. Therefore, an immediate implementation of both the Programmes shall be eagerly recommended.

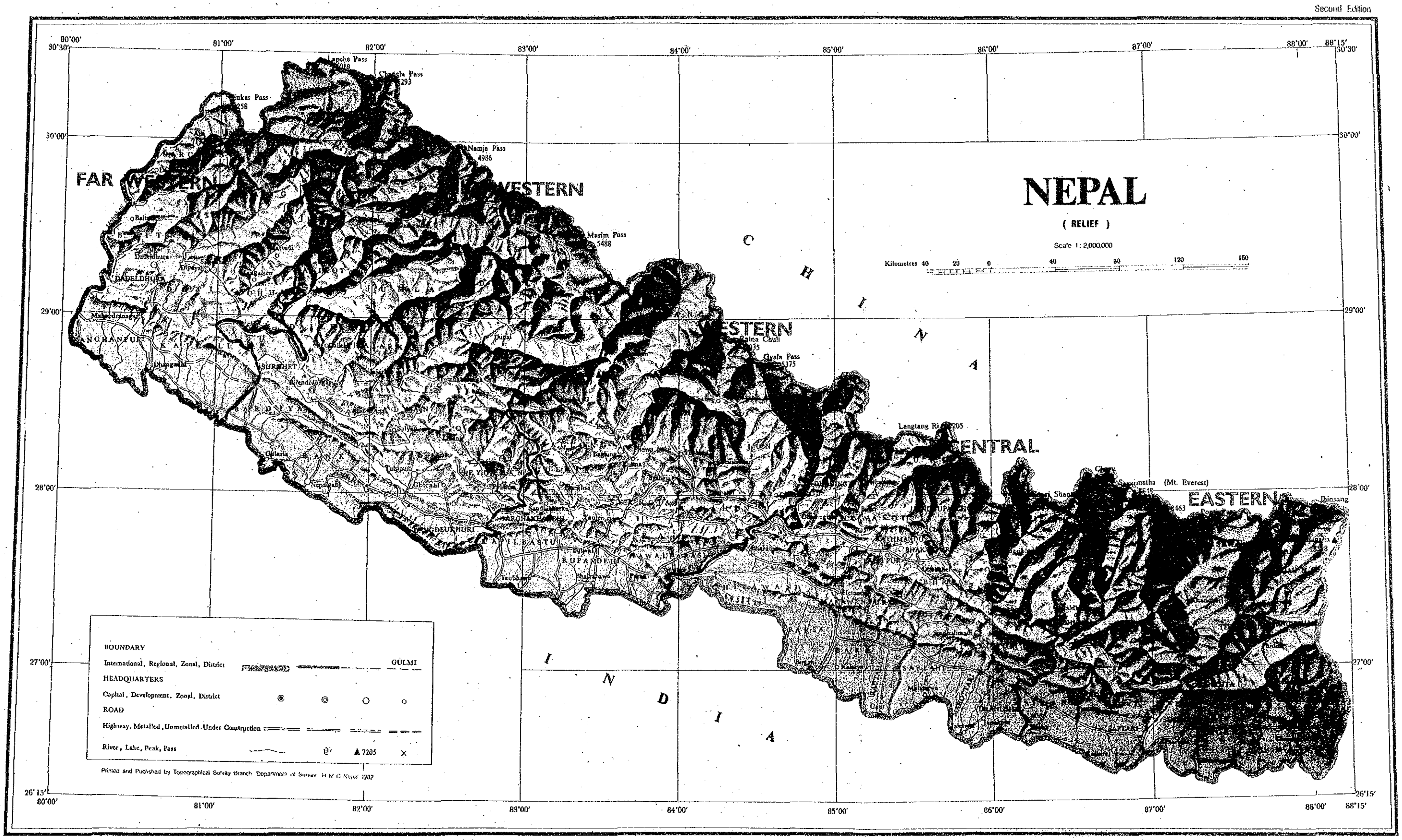
All members of the Study Team wish to express their grateful acknowledgement to the personnel from your Agency and Ministries of Foreign Affairs and Construction as well as the officials and individuals from Nepal for their kind assistance extended so far to the Study Team. Sincerely the Study Team hopes that the outputs presented in the Report will render the future improvement of the existing observation facilities and data management systems.

Yours faithfully,

M. Koshiba

Masaru Koshiba
Team Leader
Nationwide Hydro-meteorological
Data Management Project

Second Edition



SUMMARY

INTRODUCTION

1. The Project titled "NATIONWIDE HYDRO-METEOROLOGICAL DATA MANAGEMENT PROJECT" aims to formulate a plan for improvement and extension of the present systems on hydro-meteorological observation networks and data management in Nepal as well as to transfer technology to personnel and counterparts of His Majesty's Government of Nepal (HMG/N) during execution of the Project.

2. In order to attain the objectives mentioned above, investigations and studies have been carried out on Model System, Long Term Programme and Immediate Programme in Nepal and Japan from May 1991 to March 1993. All the investigation and study results are described in this Draft Final Report.

MODEL SYSTEM

3. The Model System has been established by distributing new raingauges and water level gauges in the two model basins, the Kali Gandaki river basin and the Jamuni river basin, and by installing seven sets of computer facilities in the Central and Regional Offices of the Department of Hydrology and Meteorology (DHM). Fourteen raingauges, four recording water level gauges and cableway facilities were installed in the model basins. In parallel with the above installation work, preparation of operation and maintenance manuals and training for the junior staff of the DHM have been conducted.

4. The installed raingauges, water level gauges and cableways are operated relatively in good condition after some adjustment. The introduced computers are also utilized for data entry and processing by younger DHM staff. However the progress of data collection and processing is not sufficient due to a lack of the DHM staff in charge and management. Further training of the DHM staff and part-time observers is required for more accurate and smooth operation and maintenance of the Model System.

LONG TERM PROGRAMME

5. The purpose of the Long Term Programme is to establish the firm hydro-meteorological observation system and its data management system serving to observe and manage nationwide, long term and reliable data which are useful for

and ensure analysis of hydro-meteorological characteristics throughout the whole country, evaluation of national water resources, and planning of the water resources development projects. Observation items in the Long Term Programme are precipitation, river water level and discharge, sediment load and water quality. The target year of the Long Term Programme is set at the year of 2005.

6. The minimum observation network is proposed for the whole country in the Programme, which comprises 470 rainfall gauging stations, 110 water level gauging stations, 20 sediment observation stations and 11 water quality observation stations. The number of recording raingauges is 60. The water level gauging stations are classified into 10 basic, 38 primary and 62 secondary stations, among which the basic and primary stations are equipped with recorder. The data logger is widely to be applied to the raingauges and water level gauges. The telemeter system is proposed to be introduced in three basic stations. Reinforcement of sediment laboratory and workshops and establishment of a current meter calibration facility and water quality laboratory are also included.

7. The data management work is planned by dividing it into four systems, data collection system, data processing system, data storing system, and data dissemination system. The data collection system functions to collect observed data and information by mail, staff, telephone and telemeter. The data processing system is operated to process collected data and information to meet user's requirement by using 26 computers, 19 new and 7 model computers, fully including data checking. The data storing system works for storing of data and information in the data base, shelves and optical disks. The dissemination system functions to disseminate all the data requested by users in the form of data books, floppy disks, photo copies or by on-line means. Review and revision of procedure manuals are required for all the systems.

8. In order to study further data improvement and to strengthen managerial work, five systems are introduced in the Programme, they are data quality research system, training system, progress control system, quality control system and evaluation system. The data quality research system functions to review the present observation and data management method and to recommend future improvement plan. The training system trains and educates the DHM staffs in the training center to be established or through on-the-job training. The progress control system is to control the observation, data collection and processing work to disseminate observed data within the next year. The quality control system aims to manage and

control data quality and activities of the DHM. The evaluation system is responsible for monitoring and evaluation of all the works in the DHM.

9. The Programme recommends a new organization comprising a Central Office in Kathmandu, four Basin Offices in Nepalgunj, Pokhara, Kathmandu and Biratnagar, and ten Branch Offices in the northern part of the country. The Central Office controls observation and data management, and evaluates all the activities. The Basin Office observes, maintains stations, and collects and processes data. The Branch Office observes and maintains stations.

10. The total project cost for the Programme is estimated to be NRs. 878 million including price escalation, of which the amount of foreign currency is NRs. 633 million and local currency is NRs. 245 million. The annual operation and maintenance cost is estimated to be NRs. 12.8 million in the year of 2005, which is around 16% of the projected annual budget of the DHM in the same year. Main equipments and structures proposed in the Programme are summarized in the tables below.

IMMEDIATE PROGRAMME

11. The Immediate Programme concentrates to improve the quality of the hydro-meteorological data urgently by strengthening the existing hydro-meteorological observation and data management system without a large expansion of observation instruments installation. The observation items of the Programme are precipitation, river water level and discharge, and sediment load. The target year is set at the year of 1995.

12. No additional observation stations are proposed. Ten new recording raingauges and ten basic hydrological stations are proposed at the existing station sites to be established in the Programme as well as some minor repair of the raingauges and water level gauges. The sediment observation at the proposed 20 stations is also recommended to be started. A calibration facility of the current meter is recommended to be realized.

13. The data collection system, data processing system, data storing system and the data dissemination system, which are proposed in the Long Term Programme, are recommended to be introduced urgently to strengthen data management method and procedure. A total of 21 sets of computers, 14 new and 7 model computers, will be introduced for efficient data processing and storing. The data quality research

system, training system, progress control system, quality control system and evaluation system, which are also proposed in the Long Term Programme, are strongly recommended to be introduced to raise data quality and to strengthen managerial work. A training center is proposed to be established in the Central Office.

14. The total project cost of the Immediate Programme is estimated to be NRs. 366 million including price escalation. The annual operation and maintenance cost is NRs. 4.7 million in 1995, which is around 11% of the projected annual budget of the DHM in the same year.

CONCLUSION

15. Improvement of the present system to observe and manage nationwide, continuous and reliable hydrological data is requisite for effective and economical planning and designing of water resources development, flood control and watershed management. The Long Term and Immediate Programmes are, thus, recommended to be implemented for fulfillment of the above requirement.

OBSERVATION EQUIPMENT PROPOSED IN THE LONG TERM PROGRAMME (1/2)

Item		Instrument/Facility		First Stage (Immediate Programme up to 1995)	Second Stage (from 1996 to 2000)	Third Stage (from 2001 to 2005)	Total Number
Precipitation Observation		Ordinary gauge	Repair/Replacement	82	65	43	190
			New installation	–	102	102	204
		Rainfall recorder including foundation	Replacement	4 (3 tipping & weighing type)	10 (10 tipping type)	–	14 *1
			Addition	10 (10 tipping type)	15 (10 tipping & 5 weighing type)	7 (7 tipping type)	32
Water Level and Discharge Measurement	Basic station (10)	Staff gauge	Addition *2	20 sec. (9 stations)			20
		Water level recorder	New installation	6 + 1 (4 float & 3 pressure type)			7
			Improvement *3	4 (4 float type)			4
		Gauge well	Maintenance/Repair	5			5
		Construction of pressure gauge	New construction	3			3
		Double drum winch	New installation	6 + 1			7
		Construction of double drum winch cable way	New construction	5			5
			Improvement	2			2
		Office building construction	New construction	5			5
	Primary station (38)	Staff gauge	Addition *2		68 sec. (34 existing stations)		68
			New installation		12 sec. (4 new stations)		12
		Water level recorder	New installation		20 (13 float & 7 pressure type)		20
			Improvement *3		17 (13 float & 4 pressure type)		17
		Gauge well	New construction		11 (9 existing & 2 new stations)		11
			Improvement		5		5
		Construction of pressure gauge	New construction		7 (5 existing & 2 new stations)		7
		Double drum winch	New installation		25		25
		Construction of double drum winch cable way	New construction		25		25
		Construction of single winch cable way	New construction		2 (1 existing & 1 new station)		2
			Repair/Temp. Repair *5	14			14
	Secondary station (62)	Staff gauge	New installation			17 sec. (17 new stations)	17
		Peak gauge	New installation			62 sec. (45 existing & 17 new stations)	62
		Construction of single winch cable way	New construction			27 (10 existing & 17 new stations)	27
			Repair			15	15
	Basic	Current meter	Addition	9 (9 propeller type)			9
	primary		ditto	16 (11 propeller & 5 price type)	15 (5 propeller & 10 price type)		31
	Basin office	Survey equipment	Addition	5 LS			5 LS

OBSERVATION EQUIPMENT PROPOSED IN THE LONG TERM PROGRAMME (2/2)

Item		Instrument/Facility		First Stage (Immediate Programme up to 1995)	Second Stage (from 1996 to 2000)	Third Stage (from 2001 to 2005)	Total Number
Sediment Observation	Basic Station	Point integrated sampler	New installation	9			9
		Turbidity meter	ditto	11 (including No. 550.05)			11
	Primary Station	Depth integrated sampler	Addition	5			5
		Turbidity meter	New installation		5		5
	Sediment Station	Electric oven/balance	Addition	4 sets			4
		Sieve, Hydrometer, etc.	New installation		4 sets		4
W. Quality Observation	Basic Station	Field test kits	New installation		11sets x 5years (incl. No. 550.05)	11sets x 5years (incl. No. 550.05)	
		Measuring sensors	ditto		3 sets	8 sets	11
	W.Q. Labo	BOD/COD meter	ditto		1	1	2
Work Shop	Central W. Shop	Repair/Calibration	Addition	1 LS			
	Basin W. Shop	Repair	New installation		1 LS		
Data Processing		Hand terminal/software		1 LS	1 LS		
		Memory card		1 LS	1 LS	1 LS	
Training	Foreign expert	Overall observation		24 MM (foreign expert)	60 MM (foreign expert)	60 MM (foreign expert)	144 MM
		Calibration for current meter		6 MM (ditto)	6 MM (ditto)		12 MM
		Sediment/Water Quality Observation		6 MM (ditto)	6 MM (ditto)	6 MM (ditto)	18 MM
	Manufacturer	Instrument Manufacturer		8 trips	12 trips	12 trips	32 trips

NOTE : *1 14 recording gauges in Model System are not included.
*2 3 sections of staff gauge are required at Basic and Primary stations.
*3 Addition of data logger system
*4 Temporary winch will be replaced by double winch which is installed in second stage.

MAIN CIVIL CONSTRUCTION PROPOSED IN THE LONG TERM PROGRAMME

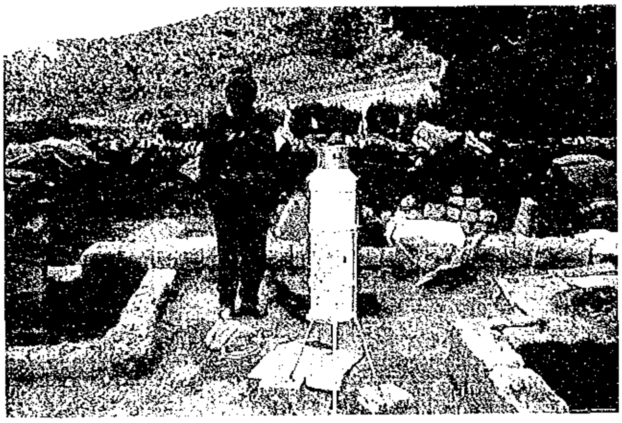
Item	Structure	First Stage (Immediate Programme up to 1995)	Second Stage (from 1996 to 2000)	Third Stage (from 2001 to 2005)	Total Number
Maintenance	Current meter calibration facility	a building with equipment			1
Training	Training center	ditto			1

NOTE : The above table excludes the construction at gauging stations.

COMPUTER EQUIPMENT PROPOSED IN THE LONG TERM PROGRAMME

Equipment and Manpower	Unit	Model System	First Stage	Second Stage	Third Stage	Total Number
1. Computer System						
(1) Design and Programming						
Basic Design	M/M		3	0	0	3
Detail Design	M/M		3	0	2	5
Programming (Foreigner)	M/M		10	0	4	14
Programming (Local staff)	M/M		50	0	0	50
System Test	M/M		1	0	0	1
(2) Computer Instrument						
Computer (1GB)			1	0	0	1
Computer (300 MB)			4	0	0	4
Computer (100 MB)			5	0	4	9
Computer (40 MB)		6	0	0	0	0
Printer		6	1	0	0	1
Digitizer			5	0	0	5
X - Y plotter			2	0	0	2
Optical disk device			5	0	0	5
Optical system			0	1	0	1
Photo copy machine			5	0	0	5
UPS			5	0	0	5
Co-processor			4	0	0	4
Stabilizer and Spike suppressor		6	18	0	4	22
Buffer			4	0	0	4
Paper	Case		10	0	1	11
Floppy disk	Box		10	0	5	15
Optical disk			2	0	0	2
Ink ribbon			10	0	5	15
Cable for LAN	m		400	0	400	800
Terminater			2	0	8	10
Ruter			0	0	5	5
Modem			0	0	5	5
Repeater			3	0	0	3
LAN board			7	0	8	15
(3) Software						
Operation system			10	0	4	14
DBMS for server machine			5	0	0	5
DBMS for client machine			7	0	8	15
LAN			1	0	4	5
Graphical software			16	0	4	20
Vaccine			1	0	5	6
Word perfect			0	0	5	5
Other software		6	10	0	4	14

Equipment and Manpower	Unit	Model System	First Stage	Second Stage	Third Stage	Total Number
(4) Furniture and Installation						
Air conditioner			14	0	0	14
Furniture	lot		5	0	0	5
(5) Staff training						
Foreign expert	M/M		5	0	5	10
2. Training Center						
(1) Computer Instrument						
Computer (120 MB)		1	0	0	0	0
Computer (100 MB)			4	0	0	4
Printer		1	0	0	0	0
Digitizer			1	0	0	1
X - Y plotter			1	0	0	1
Optical disk device		1	0	0	0	0
Optical system			0	0	0	0
Photo copy machine			1	0	0	1
UPS			0	0	0	0
Co-processor			1	0	0	1
Stabilizer and Spike suppressor		1	7	0	0	7
Buffer			0	0	0	0
Cable for LAN			100	0	0	100
Terminater			2	0	0	2
LAN board			4	0	0	4
(2) Software						
Operation system			5	0	0	5
DBMS for server machine			1	0	0	1
DBMS for client machine			4	0	0	4
LAN			1	0	0	1
Graphical software			5	0	0	5
Vaccine			1	0	0	1
Word perfect			4	0	0	4
Other software		1	5	0	0	5
(3) Furniture and Installation						
Air conditioner			1	0	0	1
Furniture	lot		1	0	0	1



0624 SAMARGAU

0623 YARAGAU

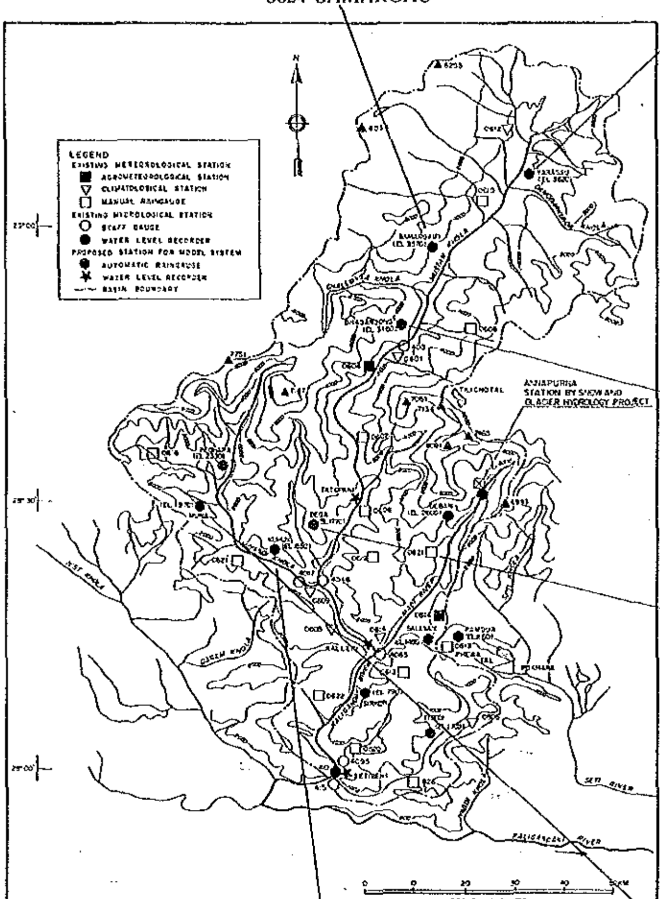
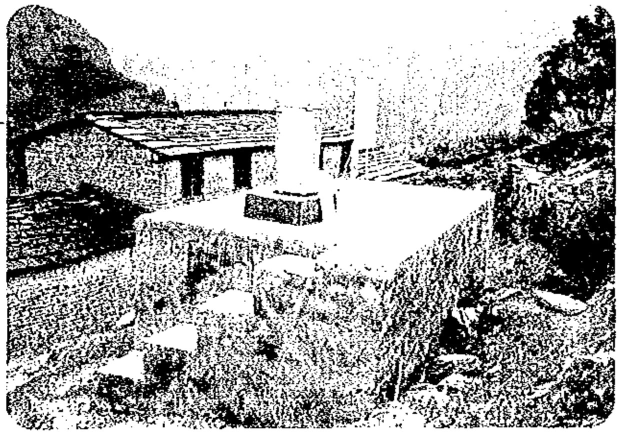
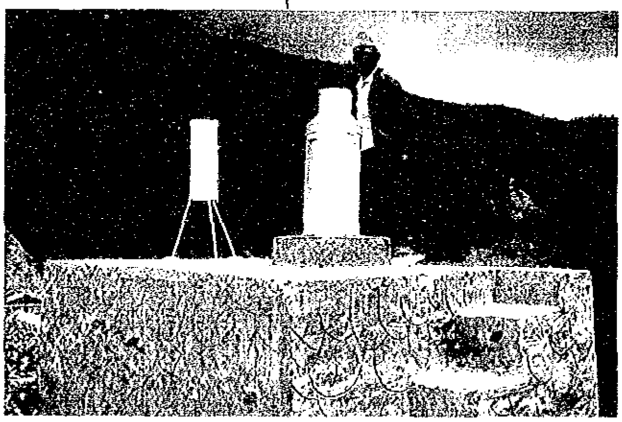


Fig. 5.1 KALI GANDAKI RIVER BASIN (MODEL BASIN)

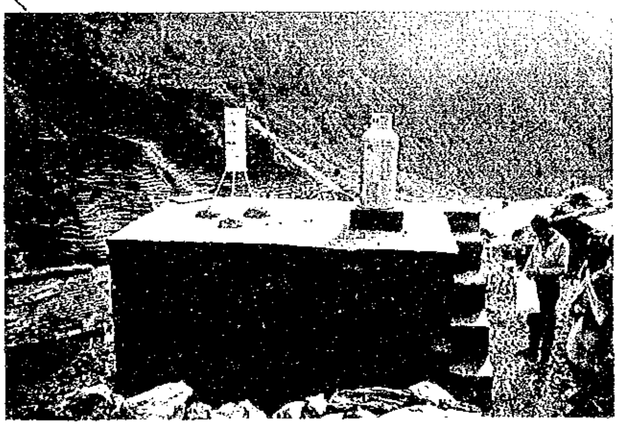
0625 DHAGARJONG



0626 BEGA

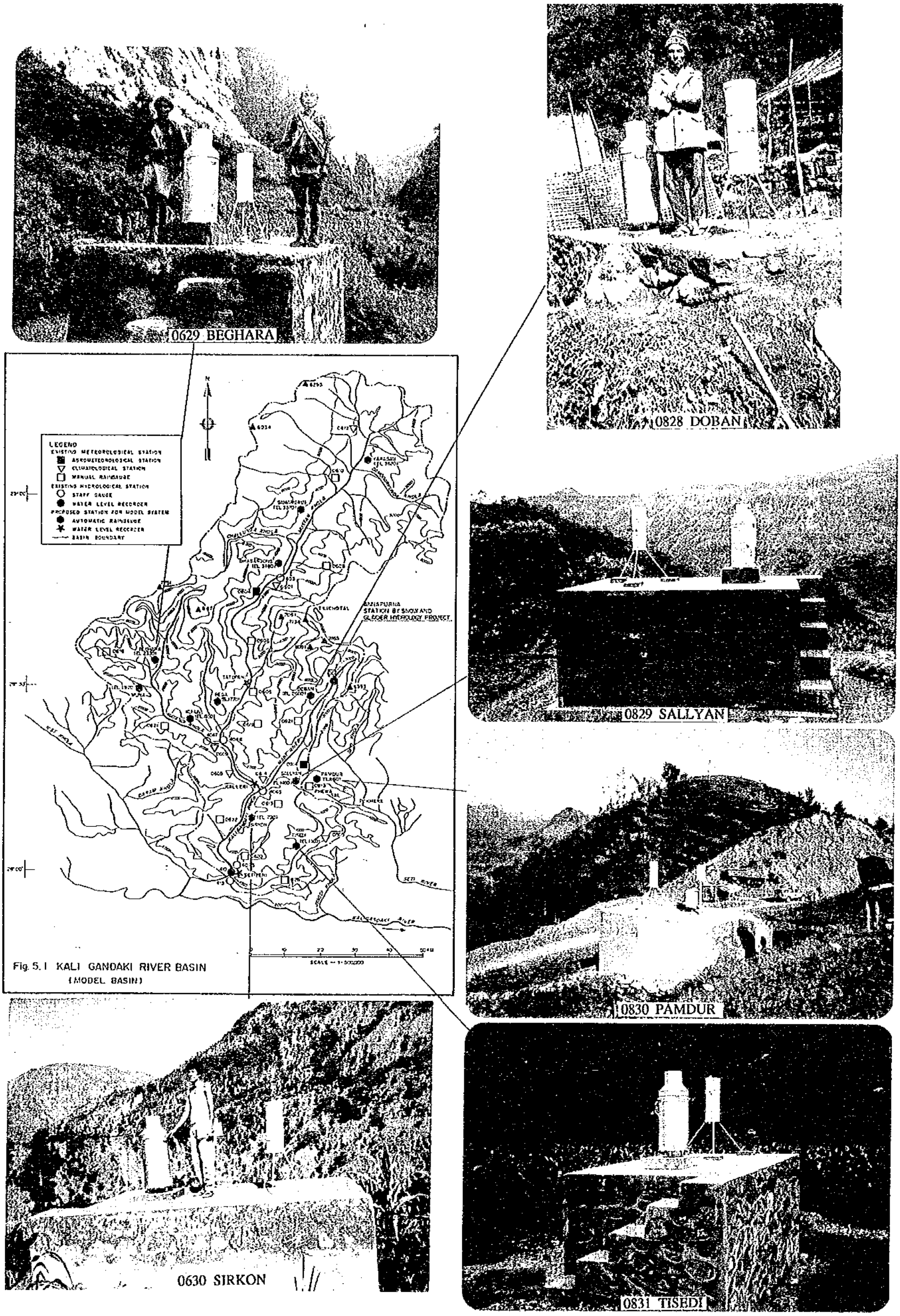


0627 KUHUN

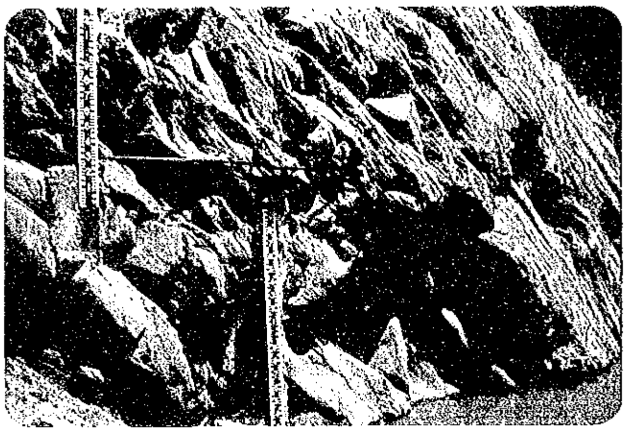


0628 MUNA

PHOTOGRAPHS OF MODEL SYSTEM (1 / 5)
(PRECIPITATION STATION)



PHOTOGRAPHS OF MODEL SYSTEM (2 / 5)
(PRECIPITATION STATION)



403.5 TATOPANI

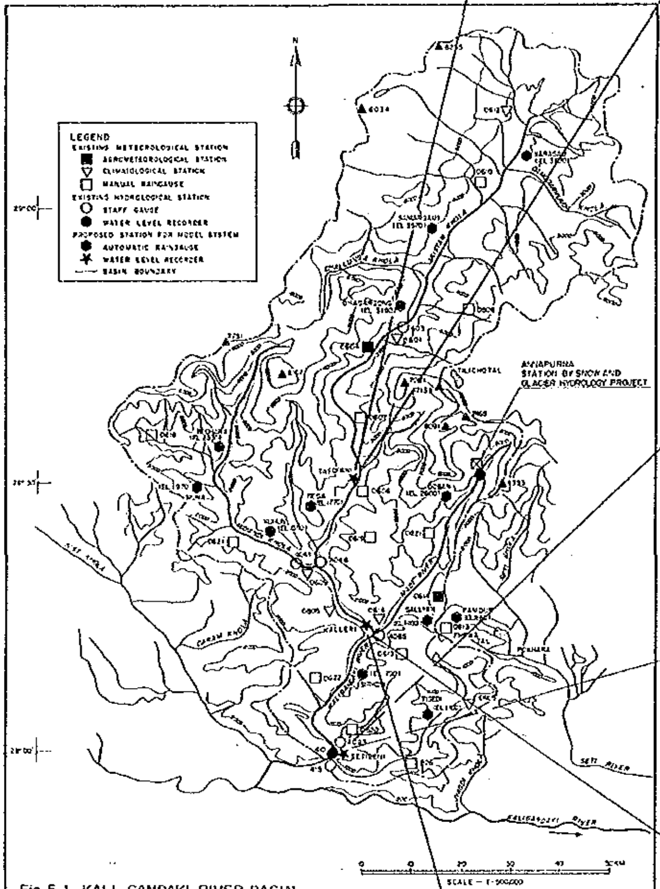
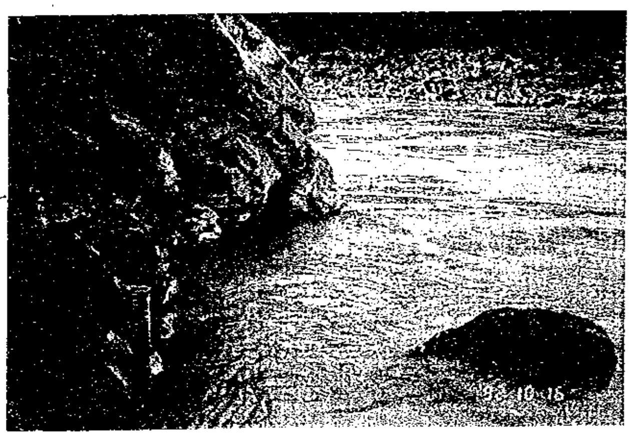
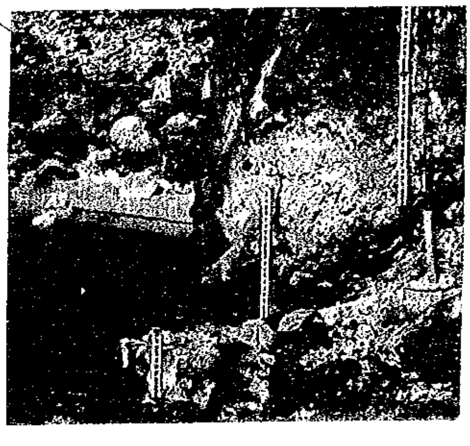


Fig. 5.1 KALI GANDAKI RIVER BASIN (MODEL BASIN)

410 SETIBENI

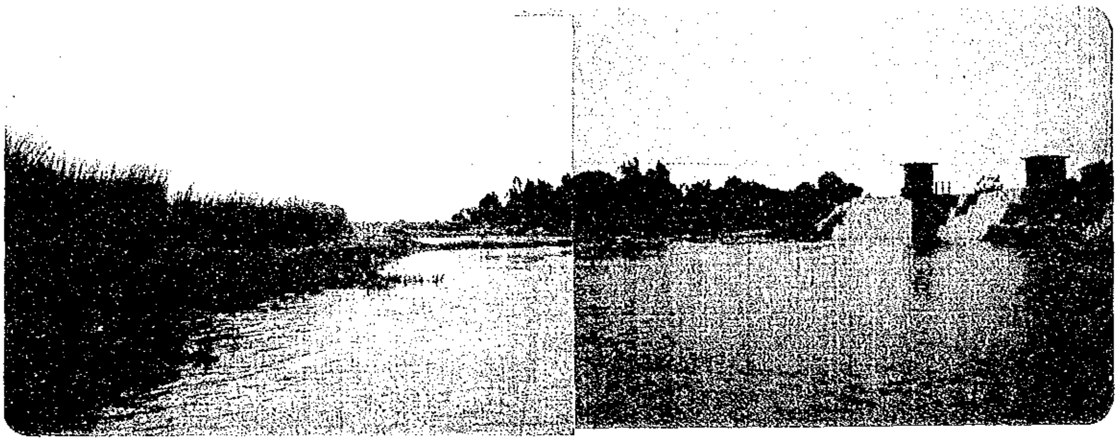


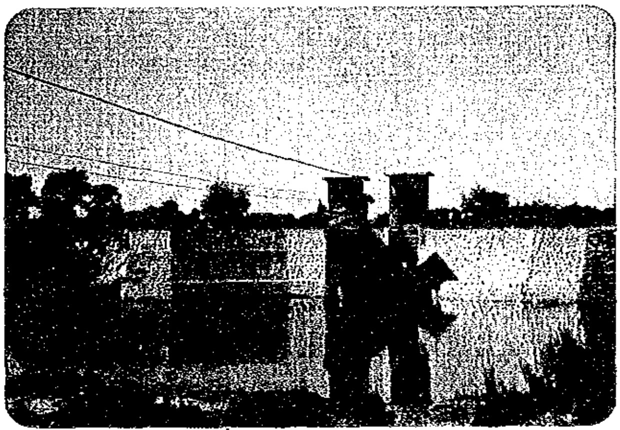


406 KALLERI

PHOTOGRAPHS OF MODEL SYSTEM (3 / 5)

(WATER LEVEL GAUGE STATION)





595 CHYUNTAHA

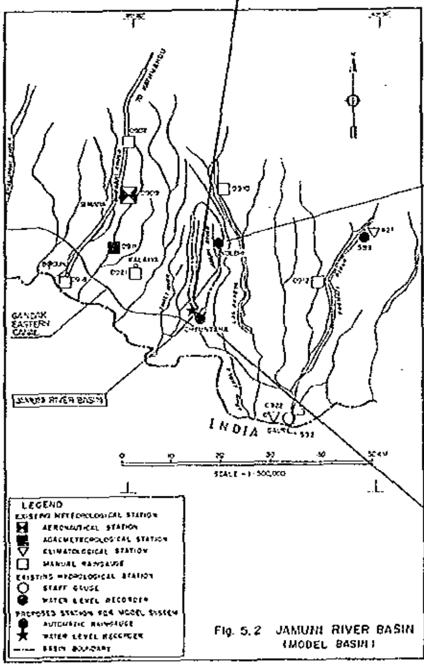
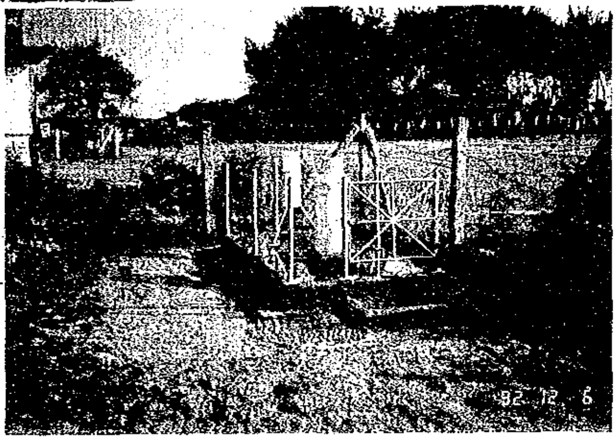
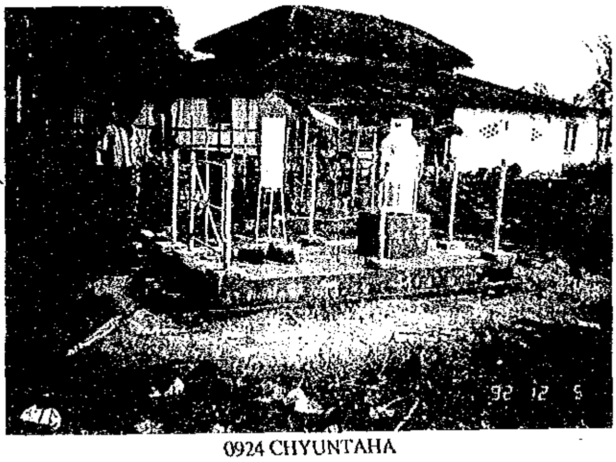


Fig. 5.2 JAMUNI RIVER BASIN (MODEL BASIN)

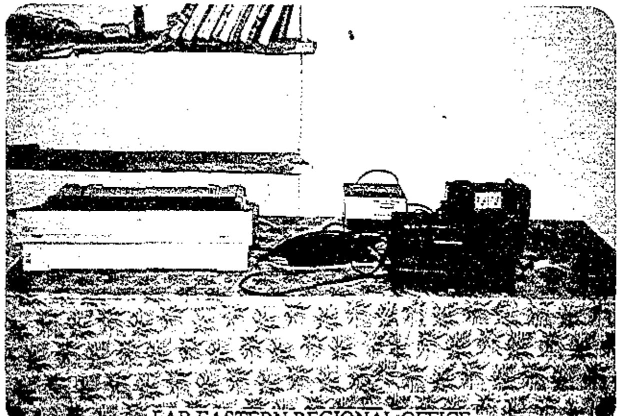


0923 KOLBHI

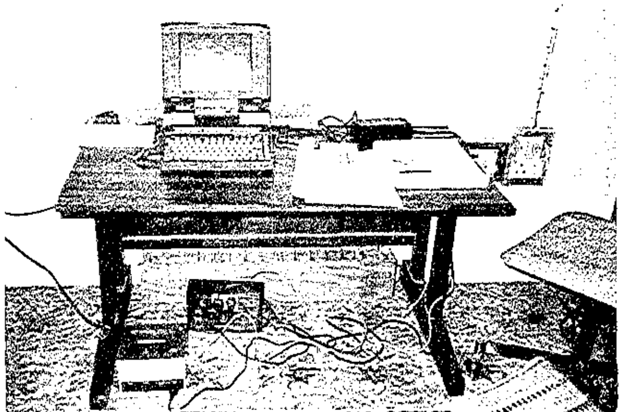


0924 CHYUNTAHA

PHOTOGRAPHS OF MODEL SYSTEM (4 / 5)



FAR EASTERN REGIONAL OFFICE



CENTRAL REGIONAL OFFICE

CENTRAL OFFICE

MID WESTERN REGIONAL OFFICE

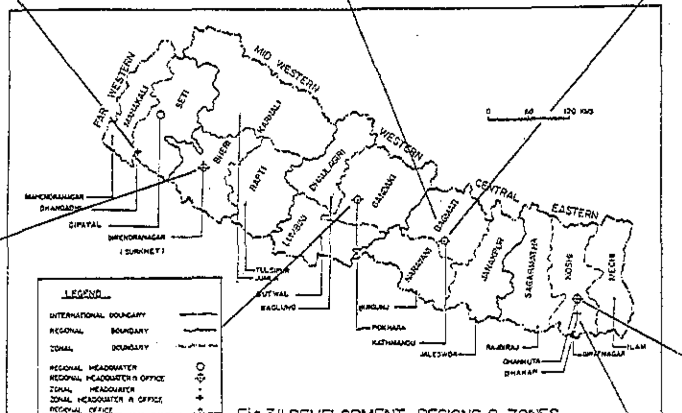
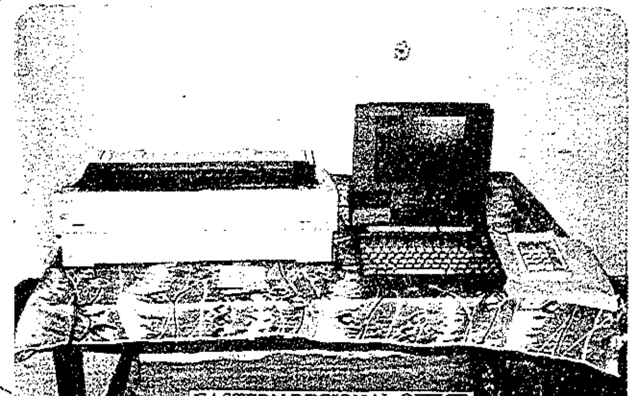
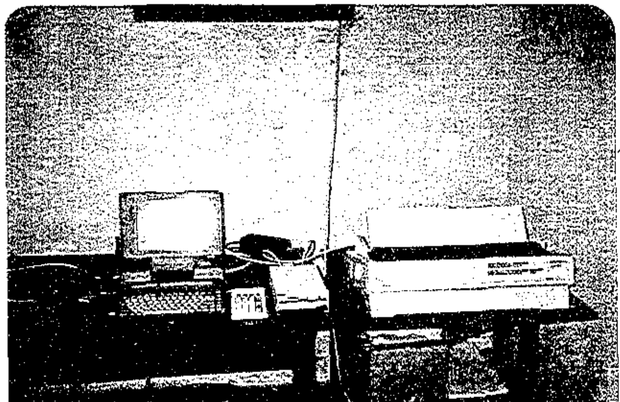


Fig 3II DEVELOPMENT REGIONS & ZONES



EASTERN REGIONAL OFFICE
(FOR METEOROLOGY)



WESTERN RIGIONAL OFFICE

EASTERN REGIONAL OFFICE
(FOR HYDROLOGY)

PHOTOGRAPHS OF MODEL SYSTEM
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NATIONWIDE HYDRO-METEOROLOGICAL
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ABBREVIATIONS

(1) Domestic Organizations

HMG/N	:	His Majesty's Government of Nepal
MOWR	:	Ministry of Water Resources
DHM	:	Department of Hydrology and Meteorology
DOI	:	Department of Irrigation
NEA	:	Nepal Electricity Authority
DSCWM	:	Department of Soil Conservation and Watershed Management
DWSS	:	Department of Water Supply and Sewerage
WSSC	:	Water Supply and Sewerage Corporation
NWSC	:	Nepal Water Supply Corporation
MLD	:	Ministry of Local Development
WECS	:	Water and Energy Commission Secretariat
NPC	:	National Planning Commission
CBS	:	Central Bureau of Statistics, NPC
DOR	:	Department of Roads

(2) International Organizations

JICA	:	Japan International Cooperation Agency
UNDP	:	United Nations Development Programme
IBRD	:	International Bank for Reconstruction and Development
ADB	:	Asian Development Bank
FAO	:	Food and Agriculture Organization
IDA	:	International Development Association
CIDA	:	Canadian International Development Agency
USAID	:	United States Agency for International Development
SATA	:	Swiss Association for Technical Assistance
GTZ	:	German Technical Cooperation Agency
GDS	:	German Development Services
USGS	:	United States Geological Survey
SAARC	:	South Asian Association for Regional Cooperation (Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka)
ICIMOD	:	International Centre for Integrated Mountain Development
DPTC	:	Water Induced Disaster Prevention Technical Centre
WMO	:	World Meteorological Organization

(3) Others

IRDP	:	Integrated Rural Development Project
GRDP	:	Gross Regional Domestic Product
EIRR	:	Economic Internal Rate of Return
GLOF	:	Glacial Lake Outburst Flood
GIS	:	Geographic Information System

(4) Abbreviation of Measurements

Length

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer

Area

ha	:	hectare
km^2	:	square kilometer

Volume

m^3	:	cubic meter
l	:	liter
MCM	:	million cubic meter
m^3/s	:	cubic meter per second

Weight

kg	:	kilogram
ton	:	metric ton

Time

s	:	second
min	:	minute
h	:	hour

Electrical Measure

kW	:	Kilowatt
MW	:	Megawatt
GW	:	Gigawatt

Other Measures

%	:	percent
10^3	:	thousand
10^6	:	million
10^9	:	billion

Derived Measures

kWh	:	Kilowatt hour
MWh	:	Megawatt hour
GWh	:	Gigawatt hour

Money

NRs	:	Nepal Rupee
US$	:	US dollar

1. INTRODUCTION

1.1 Authority

This Study was carried out in accordance with the "SCOPE OF WORK FOR THE STUDY ON NATIONWIDE HYDRO-METEOROLOGICAL DATA MANAGEMENT PROJECT IN THE KINGDOM OF NEPAL AGREED UPON BETWEEN MINISTRY OF WATER RESOURCES AND JAPAN INTERNATIONAL COOPERATION AGENCY", which was signed on September 11, 1990.

1.2 Background

Nepal holds a land area of 147,181 km^2. The river basins of the Koshi, the Gandaki, the Karnali and the Mahakali which are tributaries of the Ganges river command more than 70 percent of the whole country. The water resources of these rivers are one of the most important natural resources for the economic development of the country. On the contrary, Nepal as well as neighbouring countries such as India and Bangladesh in the downstream reaches suffers from heavy flood damage during the rainy season every year.

In view of such circumstances, His Majesty's Government of Nepal (HMG/N) had put stress on realization of river control and water resources development in the previous five-year plans of national development. Rectification and intensification of existing hydro-meteorological observation networks and data management accordingly became the most urgent requirement to the HMG/N for the effective water resources development and control.

Measures so as to rearrange existing data and to reinforce a part of existing hydro-meteorological observation instrument have been then taken by the HMG/N with the cooperation of the United Nations Development Programme (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/N. In response to this request, the Japan International Cooperation Agency (JICA) made a preliminary investigation for the technical assistance in September, 1990. The scope of work for the assistance was agreed between the HMG/N and the JICA. In accordance with this scope of work, this Study began in March 1991.

1.3 Objectives of the Study

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/N personnel and counterparts by the experts from the JICA Study Team in the course of the Study.

1.4 The Study and Report

1.4.1 Investigation and Formulation of Programme

In order to attain the objectives mentioned above, the Study is to propose Long Term and Immediate Programmes for improvement of the existing hydro-meteorological data management system, and to establish and monitor Model Observation and Model Data Management Systems. The following show investigation stages and their work periods of this Study and reports to be submitted:

Study Stage	Work Period	Submitted Report
First Field Investigation	End of May to beginning of October 1991	Progress Report (1)
First Home Works	Middle of October to end of December 1991	Interim Report (1)
Second Field Investigation	Beginning of January to end of March 1992	Progress Report (2)
Third Field Investigation	Middle of May to middle of July 1992	–
Second Home Works	Beginning of July to middle of September 1992	Interim Report (2)
Fourth Field Investigation	End of September to middle of December 1992	Progress Report (3)
Third Home Works	End of December 1992 to end of March 1993	Draft Final Report
Fifth Field Investigation	Beginning of June to end of June 1993	–
Fourth Home Works	Middle of July to end of July 1993	Final Report

The First Field Investigation was composed of four main work items, which are, collection and review of relevant data and information; review of existing networks of hydro-meteorological observation stations and current system to manage those data; preliminary study on the Long Term Programme; and planning of the Model Observation and Data Management System. The investigation and study results were compiled in the Progress Report (1).

Main study items in the First Home Works stage were basic study on the Long Term Programme; design of the Model Observation and Data Management System: and preparation of tender documents and tendering for civil construction works of the Model System. All the studies in this stage were described in the Interim Report (1).

The principal works of the Second Field Investigation were discussion with the DHM on the Long Term and the Immediate Programmes; supplemental field investigation including collection of data and informations; establishment of the Model System by constructing 18 observation stations and installing seven computers and accessories; and re-study on operation and maintenance method in the Model System. The work items and content in this stage were detailed in the Progress Report (2).

In the Third Field Investigation stage, monitoring of observation and data management activity was carried out in the Model System. Through the monitoring, problems on the observation and data management system were grasped in order to improve operation and maintenance method of the Model System and to formulate the practicable Long Term Programme.

The study in the Second Home Works stage was started at the beginning of July 1992. This study consisted of formulation of the Long Term Programme and selection of the Immediate Programme, which were conducted on the basis of results of investigation in Nepal including monitoring of the Model System and examination in Japan. The above activities were completed in the middle of September 1992 and the Interim Report (2) was prepared.

The Fourth Field Investigation commenced at the end of September 1992 and ended in the middle of December 1992. During this stage, discussions on the Programmes studied and further investigations for Programme formulation were conducted. Monitoring of the Model System was also continued and the operation and maintenance manuals were modified on the basis of monitoring results. All the above activities were mentioned in the Progress Report (3).

In the Third Home Works stage, the Immediate Programme was formulated conforming to discussion result with the DHM. The Draft Final Report was prepared during this stage which includes all the investigated data/information and study results in the preceding stages and this stage. Submittal and explanation of the Draft Final Report to the DHM in the Fifth Field Investigation and the finalization of the Report in the Fourth Home Works followed successfully.

1.4.2 Transfer of Technology

Transfer of technology has been conducted by the Study Team through on-the-job training and other training programmes during the execution of investigations and studies in Nepal.

In the First, Second, Third and Fourth Field Investigation periods, the Study of the Project was carried out in collaboration with counterpart personnels of the DHM and transfer of technology was conducted by on-the-job training. Besides the above, the following training programmes were made and training was performed to the Junior staff of the DHM:

Training	Period	Location
Introduction Training	March 15 to 23, 1992	DHM Kathmandu
Field Observation Training	June 13 to 17, 1992	Kali Gandaki river
"	June 27 to July 03, 1992	"
Computer Training	June 03 to 12, 1992	DHM Kathmandu
"	June 15 to July 09, 1992	DHM Regional Office
"	December 06 to 14, 1992	DHM Kathmandu

The introduction training aimed to introduce the Model System, train data processing including derivation of discharge rating curve and guide operation method of newly introduced observation facility and computer. The field observation training was performed in Kalleri station on the Kali Gandaki river, which included operation training of pressure type water level gauge, data logger and double drum winch. Moreover, operation training of recording raingauge in Sallyan and Pamdur was also conducted. The computer training in the DHM Central·Office and Regional Offices included operation of computers and softwares as well as guidance in data processing conforming to the Manual prepared by the Study Team.

1.5 Acknowledgement

For implementing the Study, the Study Team has appreciatively been supported by the DHM personnel and members of the Advisory Committee with a lot of helpful assistance and advice. The Study Team wishes to express grateful acknowledgement to all the concerned persons from DHM and the Committee. Besides, the Study Team received a lot of cooperation in the fields of data collection and information presentation through the public entities and agencies in the HMG/N, technical cooperation agencies of other countries and international organizations. The Study Team sincerely expresses many thanks to the officials and individuals of these groups.

2. PRESENT SOCIO-ECONOMIC AND NATURAL RESOURCES CONDITIONS

2.1 Socio-Economy

Nepal, which is located in the subtropical zone, is a traditional agricultural country having an area of 147,181 km^2 and a population of about 18.5 million in 1991 with an annual growth rate of 2.08% between 1981 and 1991. Approximately 90% of the economically active population is engaged in the agricultural and agro-industrial sectors which account for more than 50% of the Gross Domestic Product (GDP).

In the fiscal year 1991/92, the GDP amounted to nearly US$ 3,000 million, whereas the per capita GDP was only US$ 160 which was one of the lowest GDP in the world, because of a lack of natural resources and the industries with high value added. For the period 1984/85-1989/90, the real growth in the per capita GDP indicated a low rate of 2.42%.

External trade of Nepal has continued an unfavourable balance every year. In 1990/91, exports and imports were NRs. 7,604 million and NRs. 24,198 million respectively, indicating the trade deficit of NRs. 16,594 million corresponding to more than 60% of the Government budget. The exports and imports showed average growth rates of 19.83% and 20.97% per annum for the period 1985/86-1990/91 respectively. In view of the present economic situation of Nepal, such a trade deficit may continue for the time being.

The huge amount of trade deficit has influenced the balance of international payments (BIP). In 1990/91, the balance of current account in the BIP reached an unfavourable amount of NRs. 10,255 million, and a large part of this amount was compensated by the capital account which included foreign loans and grants.

Budget expenditures of the Government amounted to NRs. 26,641 million in the fiscal year 1991/92, of which the development expenditure accounted for NRs. 16,895 million, i.e. 63%. The average annual growth rate was 18.27% for the total expenditure and 18.02% for the development expenditure for the period 1986/87-1991/92. On the other hand, the foreign aid amounted to NRs. 8,317 million in 1991/92 at an average growth rate of 25.18% per annum for the period 1986/87-1991/92.

To promote the balanced development among regions, the country is divided into five development regions; Eastern Development Region, Central Development Region, Western Development Region, Mid-Western Development Region and Far-Western Development Region, under which fourteen zones and 75 districts are delineated and administrated. However, in almost all the socio-economic sectors, there exist development differentials among regions, despite active efforts of the Government. In general the Central Development Region has occupied the topmost position in socio-economic development and the Far-Western Development Region the lowest position. Details of the development situation by region are given in Annex A.

In Nepal, the Seventh National Development Plan (1985/86-1989/90) finished in 1990 and the Eighth Plan (1992/93-1996/97) was started successively. During the Seventh Plan period, agricultural sector in the GDP achieved a relatively high real growth rate of 4.65% per annum against the planned annual rate of 3.50%, while for the non-agricultural sector the real growth was a low average rate of 3.17% per annum compared with the plan rate of 5.56% for the same period. Accordingly, the real growth in overall GDP came to an average annual rate of 3.99% which was lower than the plan rate of 4.50% per annum.

The principal objectives that the Eighth Plan seeks to achieve are: sustainable economic growth; alleviation of poverty; and reduction of regional imbalances. Programmes which receive special priority in the Plan are: (a) agricultural intensification and diversification; (b) energy development; (c) development of rural infrastructure; (d) employment generation and human resource development; (e) reduction in population growth; (f) industry and tourism development; (g) export promotion and diversification; (h) macro-economic stabilization; (i) administrative reform; and (j) monitoring and evaluation. It is estimated that a 5.1 percent average annual growth rate in the GDP can be achieved during the Eighth Plan period. The agricultural Sector will share 52.7 percent in the GDP in 1996/97.

2.2 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 an average length of about 885 km from east to west and a width ranging from 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.

(1) Terai

The Terai is the part of the Ganga plain within Nepal, lying at altitudes of 60 to 300 m. Nepal has three discontinuous segments of the Terai Belt along its southern border with widths ranging up to 50 km. The northern fringe of the Terai is covered by comparatively heavy jungle and extends to the base of the Siwalik Ranges. The southern fringe has sparse jungle. The soils of the Terai are developed on alluvial.

(2) Siwalik Ranges

The Siwalik forms a sharp contrast to the Ganga plain and rises steeply to altitudes up to 1,800 m. In most places, the elevations are between 300 m and 1,500 m. The region is mainly covered by sterile soils formed largely from coarse grained sandstone, and as a result cultivation is very limited. Its slopes are highly eroded by wind and water and the forests are less dense.

(3) Middle Mountains

The region includes areas within the Mahabharat Ranges and inter-mountain area and is characterized by moderately high mountains, of which the peaks are between 1,500 m and 2,500 m and midlands of gentle slope. Geologically, it is a region of moderately metamorphosed sedimentary material. The Mahabharat Ranges form a major syncline that traverses almost the entire length of the country. Runoff from the northern slopes of the Ranges passes south through four deep gorges of rivers, Sapta Koshi river, Gandaki river, Karnali river and Mahakali river. The midlands are heavily populated and favourable for agriculture.

(4) High Mountains

The region is characterized by high mountains with steep slopes and narrow valleys. The elevation of most of the river valleys is over 2,000 m. The mountain tops are commonly above 4,000 m in this region. In the less steeply sloping areas cultivation extends to 2,500 m - 2,700 m. Steeper areas are forested.

(5) High Himalaya

The northern part of the country comprises the Himalayan Ranges. The Himalaya is not a single continuous mountain range but a series of several more or less parallel or converging ranges. West of Mount Everest the main range lies within Nepal, and is divided into several groups by deep river gorges that traverse the barrier. The main range, called Great Himalaya, includes many of the highest peaks in the world, with altitudes ranging from 7,000 m to 8,848 m. This main range is not a major drainage divide. The divide between the two major river systems, the Ganges and the Brahmaputra, lies to the north of the Great Himalaya along a mountain chain with altitudes 2,300 m to 3,000 m lower than the main range. The headwaters of the Sapt Koshi, the Gandaki and the Karnali Rivers have their origin north of the Great Himalaya and pass through it in deep gorges. In general, runoff from the area north of the Great Himalaya is low. The winter is bitter and hostile and the summer is short and moderately cold.

2.3 Geology

Nepal is divided into five physiographic divisions, which are running nearly in parallel bands from north-west to south-east. Every region has 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	300 m - 1500 m	Tertiary sand stone, Silt Stone, Shale and Conglomerates.
3. Middle Mountains zone	800 m - 2500 m Relief 1500 m with isolated peaks to 2700 m.	Phyllite, quartzite, Lime-stone and islands of granites.
4. High Mountains 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.

Basically, the general feature of the geology is strongly reflected into physiography. The rock formation comprises of parallel zones extending along the east-west direction. The Terai zone is nearly plain area with alluvial deposited dip towards the north. Siwaliks zone is relatively low hill and of youngest rock, located in the southern part of the Middle Mountains. In the Middle Mountains, the bed rocks are metamorphosed sedimentary strata of greater age, dipping towards the north. The High Mountains zone rocks are gneiss and quartzite. In the High Himalaya zones, gneisses display a normal, upward decrease in metamorphism and grade into a fossiliferous sedimentary sequence which ranges from Cambro-ordovician to Eocene.

The Main Central Thrust (MCT) is a zone of intensely fractured, imbricate thrust sheets (schuppen) up to 10 kilometres thick, which dips north at 30 to 40 degrees. The MCT began to form in the mid-Miocene, and its ramp-like geometry caused the ancestral Himalayas to rise prominently along its north side, about the same time that Siwalik molasse deposition commenced in the south. The Main Boundary Thrust (MBT) is currently the most active fault in the Himalayas, as it probably accommodates most of the present northward subduction of the Indian plate. The MBT extends the full length of the Himalayas and defines the northerly limit of the Siwaliks. The geological condition of Nepal is shown in Fig. 2.2.

2.4 Hydro-Meteorology

In Nepal, there are five major climatological zones: subtropical, warm temperate, cool temperate, alpine, and arctic. The climate of the Terai and the Siwalik is subtropical. Rainfall concentrates in the monsoon months from June to September. Winter temperatures are mild. The climate in the Middle Mountains is warm temperate. In winter there is occasional snow in the high areas. The climate in the High Mountains is cool temperate. Snow falls 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 occurs above the snow line where there is perpetual frost.

The annual mean precipitation is around 1,530 mm in the whole of Nepal. The seasonal variation of rainfall in Nepal is attributable to the south-east monsoon during the months from 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. The general characteristics of rainfall are shown in Fig. 2.3.

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 and the Mahabharat Ranges. Drier conditions prevail in the lee of these regions. Thus alternate bands 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. Monthly mean precipitations are tabulated below for three (3) stations:

(Unit: mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Kathmandu (1030)	14	16	32	56	103	248	364	299	192	68	7	12	1410
Mustang (612)	10	8	4	3	1	9	54	55	15	9	2	8	177
Lumle (814)	30	34	45	110	287	784	1401	1230	823	218	29	17	5010

Source: DHM

Air temperature rises usually during the premonsoon period from February to May. It decreases during postmonsoon period from October to January. The maximum and minimum temperatures appear in July and January, respectively. Spatial variations in air temperatures are influenced by altitude. The monthly mean temperatures are shown below for three (3) stations:

(Unit: degree centigrade)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Surkhet (0406)	11.5	14.1	18.8	24.5	27.4	27.7	26.5	26.6	25.2	21.9	16.6	12.3	21.1
Kathmandu (1030)	9.4	11.2	15.5	19.2	21.6	23.0	23.4	23.3	22.0	19.0	14.0	10.2	17.7
Dhankuta (1307)	11.4	13.7	17.4	21.2	21.8	22.4	27.8	23.1	21.5	20.4	16.3	13.2	19.2

Source: DHM

Seasonal variations in the relative humidity are related to the effects of the monsoon. At Kathmandu, the relative humidity reaches more than 80% in the monsoon season but it decreases to less than 50% in dry season.

Evaporation rates are highest just before the monsoon season, when saturation deficits are greatest. Higher evaporation rates are also seen during the monsoon season due to high temperature. Annual pan evaporation reaches around 1,400 to 1,900 mm according to records at Jumla, Okhaldhunga, Kathmandu, Chisapani and Pokhara.

Rivers in Nepal are classified into three groups in terms of sources of dry season discharge. The first group of rivers has their sources in the snow and glaciers as well as baseflows from the High Mountains or High Himalaya in the dry season. The Karnali, the Gandaki, and the Sapta Koshi rivers are included in the first group.

The second group of rivers originates from the Middle Mountains. They are fed by ground water in dry seasons and do not dry up. The Bagmati, Rapti, Mechi, Kankai and Babai are some of the second group of rivers.

The third group of rivers has their origins in the Siwalik Range or the Terai. The Kamala, Tilawa, Sirsia, Manusmara, Hardinath, Sunsari and Banganga are some examples of this group. In dry season, these river discharges show extremely less than those in the other groups.

The concentrated runoff within three months of the year, viz., July, August and September, is typical of the rivers in Nepal. The discharge during these three months accounts for about 65% of the total annual runoff, while for the rivers with smaller drainage area the percentage rises to around 75%. The general characteristics of river runoff are shown in Fig. 2.4. The monthly average runoff data are shown below for several stations:

(Unit: m^3/s)

St. River	Drainage Area (km^2)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
280 Karnali	42,890	369	335	347	442	701	1520	3310	4320	2990	1300	628	445	1400
360 Rapti	5,150	28	23	18	14	15	93	298	388	355	147	57	33	123
390 Tinau	554	4	3	2	2	2	15	58	108	47	25	8	5	24
450 Gandaki	31,100	353	288	266	349	558	1620	4280	4950	3450	1590	795	498	1590
589 Bagmati	2,700	18	14	11	12	23	98	398	364	370	90	30	22	122
695 Koshi	54,100	355	306	305	405	659	1610	3990	4220	3340	1450	769	495	1500
795 Kankai	1,148	12	9	8	11	21	72	198	145	106	51	23	15	56

Source: DHM

2.5 Rivers and River Basins

As mentioned in the previous section, rivers in Nepal are classified into three groups; (a) rivers originating from the High Mountains or High Himalaya; (b) rivers originating from the Middle Mountains; and (c) rivers originating from the Siwalik Range or the Terai. All of these rivers finally flow out of the southern border into India. The division of basic unit was made as listed below:

Basin No.	Name of River Basin	Group	Basin Area within Nepal (sq. km)
I	Mahakali river system	(a)	5,317
II	Southern border river group No.1	(c)	3,811
III	Karnali river system	(a)	43,227
IV	Babai river system	(b)	3,252
V	Southern border river group No.2	(c)	948
VI	Rapti river system	(b)	6,215
VII	Southern border river group No.3	(c)	4,849
VIII	Narayani/Gandaki river system	(a)	31,726
IX	Southern border river group No.4	(c)	3,502
X	Bagmati river system	(b)	3,681
XI	Southern border river group No.5	(c)	3,013
XII	Kamala river system	(c)	1,786
XIII	Southern border river group No.6	(c)	1,896
XIV	Sapta Koshi river system	(a)	27,863
XV	Southern border river group No.7	(c)	3,462
XVI	Kankai river system	(b)	1,317
XVII	Southern border river group No.8	(c)	1,316

Among the above rivers, the Mahakali, Karnali, Gandaki, and Sapta Koshi rivers have drainage areas outside Nepal. The map of rivers and river basins in Nepal is shown in Fig. 2.5 and the drainage areas are given in Table 2.1.

2.6 Communication and Transportation

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

Communications are very important in Nepal where road transport is not well developed. In view of the importance of 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-year plan. The major communications in Nepal are telecommunication and postal services. However, the number of these telecommunication and postal facilities is insufficient to serve a population amounting to about 18.5 million in 1991.

(1) Road

In 1989, the total length of roads in Nepal was 7,006 km which comprised 1,745 km (25%) in the Eastern Development Region, 2,575 km (37%) in the Central Development Region, 1,310 km (18%) in the Western Development Region, 826 km (12%) in the Mid-Western Development Region and 550 km (8%) in the Far-Western Development Region as shown in Fig. 2.6.

During the period 1984-1989, the total road length of Nepal increased at an average rate of 4% per annum, especially 14% for gravel roads. However the increase rate of black topped roads was only 2% per annum during the same period. Ratio of the paved road to the total road length was 35%, 50%, 54%, 28% and 13% for each region from east to west, and the average ratio was 41%. Relatively, the Central Development Region dominates regarding the road facilities and the Far-Western Development Region occupies the lowest position. In the mountain and hill area, the road mainly consists of trail network which is still extensively well-used.

The Department of Roads (DOR) is in charge of the development and maintenance of roads in Nepal. The DOR has chosen priority road development projects which are to be completed by the year 2000 conforming to the basic policy shown below:

1) East-West Highway should be completed,
2) One North-South Highway should be constructed for each zone and the access road from this highway to Regional Head Quarter should be also completed, and
3) The second East-West Highway should be linked.

However, it will be very difficult to realize these priority projects judging from the results of the seventh plan that shows that only 52.9% of road construction was completed.

(2) Airway

Since most of the hilly and mountainous areas of Nepal are not easily accessible by other means of transport, airways prove to be of tremendous significance. There are at present

43 airports. However, the flight is sometimes cancelled due to bad weather and lack of planes. Especially in the mountainous area in the rainy season, flight cancellation increases. The domestic airline network is given in Fig. 2.7.

(3) Railway

The Janakpur-Jayanagar Railway (51 km long, 2.6 gauge) is the only one in Nepal. It started operation in 1935, mainly rendering services for the transportation of passengers and goods. Due to a lack of proper maintenance and repair, it cannot provide the expected extent of services. Moreover, the recent people's movement had damaged some railway leagues and compartments.

(4) Ropeway

The Kathmandu-Hetauda Ropeway (42 km long, 42,000 m. ton annual capacity) has been used for the transportation of goods. However, due to a lack of proper repair and maintenance, its annual capacity has decreased by 25 percent since the year 1974/75.

(5) Postal Service

In 1990, there were 2,232 post offices in Nepal including 5 district post offices, 478 area post offices and 1679 additional post offices and others. One post office services on average an area of about 66 km^2. In the mountainous area, the density is lower. There are several hydro-meteorological observation stations located far from the post office which need 2 to 3 days walk to reach the office. The post office distribution is summarized below:

Region	Number of Post Office	Area (km^2)	Density (km^2/office)
Eastern Region	593	28,456	48
Central Region	608	27,410	45
Western Region	480	29,398	61
Mid Western Region	299	42,378	142
Far Western Region	252	19,539	78
Total	2,232	147,181	66

Source: Statistical Year Book of Nepal, 1991

(6) Telecommunication

Telecommunication was introduced in Nepal in 1913 and its systematic development started only after 1956. By the year 1990, Nepal had 42 telephone exchanges, 76 public call offices and 55 wireless stations. However, these facilities are insufficient in quantity and quality especially in remote area.

2.7 Power Supply

Total installed capacity of power generating facilities in Nepal was 257 MW, but their possible output was 228 MW in total as of 1990. Most of those facilities (98%) are interconnected to the Central Nepal Power System (CNPS) by 132kV and 66kV transmission lines. During 10 years from 1981 to 1990, hydropower stations of 176MW in total have been developed in the country. Main hydropower stations such as Kulekhani I (60MW), Kulekhani II (32MW), Devighat (14MW) and Marsyangdi (69MW) were commissioned in 1982, 1984, 1986 and 1990, respectively. Due to the commissioning of these hydropower stations, the share of hydropower to total installed capacity in the country has increased from 67% in the year 1980 to 89% in 1990. Following is a summary of installed capacity:

Facility	CNPS	Others	Total
Hydro	227.2MW	1.9MW	229.1MW
Diesel	25.0MW	3.1MW	28.1MW
Total	252.2MW	5.0MW	257.2MW

In addition to the above existing generating facilities, the following power plants are under construction:

1) A diesel power plant of 26MW (4 units) in Biratnagar in the Eastern region
2) Jhimruk hydropower plant of 12MW (3 Francis turbines) in Pyutan district of the Mid-Western region

Besides, private generating facilities of about 15MW by diesel and steam are also in operation.

The present transmission line voltages employed in the country are 132kV, 66kV and 33kV. The voltage of 132kV was firstly employed for the line between Gandak power station and Hetauda substation. The 132kV system has been extended to Kathmandu Valley in 1986 via Kulekhani II-Siuchatar line and in the Eastern region towards

Biratnagar and further extended to Anarmani substation. In addition, another 132kV system was extended towards the Western region from Dumkibas to Butwal and from Butwal to Nepalgunj.

Under the Marsyangdi hydropower project, a 132kV single circuit line was constructed over 110km from the power station to Kathmandu (Balaju) and to Bharatpur. Another 132kV system is under construction from Nepalgunj to Mahendranagar in the far west, and its completion will form a complete interconnection of the power system among main demand centers in Nepal. General information on transmission lines and transformers in the country is summarized below:

Voltage	Transmission Line (Circuit-km)	Capacity of Transformer Whole system	(MVA) *1 Bagmati Area
132kV	1,000.0	213.8 *2	82.8
66kV	379.5	188.7	153.9
Total	1,379.5	402.5	236.7

Note: *1 excluding step-up transformers at power stations
*2 including 132/66kV transformers

The existing and planned power stations and transmission lines are shown in Fig. 2.8.

3. PRESENT CONDITION OF HYDRO-METEOROLOGICAL OBSERVATION AND DATA MANAGEMENT SYSTEMS

3.1 Role of DHM

3.1.1 History of DHM

In 1921, the first rainfall station was established at the Indian Embassy in Kathmandu. Following this station, four climatological stations and about a hundred precipitation stations were established and operated in Nepal by the India Meteorological Department. The systematic collection of hydrological data in the Karnali basin was started in 1961 by the UN Special Fund for the feasibility study on power project.

The Hydrological Investigation Project, a joint venture project between the HMG/N and the USAID-mission, began in 1961. This project was designed to establish a nationwide hydrological data collection system with centralized agency to collect, compile, and publish data produced by the network. The Hydrological Investigation Project was substantially commenced in May 1962 and ended in 1968.

The Hydrology Survey Section, which was established under the Department of Electricity, designed a nationwide hydrological data collection system under the supervision of two technical advisors from the U.S. Geological Survey. Thirty regular stream gauging stations and more than twenty partial stream gauging stations were established between 1962 and 1965. The Hydrology Survey Section grew up into Hydrological Survey Department and the Nepal Meteorological Service (NMS) was established in 1965. The Hydrological Survey Department took over the responsibility for meteorological data collection from the India Meteorological Department and was renamed the Department of Hydrology and Meteorology in 1966.

Surface water records of Nepal for the period up to December 1965 were compiled and published in February 1967 which was the first publication of basic information on rivers in Nepal. The first publication was followed by supplement No. 1 presenting surface water records collected within Nepal during 1966.

All the hydrological and meteorological programmes and activities were handled entirely by the Department of Hydrology and Meteorology in 1968. During the period from 1962 to 1968 a priority network of river stations was established on the major rivers possessing structures such as cableways, stilling wells and sediment sampling facilities. The network was expanded with 120 stations by 1968. Since the USAID project finished in 1968, the hydrological network was further expanded to a maximum total of 320 stations.

The Ground Water Investigation Project was started under the joint agreement between the HMG/N and the USAID in 1969. Combining Hydrology Section, Meteorology Section and Ground Water Section with the Department of Irrigation, the Department of Irrigation, Hydrology and Meteorology (DIHM) was organized with Regional offices in Biratnagar, Kathmandu, Pokhara and Nepalgunj in fiscal year of 1972.

The WMO Agrometeorology and Instrument Maintenance Project, which started in 1974 and finished in 1980, increased the number of agrometeorological stations from 20 to 30. From 1981 to 1984, four regional training courses for hydrology technicians were organized in Kathmandu under the joint sponsorship of the HMG/N and the UNESCO. The meteorological database was developed by the DIHM from 1982 and it continues to be developed.

In 1982, the UNDP Project on development of operational hydrology services was started to be implemented in Nepal. At the beginning stage of the UNDP Project, 102 hydrological stations had been closed and the remaining 218 stations were in operation. Two micro computer sets for data entry were undertaken by the UNDP Project in 1984, which were followed by four computer sets in 1986. In 1985, a plotter and a digitizer were installed under the UNDP Project. The database system for the hydrological data was developed with this equipment.

In 1987, the Snow and Glacier Hydrology Project was initiated with the technical assistance of the GTZ. In the same year, the Department of Irrigation, Hydrology and Meteorology was reorganized into the Department of Irrigation (DOI) and the Department of Hydrology and Meteorology (DHM).

In 1988, after completion of the UNDP Project, 94 hydrological stations were closed according to the DHM's decision considering the factors such as accessibility of a station, facilities, type of a station, reliability of rating curve, availability of an observer, constraint of budget for operation and maintenance and importance of stations. In 1990, the DHM Regional Office for hydrology at Nepalgunj was joined with meteorology office at Birendranagar in the Mid Western Region. In 1991, the Regional Office at Chisapani in the Far Western Region was moved to Dhangadhi.

3.1.2 Present Organization and Function of DHM

There are twenty one Ministries under the Office of the Prime Minister in the Government. The Ministry of Water Resources (MOWR) 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 as shown in Fig. 3.1.

The DHM is responsible to fulfill the role of observation, management, analysis, forecast and dissemination of hydrological and meteorological data and information. The DHM consists of three (3) Divisions, five (5) Regional Offices and two (2) Sections as shown in Fig. 3.2. 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 locations of the Regional Offices are indicated in Fig.3.3.

The functions of the Divisions, Sections and the Regional Offices are briefly explained below and shown in Table 3.1:

1) The Hydrology Division studies different hydrological aspects, models and glaciers and issues reports on data and study results.

2) The Climatology Division studies different climatological aspects, prepares the reports and provides necessary services to agriculture sector.

3) The Meteorology and Weather Forecasting Division provides weather forecasts and flood warning, and arranges information from abroad.

4) The Administration and Accounts Section administrates and supervises budgets, staffs and properties.

5) The Other Technical Services Section controls construction, operation and maintenance of observation stations, data collection and processing, chemical laboratories and staff training.

6) The Regional Offices establish, operate and maintain observation stations, and collect and process data.

There are 14 synoptic stations including 5 aeronautical stations, which belong to the Meteorology and Weather Forecasting Division and five Regional Offices. These stations function to observe synoptic parameters and supply the data every three hours from 5:45 to 17:45 to the Meteorology and Weather Forecasting Division in the Kathmandu airport through wireless equipment for weather forecasting and civil aviation purpose. A hydrology station has been established at Chisapani under the control of the Far Western Regional Office in cooperation with the Karnali Multipurpose Project. This station has the responsibility to operate and maintain river gauging stations, collect and process data, and measure the discharge and sediment concentration in western part of the Karnali River System. The other hydro-meteorological observation stations are operated by part-time field observers under the control and supervision of the Regional Offices.

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

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.

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

Further discussion on restructuring of the DHM organization was done in the HMG/N so as to make administration strong enough, and new organization has been effective from mid-July 1993.

3.1.3 Present Work Flow in DHM

Hydrological and meteorological observations are carried out in the whole country by the DHM. There are two types of observation stations with regard to observation staff. One is meteorological synoptic station and hydrology station, in which well trained staffs of the DHM stay and operate the stations. The other is ordinary and/or recording gauging stations for hydrological and meteorological observation, at which part-time observers are employed by the DHM and they operate the stations. Inspection and maintenance works of stations and instruments are conducted periodically by the staff from the Regional or Central Offices.

The data observed at the above stations are sent to the Regional Office by mail or by hand by the Regional Office's staff varying from once a month to once every six months. The data of the synoptic stations are transmitted by wireless equipment to the Kathmandu airport every three hours for weather forecasting. Samples of suspended sediment load are forwarded by bottle runners to the Regional Offices.

At Regional Offices, the data sent from the observation stations are preliminarily processed after registration. The data processing includes duplication of the original records, calculation of average and cumulative values and development of discharge rating curves. The sediment load samples are analysed in laboratories of the Regional Office. A tracer laboratory is in operation in Kathmandu for discharge measurement. In 1992, this Project introduced computers to all the Regional Offices. The data processing work is now carried out by using these computers.

The original records and data processed at the Regional Offices are sent to the Central Office by hand by staff from the Regional Offices. The data sending is not so frequent and only two to four times a year. In the Central Office, the data sent from the Regional Offices are firstly stored in the hydrological and meteorological data acquisition units of the Other Technical Services Section through the Director General. Next, the data are entered into the database and the original ones are stored permanently in storerooms. Data dissemination is made upon requests from users by data books, computer output or disk.

The hydrological and meteorological aspects in the country are examined and analysed by some Hydrologists or Meteorologists. The weather forecasting is one of the important roles of the DHM, which is disseminated every day through broadcasting. The present work flow in the DHM is illustrated in Fig. 3.4.

3.1.4 Data Observed 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.

3.2 Observation

3.2.1 Precipitation Observation

(1) General

Prior to the year of 1964, the India 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. A number of the WMO projects have assisted the NMS in establishing its own network of meteorological stations which consists of Precipitation, Climatological, Agrometeorological, Synoptic, Aeronautical ones, and in developing station inspection and maintenance program, forecasting unit at Kathmandu airport and radio telecommunication and so on. Training both on-the-job and through overseas fellowship and initiation of data publication were also provided by many WMO projects.

At present, 252 meteorological stations are operational in the whole Nepal. The density of distribution is around 580 km^2/gauge on an average. This density is considered to be insufficient judging from the assessment of rainfall distribution patterns in such a mountainous area and the 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 difficult access in the high mountainous area, difficulty in finding adequate-trained persons for observers, budgetary constraints and so on. In the Model System of this Project, 14 new precipitation stations were established in 1992 and are being operated.

(2) Precipitation Observation Network

A total of 252 meteorological stations except for 14 model precipitation observation stations are in operation under the management of the DHM as of August 1991. The meteorological network consists of 14 Aeronautical and Synoptic, 24 Agrometeorological, 65 Climatological and 149 Precipitation stations. The observation items of these stations are summarized below:

	Observation Item	Aero/Synoptic Station	Agrometeo-rological Station	Climatological Station	Precipitation Station
(1)	Sky condition	O			
(2)	Visibility	O			
(3)	Atmospheric pressure	O			
(4)	Min/Max temperature	O	O	O	
(5)	Relative humidity	O	O	O	
(6)	Precipitation	O	O	O	O
(7)	Wind velocity and Wind direction	O	O		
(8)	Sunshine duration and Solar radiation	O	O		
(9)	Evaporation		O		
(10)	Soil/Grass min temperature		O		
	Number of Station	14	24	65	149

The existing network of the meteorological stations is insufficient in rainfall gauge density comparing with the norm of the WMO which proposes the density of 100km^2 to 250km^2/gauge in mountainous area. Moreover the network is biased having the greatest density in the Central part, especially Kathmandu Valley, then followed by 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 3.2 and the locations are shown in Fig. 3.5 to 3.7. No systematic snow measurement is performed at present except for six stations under the Snow and Glacier Hydrology Project.

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

(3) Precipitation Observation Instrument

All of the 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.

The U.S. standard 8 inch precipitation gauge is in common use in Nepal. This gauge is 1 m high and consists of an over flow can, a measuring tube, a funnel and three legged support. As recording rainfall gauges, weighing-type and float with syphon-type ones are used with chart type recorder. Recording charts are one-day or one-week long type. Recording stations are at 0104 Dadeldhura, 0219 Dhangadhi, 0303 Jumla, 0406 Surkhet, 0515 Ghorai, 0705 Bhairhawa, 0804 Pokhara, 0909 Simara, 1030 Kathmandu, 1206 Okhaldhunga, 1304 Pakhribas, 1307 Dhankuta, 1319 Biratnagar, and 1405 Taplejung.

(4) Precipitation Observation Staff

The Aeronautical and Synoptic stations are operated and maintained by 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 and send data to the Regional Offices. Part-time observers' qualifications are mostly below School Leaving Certificate (SLC) and their technical level on observation is relatively low due to insufficient training.

(5) Precipitation Observation Method

The meteorological stations observe precipitation, maximum and minimum air temperature, relative humidity, wind speed and direction, evaporation, sunshine duration, solar radiation, atmospheric pressure, soil temperature and so on.

Ordinary raingauge measurement in Precipitation stations is carried out once a day at 8:45 in the morning. Rainfall measurement in Synoptic, Aeronautical, Agrometeorological and Climatological stations is made twice a day at 8:45 and 17:45. Recording charts are changed every day or every week according to chart type. Suitable operation manual has not been used for meteorological observation, and thus improvement of the existing operation manual is required.

3.2.2 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 from 1962 to 1968 a priority network of river stations was established by the USAID project on the major rivers possessing structures such as cableways, stilling wells and sediment sampling facilities. The network was expanded to 120 stations by 1968. Discharge data of the most important 38 stations were published successively. After completion of the USAID project, the network had been expanded to more than three hundred stations consisting of regular stream gauging stations and partial record ones. In 1988, all partial stations and some regular stations were closed due to limitation of budget for operation and maintenance. At present a total of 136 river gauging stations are in operation. In the Model System of this Project, 4 water level gauging stations were constructed, among which 3 stations were newly established ones and a station was reinforced one.

(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 the model observation stations. The list of the stations is given in Table 3.3 and the locations are shown in Fig. 3.8. 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 number of the stations are 13, 31, 25, 38, and 29 in the Far Western, Mid Western, Western, Central and Eastern Region, respectively. The average gauge distribution density of around 1,100km^2/gauge is nearly sufficient comparing with the WMO norm which shows 300km^2 to 1,000km^2/gauge. However biased gauge distribution should be corrected from the viewpoint of the nationwide hydrological observation. The water level gauging stations are categorized in terms of installed instruments as follows:

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

The automatic recorders are installed in 34 stations. Suspended sediment sampling is carried out in 18 stations as seen in Fig. 3.9 which is insufficient from the viewpoint of nationwide observation. There is no nationwide observation system of water quality.

(3) Hydrometric Instrument

The number of recording water level gauging stations is 34 which is 25% of the total 136 stations. Some main tributaries do not have recorders. Float-type gauge installed in a stilling well is in common use in Nepal. However, some gauge wells are suffering from sedimentation in the monsoon season and scouring of the riverbed in the dry season. Since the pressure-type gauge has an advantage to be able to be removed easily when sediment deposits or riverbed is scoured, the first pressure-type gauge was installed in Chepe Khola in the Western Region in November 1990 in collaboration with the German Development Services. At present, four pressure-type gauges are operated and monitored under different geological, sedimental, climatic and polluted rivers conditions except for gauges in the Model System.

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, manpower is utilized and the flushing facilities are provided in some gauge wells. But no effective means have been found yet except for manpower.

The existing float-type recording gauge employs one-year recording chart while the pressure-type one has one or three months recording chart in the dry season and daily or one week recording chart in the monsoon season.

Eighty two (82) observation stations are equipped with cableway facilities for discharge measurement. Most cableways are provided with manual single-drum winch while the others are still a pulley operation. Two stations at No. 150 Pancheswor and No. 280 Karnali/Chisapani are equipped with a manual double winch bank operating system. Most winches are not maintained properly and get rusty and some traction cables are not stretched properly.

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

There are some suspended sediment sampling apparatus. However, a part of them are damaged and useless.

(4) Hydrometric Staff

In hydrometric stations, gauge readers, sediment sample collectors, winch operators, and bottle runners carrying sediment sampling bottles to the laboratory are employed by the DHM as part-time observers/workers. Field technicians of the Regional Offices are in charge of discharge measurement, levelling and river cross section survey, field inspection and minor maintenance activities. In the Hydrology station at Chisapani, staffs of the DHM station and observe river water level, discharge and sediment continuously. Qualification of the part-time observers and technical staffs is not well due to insufficient training.

(5) Hydrometric Method

Observations of hydrometric stations consist of (a) daily manual water level gauge reading, (b) recording water level gauge observation, (c) discharge measurement, (d) sediment sampling and (e) 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. In all sites discharge measurements are done by employing a current meter from a cable way or a bridge deck. Wading rod is applied when river discharge takes low water level at some stations. The discharge measurement conforms to standards of the United States Geological Survey (USGS). The measurements are carried out averagely three to four times per year in each station, which is normally not enough to derive stage discharge relationships.

Flood water level reading and discharge measurements are scarce due to infrequent station visits and difficult flood measurement. There is no hydrometric observation manual prepared in the DHM. River cross section survey is also seldom carried out due to a lack of staff and budget.

Suspended sediment sampling is executed by applying the depth integrated method in all stations except for station No. 280 Chisapani/Karnali which uses the point integrated method. However in all the sediment stations no velocity measuring and grain size analysis is done. 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 including flood time.

3.3 Sediment and Water Quality Analysis

3.3.1 Sediment Analysis

One sediment laboratory is operated in the Central Office in Kathmandu and four sediment laboratories are distributed 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 estimates discharge of rivers by tracer technique.

In August 1991, 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 because of lack of training. And, there is not 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.

3.3.2 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. Many reports state that some zones of the Bagmati River are polluted and the self depuration capability is badly damaged. On the other hand, there is no systematic water quality analysis.

In this circumstances, the GDS prepared a report on establishment of a water quality laboratory in the DHM in December 1991. This report is based on an issue "Report on Water Quality Study Programmes, July 1991, by Environment & Public Health Organization and DISVI International Cooperation". Subsequent to the above GDS report, the GDS prepared a proposal in July 1992 for the activity 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