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 in the Kathmandu valley. It is scheduled that the first water quality index map is to be made for the Kathmandu valley after six months of water sampling and analysis. The work will be extended to the different regions, which will be selected from the viewpoint of high water pollution.

To fulfill the short term objective, water sampling and chemical analysis will be made. Thirty points in the Kathmandu Valley are selected to take water sample at an interval of two months. 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.

Expanding the GDS's plan, the nationwide water quality analysis system will be needed to collect fundamental water quality data and to utilize to the relevant projects.

3.4 Establishment, Inspection and Maintenance of Facility

3.4.1 Inspection and Maintenance in Regional Office

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 and this is still used. However, there is no inspection manual. 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 workshop in each Regional Office.

Field inspection of hydrometric stations is carried out on average two or three times a year. During this field investigation, the technicians of the Regional Office take record of and report the condition of the station and its equipment. After return, at the office, if necessary, they make an estimate of cost for repair and maintenance works of the station and equipment based on their report. Inspection form is provided but there is no inspection and maintenance manual. Junior technicians are trained by experienced staffs through on-the-job training during the time of inspection. Technical level of staff on inspection and maintenance is however not sufficient due to a lack of proper training.

For both of meteorological and hydrometric stations, station and instrument inventories are incomplete and not updated. And result of inspection, adjustment, calibration and repair is not recorded sufficiently.

3.4.2 Inspection and Maintenance in Central Office

Meteorological calibration laboratory was provided in the Central Office by the Agrometeorology and Instrument Maintenance Project implemented between 1974 and 1978. The staff of the Meteorological Instrument Workshop deals with all the meteorological instruments. There is a Hydrological Instrument Workshop in the Central Office. Two instrument mechanics, who were trained during the UNDP/WMO project, are engaged in this workshop. Operation condition of both workshops is not good due to lack of tools and spare parts and staff training. There is no calibration facility of the current meter and most current meters have been used without calibration. Record of instrument adjustment, calibration and repair is insufficient.

3.5 Data Processing and Management

3.5.1 Data Collection in Regional Office

The present data flow in the DHM is illustrated in Fig. 3.10. Soon after the monthly recording forms are filled in with observed data at the observation station of ordinary raingauge and staff gauge, they must be sent to the Regional Offices by mail to arrive within one month after finishing observation. However some data do not arrive at the Regional Offices within one month. The present condition of data collection in Regional Office is shown below, which is derived from records from January 1991 to October 1992:

Term Data	within one month	within two months	within three months
Hydrological Data	42%	57%	74%
Meteorological Data	47%	75%	90%

The reasons why the data are not collected within one month are:

1) delay of data sending by observers due to severe and long accessibility to post offices in the mountainous and remote area, especially in northern part of the Mid Western and Western Regions,

2) irregular data sending by observers' convenience at an interval of more than two months,

3) refusal of data sending by observers because of delay in salary payment,

4) non systematic data collection by staffs of the Regional Office on the occasion of station visit, and

5) insufficient and improper management of the Regional Office for data collection activities.

The detailed condition of data collection of ordinary raingauge and staff gauge is shown in Table 3.4. As seen in this table, more than 80% of the data are collected within three months except for the hydrological data of the Central Region. The following are present status of each Regional Office:

(1) Far Western Regional Office

The Far Western Regional Office has the Chisapani Hydrology station. Some hydrological data in the Karnali River basin are collected by the staffs of this station and then it takes time to transfer it to the Far Western Regional Office. This is one of the reasons why 46% of the hydrological data did not arrive at the Far Western Regional Office within one month. Meteorological data collection is smooth and almost all the meteorological data are collected within three months in spite of difficult topographical and traffic condition.

(2) Mid Western Regional Office

The Mid Western Region is the largest among five regions in Nepal and the remotest with high altitude. The post office distribution density is about 142 km^2/office, which is half of the national average. However more than 80% of hydrological and meteorological data are collected within three months.

(3) Western Regional Office

92% of hydrological data and 84% of meteorological data are collected within three months in the Western Regional Office. Almost stations from which data collection is delayed are in the northern part of the Western Region, where is the mountainous and high altitude area and the density of post office distribution is low.

(4) Central Regional Office

Although the density of post office distribution is high, about 45km^2/office, and the network of road is relatively developed in the Central Region, hydrological data collected are only 55% within five months. 90% of meteorological data are on the contrary received within three months by the Central Regional Office. It may be suggested that the above fact does not result from topographical/traffic conditions and access to post offices but managerial matters.

(5) Eastern Regional Office

The condition of hydrological and meteorological data collection is good and around 90% of data are sent to the Eastern Regional Office within three months. Recording charts of automatic raingauges and water level gauges, and discharge measurement data are collected and forwarded by staffs of the Regional Office irregularly. Sediment sample bottles are carried by bottle runners employed by the DHM to the laboratory of the Regional Office irregularly, though they should be sent once a month. Registration of data/sample receipt is made in the Regional Office just after receiving them. However, the form of registration is not uniform and the registration is delayed or forgotten due to absence of staffs in charge.

3.5.2 Data Processing in Regional Office

The collected data were preliminarily processed at the Regional Offices by hand without using computer till 1991 except for the Western Regional Office, where a set of computer was utilized. Then the processed data were sent to and again processed at the Central Office by using computer. The collected data were written by hand on the specific forms with some calculation such as total and average in the Regional Office, which led to a wastage of time and mistakes. A set of hand copied data was stored in the Regional Office without efficient filing system. In 1992, this Project introduced laptop type computers to all the Regional Offices and some processing works are being done by using these computers for daily rainfall and water level data and others. The processed data are printed or copied in diskets and sent to the Central Office.

The present meteorological data processing is in good progress. However, hydrological data processing shows some facts to be improved. Discharge rating curves especially were not developed after 1986 until 1991 for almost all the stations in which several measurements of discharge had been done. This may be caused by insufficient number of discharge measurements, lack of trained and experienced hydrologists to develop it, and lack of monitoring systems to expedite the development, though the activity of rating curve development was newly added in 1991 to the Regional Offices. In 1992, the DHM made efforts to derive rating curves in the Regional Offices with the support of Hydrologists in the Central Office.

Data checking is not sufficiently carried out at present, though it is essential to obtain reliable data. And there is no data processing manual and processing schedule except for a computer manual. A monitoring form to inspect progress of data processing is used, but it does not function well due to poor monitoring works. There is no exclusive staff of data processing except for the Western Regional Office. The dissemination of the data and hydrological analysis have not yet been carried out in the Regional Offices.

3.5.3 Data Collection in Central Office

All the data are sent to the Central Office from the Regional Offices by the staffs with letters describing the code numbers, station names and other related information. The original data such as chart, notebook type form and synoptic station form are sent to the Central Office once a year. The processed data are sent several times a year normally on the occasion of duty trip of the staffs of the Regional Offices to the Central Office without schedule.

At the Central Office, registration is made at the meteorological and hydrological acquisition unit of the Other Technical Services Section just after receipt of the data from the Regional Offices. However, the registration is incomplete and sometimes delayed.

3.5.4 Data Processing in Central Office

(1) Meteorological Data Processing

The progress of the meteorological data processing is relatively good. Almost all the daily precipitation data in the whole country until 1990 were completed to be processed. Around half of the precipitation data in 1991 and a part of the data in 1992 have also been processed. The data are checked by using the entry programme of the existing database and visual check by the Meteorologist. However, continuous rainfall data have remained unprocessed. There is no meteorological data processing manual.

(2) Hydrological Data Processing

After the UNDP/WMO Project processed the hydrological data observed up to about 1985 during the project implementation period between 1982 and 1987, substantial progress of the hydrological data processing was less. The data were processed without processing schedule, manual, sufficient quality checking and management. A large back logs then remained at the Central Office. In 1991 the DHM decided to transfer the main function of data processing from the Central Office to the Regional Offices. From 1992 each Regional Office is trying to process data with the assistance of the GDS.

The present processing work on mean daily water level data shows relatively good progress with approximate completion of data entry and estimate of mean value in 1991. However, calculation of mean daily discharge is not in good progress as given in Table 3.5. In recent years, discharge data of less than 10 stations are available. This may result from the delay of discharge rating curve development, though staffs of the Regional Offices as well as the newly assigned Hydrologists in the Central Office have concentrated on the work. There is no hydrological data processing manual except for a computer manual.

Overall data checking has been carried out by the Hydrologists mentioned above through attesting their consistency or comparing each other. Several hydrological analyses have been conducted by the DHM occasionally on requests. Regular and nationwide hydrological analysis should be carried out to grasp hydrological characteristics and to study data quality.

(3) Present Computer System

The DHM has two data base systems, one is a meteorological data base system and the other is a hydrological data base system. These systems consist of IBM computers and their accessories as illustrated in Fig. 3.11 excluding the model system.

The meteorological data base system comprises one (1) IBM PS/2 80 for data base and two (2) IBM PS/2 30 for data entry. This is an off line system. The data base programme is being developed by the DHM's staff using the language of BASICA. The present system deals with the data of precipitation, temperature, relative humidity and dew point on daily and monthly basis.

The hydrological data base was introduced by the UNDP/WMO Project in 1984 to 1986. The present hydrological data base system includes one (1) IBM PC-AT and one (1) IBM

PC-XT in the Central Office, and one (1) IBM PC-XT in the Western Regional Office. The data base programme was developed using the language of QUICK BASIC and it's general process flow is shown in Fig. 3.12. The main parameters for entry of the hydrological data base are hourly water level record, staff gauge reading, discharge measurement, rating table, station description and sediment concentration. The discharge values are estimated from the water level record and rating table. Using these discharge values, the suspended sediment transport is estimated by the computer. The output items are; mean daily water level, discharge and sediment transport; extreme discharges and sediment transport; mean, maximum and minimum monthly discharges and sediment transport; maximum and minimum instantaneous discharges and sediment transport; long term average of discharge and sediment transport; year book form; and inventory. These data are offered to the users by the computer output list or floppy disk as well as year books. In the Model System of this Project, one IBM PS2/80 and six Toshiba T3100SX were introduced to the Central Office and the Regional Offices, respectively.

3.5.5 Data Storing and Dissemination in Central Office

The original hydro-meteorological records sent from the Regional Offices are kept in the storeroom of the DHM Central Office after processing. However the hydrological data are piled randomly, which should be improved for proper storing and future use. The processed data are stored in the present data bases.

Only the Central Office disseminates hydro-meteorological data and results of analyses to the users. The meteorological data and analyses results are disseminated in the form of summary report, data book, computer output, report on weather forecasting and broadcasting programme. The meteorological data books until 1986 were published in 1988. In July 1992, the DHM published a databook on precipitation, which contains monthly precipitation records and summaries of maximum amounts, dates occurred, and frequencies of number of rainy days for different amount intervals recorded at 253 meteorological stations for the period of 4 years from 1987 to 1990. The hydrological data and information can be obtained from floppy disc and output list for the purpose of water resources project study after getting approval of the DHM. The year books have been also published for the hydrological data until 1985.

The DHM has the following plan to issue the meteorological and hydrological data:

1) Publication of nationwide meteorological data recorded in Agrometeorological and Climatological stations by the end of the fiscal year 1992/93, which include air

temperature, relative humidity, vapour pressure, sunshine hours, evaporation, wind speed, precipitation, soil temperature and so forth.

2) Publication of nationwide hydrological data by the end of the fiscal year 1992/93.

3.6 Data Quality Improvement and Training

No continuous and systematic survey and study on observation network and data management have been conducted for the purpose of their improvement. The existing manuals or forms have seldom been modified and intensified. There is no routine dialogue with users of the hydro-meteorological data.

The qualifications of the Hydrologists and Meteorologists of the DHM 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 and other supporting projects.

However, young junior Hydro-Meteorological Assistants and Field Assistants who have obtained School Leaving Certificate or Under School Leaving Certificate grades have difficulties to have such opportunities because their ability of language is insufficient. So it is necessary to prepare 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. In the year of 1992, four training courses were conducted by the DHM for their staffs by this time:

1) Orientation training for the DHM Hydrologists and Meteorologists on February 23 to March 06, 1992 in Kathmandu,
2) Hydrometric Gauge Readers' and Meteorological Observers' field work training on May 03 to 08, 1992 in Dharan for the Eastern Regional Office's staffs,
3) Junior Hydrological and Meteorological Technicians' training in Kathmandu and some fields on June 15 to September 16, 1992 with both of theoretical and practical courses,
4) Hydrometric Gauge Readers' training for the Far Western and Mid Western Regional Offices' Readers at Chisapani mainly by means of field exercises in December 1992.

A lot of senior field technicians will be retired in 1993 who have much experience in the field work. In future, then, a training programme for remaining field technicians will be formulated, which will include theoretical courses as well as practical training in the field. All the above programmes were or are to be formulated and conducted by the training unit of the DHM in collaboration with the GDS staffs.

The field works are usually taught through on-the-job training by experienced technicians as well as training courses. 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. Their guidance is verbal. Their main occupation is farming, business, or with employee in other agencies.

3.7 Organization and Staff

The DHM 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.

In the Central Office, 122 technical staff are engaged in the technical Divisions/Sections. Technical staff 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, 3 Silt Analysts and 3 Laboratory Boys. The total number is 102. Among them 32 staff belong to 13 Synoptic stations. There exist 30 vacant seats of personnel including 23 junior Hydro-Meteorological Assistant positions, 7 of them are in Synoptic stations. Not only the shortage of technicians but also the shortage of trained field technicians should be solved and improved.

Field technicians under the senior Hydro-Meteorological Assistant class are in charge of field activities such as discharge measurement, levelling and river cross section survey, field inspections and minor field maintenance. In hydrometric stations, a gauge reader, collector, winch operator, and runner who carries sediment sampling bottles to the laboratory are employed as part-time observers. On the other hand, staff of Aero/Synoptic stations consist of the DHM technicians. And in other meteorological stations a part-time observer takes observations. Part-time observer's occupation is mostly in agriculture, business as small shop owner or employee. His/her qualification is mostly under School

Leaving Certificate and experience is mostly 10 to 20 years. The number of staffs in the present Central and Regional Offices is summarized in Table 3.6 and 3.7.

The present monitoring and evaluation system for all the DHM activities does not function properly. Recently, the HMG/N are trying to activate the system for not only the DHM but also all the other governmental agencies.

3.8 Budget Expenditure

Total budget expenditure of the DHM in the fiscal year of 1992/1993 was NRs. 26,984 thousand including regular budget of NRs. 6,304 thousand and development budget of NRs. 20,680 thousand as seen in Table 3.8. During the period 1988/89-1992/93, the average annual growth rate of the DHM's budget expenditure was about 11 % at current prices, which exceeded slightly the average price rise rate of 10 % per annum. The annual budget expenditures of other agencies were being increased at a high average rate of 25 % for the Department of Irrigation and 14 % for the Nepal Electricity Authority, during the period 1987/88-1992/93.

Table 3.9 provides the historical development budget expenditures by Division and Region in the DHM. The development expenditures of four Regions, except the Central Region, have been increased at the average annual rate of 10 % or more at current prices, during the period 1987/88-1992/93. To the contrary, the development expenditures of Divisions in the Central Office and the Central Region were a minus growth, during the same period.

In connection with formulating the investment scale of the project, the future budget expenditures of the DHM and the said agencies are estimated by five years for the period from 1995/96 to 2010/11 as shown in Table 3. 10 and 3.11.

3.9 Preceding and Ongoing Projects Related to DHM

3.9.1 Development of Operational Hydrology Services

The 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/N 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:

(1) Reliable operation of river gauging and sediment sampling stations with proper and timely collected data

The activities under this output are as follows:

1) Complete repair where required on 25 stations at No. 240 Asara Ghat, No. 250 Benighat, No. 260 Banga, No. 262 Khanayatal, No. 270 Jamu, No. 280 Chisapani, No. 290 Bargadha, No. 350 Bagasoti Gaon, No. 390 Butwal, No. 410 Setibeni, No. 415 Dumrichaur, No. 439.8 Gopling Ghat, No. 445 Arughat, No. 446.8 Betrawati, No. 448 Tadipul Belkot, No. 465 Manahari, No. 505 Sundarijal, No. 550.1 Sampkhel, No. 536.2 Budhanilkantha, No. 589 Pandheradovan, No. 610 Barabise, No. 620 Jalbire, No. 630 Pachuwar Ghat, No. 647 Busti, and No. 795 Mainachuli.
2) Preparation of detailed description of 35 stations.
3) Installation of seven rainfall and three river stations in the Bagmati river basin.
4) Strengthening of the sediment data collection programme including establishment of two sediment laboratories in the Western and Eastern Regional Offices.
5) Improvement of the operational condition of stations recommending to increase the number of discharge measurement and to provide continuous maintenance.
6) Improvement of facilities at nine stations with priority status where rating curves merit this work including rehabilitation/ construction of recorder houses and cableways.

(2) Storage of hydrological data files on computer compatible support

The aim of this output was to introduce a decentralized system of data collection and primary processing in the Regional Offices at Dharan, Kathmandu and Pokhara. Three IBM PC-XT computers were installed in these offices. An IBM PC-AT computer was installed in the Central Office in combination with a digitizer and a plotter. A comprehensive computer program of hydrological data processing system was provided and introduced. The opportunity was also taken to review the format of the data collection form. In particular the gauge book for water level record was redesigned.

(3) Establishment of statistical summaries and estimates based on data files

Statistical summaries were generated for flood frequency, lowflow frequency and flow duration curves at 36 stations. Catchment characteristics were also abstracted using the digitizer.

(4) Printouts of year books containing daily values of river stages and discharges, extremes, monthly and yearly averages, data on sediment transport and water temperature

The activities under this output are as follows:

1) Processing back log of data collected from 1977 to 1985 including updating of rating curve, process of chart records, entry of gauge heights on computer and calculation of daily discharge.
2) Increasing the quantity and quality of data processed by installing storage cupboards, files and a photocopier, and process of sediment record at 15 stations and staff gauge reading at 218 stations.

(5) Supply of quasi-realtime operational information

The modest activities under this output fall into two categories:

1) undertaking an in-depth hydrological study of the Bagmati catchment.
2) installation of a pilot realtime data collection system in one basin, which was deleted due to budgetary constraint, etc.

(6) Establishment of a team of qualified and motivated professional hydrologists, hydrological technicians, and assistants

The activities under this output are 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.

(7) Establishment of hydrological equipment workshop facilities

The output is a continually functioning central workshop sufficient to meet the maintenance requirement.

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.

The above mentioned seven outputs including conclusions may suggest the following in formulating the improvement plans:

1) Among 25 stations repaired by the UNDP project, six stations are closed, washed away or troubled due to flood and sedimentation. Site and equipment type selection of observation network should be made carefully.
2) Detailed description of stations prepared by the UNDP has not been updated since the project. Periodical updating and its procedure should be studied.
3) In the UNDP project, computers were introduced to three Regional Offices and they work well at present except for that in the Eastern Regional Office due to damage of CPU. The data processing by using the computer is proved to be efficient in the Regional Offices.
4) Strengthening the responsibility of the Regional Offices should be examined to smoothen the activities and to motivate the staff of the Regional Offices in combination with staff training.

3.9.2 German Development Services

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 complete the tasks are being stationed at four (4) offices named the Central, Eastern, Western and Mid-Western Regional Offices, respectively. One environmental engineer is also working in the Central Office.

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

1) Guidance in hydrological observation including discharge measurement,
2) Guidance in inspection and maintenance of hydrological observation stations and equipments,
3) Guidance in data processing including hydrological data entry into the computer and development of discharge rating curve,
4) Assistance in planning a training programme for the DHM's junior technical staffs,
5) Recommendation on future plans of the DHM for water quality observation and assistance in establishing a water quality laboratory,
6) Installation of four pressure type water level gauges as shown in Fig. 3.13 and so forth.

The GVS was renamed to German Development Services (GDS) in 1991. The work programme and activities being carried out by the GDS's engineers 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 GDS's engineers are reciprocally interchanged and incorporated in each study so as to develop their subsequent studies and plan formulation.

3.9.3 Snow and Glacier Hydrology Project

The Snow and Glacier Hydrology Project was initiated in 1987 with the technical assistance of the German Technical Cooperation Agency (GTZ) on the request of the HMG/N. 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 to water resources planning.

The project has established six hydro-meteorological stations in the upper Langtang Valley, Khumbu Everest, Modi Khola Valley, Makalu, Kanjiroba Himal and the upper Karnali basin near Simikot as shown in Fig. 3.13. Seven observation items, temperature, relative humidity, precipitation, wind speed, wind direction, global radiation and water gauge height including discharge measurement by tracer technique are taken and measured in these stations. These six stations extend widely over the snow and glacier regions and are considered to represent the spatial differences of snow and glacier hydrological conditions in Nepal.

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.

Seven outputs are expected in the course of execution of the next phase, they are:

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.

In addition to the above mentioned workshop and planning of the next phase, the Project organized and held an international symposium on snow and glacier hydrology in collaboration with the DHM from 16th to 21st November, 1992 in Kathmandu.

3.9.4 Flood Forecasting/Mitigation Projects

(1) 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 by establishing 20 water level gauging stations along with ordinary and recording raingauges and other 25 raingauging stations shown in Fig. 3.14. 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 times are 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. Then, the number of the planned water level gauging stations became 18.

(2) Nepal-Bangladesh Joint Study

After the devastating flood of 1988, Bangladesh undertook working visits to India, Nepal, Bhutan and China for seeking regional cooperation leading to a long lasting solution of the flood problem. A meeting was held between Nepal and Bangladesh at Kathmandu in October 1988, wherein both parties agreed to create a joint study team.

The Joint Study Team held four meetings, exchanged data/information and finalized the report "REPORT ON FLOOD MITIGATION MEASURES AND MULTIPURPOSE USE OF WATER RESOURCES" in November 1989. This report contains geo-climatic setting, types and causes of floods, probable measures for flood mitigation, multiple and optimal use of water resources of the region and so forth. The recommendations of the study are as follows:

1) Flood mitigation
   - development of flood forecasting and warning system by wireless communication for transmission of water levels and flow discharges between Nepal and Bangladesh
   - initiation of catchment management, afforestation programme aimed at soil conservation
   - coordination of development activities aiming at getting away from drainage congestion
2) Harnessing of water resources of the region
   - creation of reservoirs at upstream reaches for optimal and multipurpose use of water resources to reduce the flood peak discharges
3) Study, research and investigation
   - study, research and investigation programme on appropriate catchment management to reduce the adversities such as top soil erosion, land slides and consequential influx of sediment into the rivers, and glacial and snow melt phenomenon.

Another meeting was held between Nepal and Bangladesh in September 1992 in Kathmandu and the following items were discussed on the basis of the above report issued:

1) exchange of necessary data for flood mitigation and water usage purposes,
2) future study on flood forecasting,
3) future study on watershed management in the upper basin with financial assistance of donor countries.

3.9.5 Water Induced Disaster Prevention Technical Centre

In order to promote prevention/mitigation of water induced disasters, it was agreed in October 1991 between HMG/N and the Government of Japan to establish Water Induced Disaster Prevention Technical Centre (DPTC). The objective of the DPTC is to strengthen capability of the HMG/N to cope with water induced disasters through technology development, provision of training and establishment of data base.

The DPTC comprises mainly four Divisions, Technology Development Division, Training Division, Information Division and Administration Division under the Joint Committee with advising group of the JICA Experts. The Joint Committee members are seven Ministries and Commissions, they are the Ministry of Water Resources, the Ministry of Forests and Environment, the Ministry of Home Affairs, the National Planning Commission, the Water and Energy Commission Secretariat, the Ministry of Works and Transport and the Ministry of Finance.

Activities of the DPTC cover such areas as 1) Sabo, which is watershed management with emphasis on erosion control, 2) Landslide prevention, and 3) River training. The Technology Development Division aims to pursue technology development with a certain construction works and to prepare technical standard and advice to on-going projects. The Training Division provides and conducts the training to Nepalese personnel in the form of lectures, experiments, on the job training and training in Japan. There are three training courses, General Course, Advanced Course and Intensive Course. The Information Division collects relevant data and establishes the Data Base. The Administration Division is responsible for administrative affairs. In addition to the above activities, a Hydraulic Experiment Laboratory was constructed in Godawari and is operational with experiment facilities for river hydraulics, landslide and debris flow.

Some training programmes to be proposed in future in the DHM could be organized in cooperation with the DPTC by receiving or sending trainees and trainers each other in the field of hydrology and meteorology.

4. FORMATION AND CONCEPT OF THE PROJECT

4.1 Purpose of Improvement Programme

4.1.1 Need of Data for Analysis of Hydro-Meteorological Characteristics

The DHM has operated the hydro-meteorological stations and has tried to investigate and assess nationwide hydrological features and characteristics by using the observed data. As one of those trials, the DHM prepared a study report "Methodologies of Estimating Hydrologic Characteristics of Ungauged Locations in Nepal" in collaboration with the WECS. In this report, certain methods are presented for estimating lowflow, flood flow, and long term flow characteristics of ungauged and poorly gauged sites within Nepal. These methods are obtained through various studies such as delineation of homogeneous physiographical, climatological and hydrological regions.

The methods mentioned above are considered to be very useful. Unfortunately, however, the report recommends to use the method only for reconnaissance and prefeasibility level studies due to limitation of available data used for the study. Therefore, the DHM is eager to improve and extend the hydro-meteorological observation system and to continue such a study as above to grasp in detail the nationwide hydro-meteorological characteristics by using long term, reliable and widely observed data.

4.1.2 Need of Data for Water Resources Development Planning

(1) Hydropower Development

The present installed capacity of electricity amounts to about 257 MW in Nepal. While, power load demand has been forecast to reach 359 MW in the year of 1995 and 655 MW in the year of 2001 according to the electric load forecast data by the Electricity Department (1983). Comparing the current installed capacity with the forecast, electricity deficit in Nepal is obviously predicted to occur and will reach about 398 MW in the year of 2001.

To cope with the predicted deficit the Government has made efforts on identifying the hydropower development projects and investigations, studies and design works have been made to realize these projects as early as possible. Fig. 4.1 shows the locations of the identified hydropower project.

Among the above identified projects, Arun No. 3, Sapt Gandaki, Kali Gandaki A, Upper Arun, Karnali, Sapt Kosi High Dam, Lakharpata, Upper Karnali, Kali Gandaki No. 2 and

Adhikhola No. 1 are considered to be prospective projects in the next decade according to the information of the NEA, the result of "A Relative Ranking of Potential Hydroelectric Projects for Nepal" in 1984, and progress of each project study and design.

(2) Irrigation Development

The present production volume of major crops is around 5.5 million tons, which includes paddy, maize, wheat, barley, millet, potato and pulses. In the Master Plan for Irrigation Development (UNDP/WB), food requirement in the year of 2001 is estimated to be 9.7 million tons.

The present cropped area is 3.2 million ha. Among this cropped area, irrigated area is 0.9 million ha and the remainder is rainfed area. In the remaining irrigable areas of 1,245 thousand ha many projects are identified by the Department of Irrigation (DOI) as shown in Fig. 4.2. The above Master Plan proposes the following:

1) Implementation of Mahakali II, East Rapti, and Babai projects committed for construction by the DOI.

2) Implementation of the most viable project, Bhairawa-Lumbini III DTW and eastern Terai projects.

3) Completion of the studies for Karnali Multipurpose, Bheri-Babai diversion and Sun Kosi-Kamala diversion projects.

4) Refinement of the study for Kankai multipurpose project.

5) Examination of options for the use of Narayani river waters in Chitwan, Nawalparasi and Rupandehi districts.

(3) Water Supply

Water supply in urban and rural areas is carried out mainly by the Department of Water Supply and Sewerage (DWSS), and the Nepal Water Supply Cooperation (NWSC) both under the Ministry of Housing and Physical Planning. To supply safe water to the increasing urban and rural population, water supply requirement is estimated by the Water Supply and Sanitation Sector Study (UNDP/WB) as follows:

Water Supply Bodies	Population Served (1000 persons)		
	By 2001	1986	Incremental
Urban water supply	3,579	1,177	2,402
Rural water supply	19,276	3,162	16,115
Total	22,855	4,339	18,517

The location of the water supply projects, which were identified in the above study, is given in Fig. 4.3.

(4) Natural Disaster Prevention Works

In Nepal, natural disasters due to heavy rainfall are classified into three types: flood in the Terai plain, glacial lake burst and landslide/soil erosion in the mountainous areas.

Flood control works have been carried out by the River Training Division, the Department of Irrigation (DOI) which mainly implements such minor river training works as small dike construction, river bank protection by gabion mattress, etc. so as to protect the irrigation areas from the floods. Several studies have been made by the DOI on flood damage assessment, river training and/or flood control measures for rivers in the Terai and hilly areas, of which banks and adjacent agricultural areas have suffered from flood inundation or erosion as given in Fig. 4.4. The DOI has also carried out the drainage works within the irrigation areas and has further plan to implement river training works in the lower reach of the Kamala and Bagmati irrigation areas. Also, the multipurpose projects of Kosi High Dam and Karnali schemes include the flood mitigation effect in the project purposes. However, detailed damage and inundation surveys will be required to be carried out for establishing a certain flood control plan because those data are quite insufficient at present in the DOI.

The Standing Committee between Nepal and India on Inundation Problems was formed so as to identify the problem areas in Terai plain, itemize the actions to be taken, and suggest the solution of the problems. The meeting has already been held eight times and is scheduled to be continued. The identified inundation areas are illustrated in Fig. 4.4.

The Water Induced Disaster Prevention Technical Centre (DPTC) is being established to increase technical capability of Nepalese engineers through research on disaster prevention works due to heavy rainfall including hydrological study under technical and financial assistance of the Japanese Government.

Glacial lakes are distributed above the altitude of about El. 4,300 m in the High Mountain regions. Most of glacial lakes are found east of Pokhara valley. There are 229 lakes in the Arun and 45 lakes in the Bhote-Sun Kosi river basin. Glacial lake burst caused damage on the upstream bridges, houses, and existing powerhouses. Countermeasures to the bursts are under study by the WECS.

A long term programme on soil conservation and watershed management until 2001 was established in 1989 by the studies under the technical assistance of the UNDP/FAO. This programme proposed the works on: farm conservation, plantation, terrace improvement, grass land establishment, water harvesting, landuse change, agroforestry, fodder production, promotion of stall feeding of cattle, establishment of demonstration farms, land rehabilitation, trail improvement, torrent/gully control, channel improvement, and road erosion control. The present watershed condition in Nepal is illustrated in Fig. 4.5.

(5) Requirement of Data

Long term and reliable hydro-meteorological data are requisite for planning and design of the future water resources development projects mentioned above. In order to fulfill the requirement, the DHM has strong intention to improve and extend the existing hydro-meteorological observation and data management systems and accumulate long term, reliable and widely observed data. The Eighth Plan of the national development also targets in the hydrology and meteorology sector to expand observation network and to improve quality of the data observed.

4.1.3 Purpose of Improvement Programme

The objective of this Study is to formulate the Improvement Programme presenting improvement and reinforcement plans of the existing hydro-meteorological observation and data management systems in the DHM. As stated in the preceding sections, need of reliable hydro-meteorological data is great and urgent for analysis of hydro-meteorological phenomena and planning of the water resources development projects. The purpose of the Improvement Programme is, therefore, establishing 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 hydrometeorological characteristics in the whole country, evaluation of national water resources, planning of the water resources development projects comprising hydropower, irrigation, water supply, flood control and watershed management including priority projects, and management of river discharges.

Observation items in the Improvement Programme are precipitation, river water level and discharge, sediment load and water quality, all of which are fundamental and essential to disclose hydrological features of the whole Nepal and to plan and design water resources development projects.

The Improvement 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 the above mentioned four items are excluded in the Improvement Programme, it is emphasized that these items should be reviewed and their improvement plans should be studied under the DHM on the earliest occasion.

4.2 Present Problem of Observation and Data Management System

There are generally eight work groups in the present DHM as illustrated in Fig. 3.4, they are: 1) Observation, 2) Sediment and water quality analysis, 3) Establishment, inspection and maintenance of facility, 4) Data processing and management, 5) Data quality improvement and training, 6) Monitoring and evaluation of activities, 7) Study and forecast and 8) International cooperation.

Among these groups, the first 6 items are selected as items to be included in the Improvement Programme by considering the purpose of the Programme. The present problems of the existing observation and data management system in the DHM are summarized with the corresponding items to be improved as follows:

	Existing Problem	Improvement Item
1)	Observation	
	- Insufficient sediment observation and no water quality analysis	Observation item
	- Insufficient or biased observation network	Observation network
	- Lack and malfunction of instrument and improper type	Instrument
	- Insufficient and improper observation method without manual	Observation method and manual
	- Low technical level of observer and staff	Staff training
2)	Sediment and Water Quality Analysis	
	- Insufficient laboratory space	Laboratory plan
	- Lack and malfunction of instrument	Instrument
	- No analysis manual	Analysis method and manual
	- Insufficient technical level of staff	Staff training
3)	Establishment, Inspection and Maintenance of Facility	
	- No systematic inspection and no manual	Inspection method and manual
	- Little calibration of current meter	Calibration facility
	- Insufficient spare parts and workshop	Repair
	- Insufficient record of station, instrument, inspection, adjustment and repair	Inventory and record
	- Insufficient technical level of staff	Staff training
4)	Data Processing and Management	
	- No periodical data collection and improper registration of receipt	Data collection
	- Hand writing data processing in Regional Office without proper check list and manual	Data processing
	- Data processing in random manner	Data processing
	- Insufficient data check	Data checking
	- Random data storing	Data storing
	- Irregular publication of data book	Data dissemination

- Insufficient computers, peripheral and accessories	Computer facility
– Insufficient technical level of staff	Staff training

5) Data Quality Improvement and Training

- No systematic and regular training	Staff training
- No continuous survey and study on observation network and data management	Quality improvement survey and study

6) Monitoring and Evaluation of Activities

- Insufficient monitoring and evaluation work	Monitoring and evaluation
- No systematic dialogue with users	Dialogue

4.3 Improvement Item and Level

Improvement items and their improvement levels to be undertaken in the Improvement Programme are stated below. The items and levels are proposed after consideration of the purpose of the Programme, target year, present situation and surrounding condition in future.

(1) Observation

For the items of precipitation and water level, continuous and daily observations are taken to assess not only amount but also distribution, intensity and instantaneous peak. Discharge measurement activity is required for every flow condition from drought to flood. Suspended sediment load and bed load material are to be analyzed in the Programme in combination with river survey for sediment transport analysis.

Water quality observation parameters are selected by considering basic physical and chemical property, basic environmental item and eutrophication item to monitor nationwide environmental aspects and use for water resources development project. From the viewpoints of economic, easy maintenance and minimum requirements, the simple field method such as test kit and portable instrument is recommended. Observation parameter in respect of protection on human health and life is not involved, however necessity of these parameters is to be studied during implementation of the Programme.

The observation network of the above mentioned observation items should fulfill the minimum in order to enable nationwide assessment and master planning of water resources projects.

(2) Sediment and Water Quality Analysis

Systems of sediment and water quality analysis should fulfill the requirement of accurate, timely and economical analysis.

(3) Establishment, Inspection and Maintenance of Facility

Establishment, inspection and maintenance of observation and analysis facilities are essential for accurate, long period and nationwide observation and analysis and these activities should be performed with proper method and effective schedule.

(4) Data Processing and Management

Final target of the Programme on data dissemination is to compile and publish the observed high-reliability data within the next year. In order to achieve this target, the following data flow is recommended which is one of the decentralized data processing modes:

1) Basin Office and Branch Office are introduced instead of Regional Office for proper management of data. One Basin Office will manage one main river basin with adjacent small river basins. The Basin Office or the Branch Office under the Basin Office will collect observed data. In case that the Branch Office will collect observed data, it will send them to the Basin Office.
2) The Basin Office will process collected data by themselves including data checking.
3) The Basin Office will transfer processed and also original data to the Central Office periodically.
4) The Central Office will check data finally, store and disseminate them.

(5) Data Quality Improvement and Training

Continuous efforts should be made not only on data checking but also on improvement of data quality. Factors affecting the quality are always to be monitored and the required actions are to be taken if necessary. Staff training is essential to maintain and improve data quality.

(6) Monitoring and Evaluation of Activities

Monitoring and evaluation of all the activities for the proposed systems are quite important to smoothen the performance and guide the staff. The dialogue with all users of data leads to data improvement and recognizing further requirements.

In order to improve the above mentioned items and attain the targets of the Improvement Programme, the following 18 Subsystems are introduced into the nationwide hydro-meteorological data management system:

(1) Observation
- Precipitation Observation System
- Water Level Observation System
- Discharge Measurement System
- Sediment Sampling System
- Water Quality Sampling System

(2) Sediment and Water Quality Analysis
- Sediment Analysis System
- Water Quality Analysis System

(3) Establishment, Inspection and Maintenance of Facility
- Establishment System
- Inspection and Maintenance System

(4) Data Processing and Management
- Data Collection System
- Data Processing System
- Data Storing System
- Data Dissemination System

(5) Data Quality Improvement and Training
- Data Quality Research System
- Training System

(6) Monitoring and Evaluation of Activities
- Progress Control System
- Quality Control System
- Evaluation System

The relationship between the above Subsystems and the flow of hydro-meteorological data and managerial information/action are illustrated in Fig. 4.6. And, the Subsystems are explained in detail in the following Chapters.

4.4 Target Year

The target year of the Improvement Programme is set at 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 Improvement 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 large expansion. This strengthening work includes 1) restructuring of the DHM organization with introducing Basin and Branch Offices, and institutional rearrangement by employing 18 Subsystems, 2) improvement of observation and its maintenance activities by repairing existing observation/analysis equipment and facility, introducing basic stations and current meter calibration facility and preparation of manual and staff training, 3) improvement of data processing and management activities by introducing computers and manuals with staff training, and 4) improvement of monitoring and evaluation works 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 aims to expand the hydro-meteorological observation network to the interim scale with the completion to establish primary water level gauging stations as well as ordinary/recording raingauges and to introduce new observation items such as sediment and water quality. The improvement of observation accuracy and smooth operation of data management system, which are to be initiated in the first stage, are also items to be continued by reinforcing computer facility and training staffs.

(3) Third Stage: target year of 2005

The third stage is the final stage of the Improvement Programme and aims to complete the observation network to the minimum required one and to improve the system of data dissemination to the users. The improved dissemination system includes publication of yearbook within the next year, on-line data dissemination and dissemination of data in Basin Offices.

4.5 Long Term Programme, Immediate Programme and Model System

The Improvement Programme consists of the Long Term Programme and the Immediate Programme. The Long Term Programme is the long span master plan for improvement and reinforcement of the existing hydro-meteorological observation and data management system. The Programme includes all the stages from the first to third of the Improvement Programme. The target year is 2005.

The Immediate Programme is the programme expected to be implemented firstly for the urgent improvement. The Programme is the first stage of the Improvement Programme.

In order to formulate more realistic and practicable Improvement Programme, the Model System was designed, established and operated. The Model System consists of model observation system and model data management system. Main components of the Model Observation System are recording raingauges and water level gauges. The Model Data Management System introduced computers. Through operation as well as design and installation of the Model System, proper and preferable ideas to reflect to the Programme formulation were obtained.

5. EXAMINATION OF MODEL SYSTEM

5.1 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 and Immediate Programmes 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.

5.2 Study on Model System

5.2.1 Selection of Model Basin

The Model Basins, in which model observation networks were 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 as shown in Fig. 5.1. These groups show different hydrological characteristics as seen in Table 5.1 and 5.2. The first screening was made by introducing the following selection criteria:

<u>from the viewpoint of various attempts of observation and data management</u>

1) Basin has great variation of annual rainfall spatially,
2) Basin has great variation of ground elevation spatially, and
3) Basin has various degrees of accessibility within the area.

from the viewpoint of effective technology transfer

4) Basin is connected to Kathmandu with good access for frequent visits.

from the viewpoint of effective reinforcement of the existing system

5) Basin has less dense observation network at present,

6) Basin has high potential water resources development plans.

from the viewpoint of detailed hydo-meteorological analysis

7) Basin is located within Nepal,

8) Basin does not have big river structures,

9) Basin has proper area to smoothen system operation and maintenance.

The first screening for river basins originating from the Himalaya mountains led to two candidates of Seti Gandaki river basin and Kali Gandaki river basin. On the other hand, the first screening work with the above criteria for river basins originating from the Mahabharat mountains/Siwalik zone suggested the possibility of all the basins to be selected as a model basin due to similar rainfall characteristics, topographic condition and development potential. Then, small river basins of the Terai plain were selected for the second screening, since few water level gauges are installed in such rivers in spite of strong need for future water resources project planning including flood control. The results of the first screening are shown in Table 5.3.

The second screening of river basins originating from the Himalaya mountains was made by comparing the Seti Gandaki river basin and the Kali Gandaki river basin. In this screening, the Kali Gandaki river basin was finally chosen as one of the Model Basins taking the following into account:

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 and the detailed design is being carried out.

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, of which the data will be available for future hydrological studies.

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 Basins due to the following reasons:

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

2) Few river structures exist except for the Gandak 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 the Jamuni river basins, are given in Fig. 5.2 and Fig. 5.3.

5.2.2 Study on Model Observation System

(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 and continuous precipitation, 2) daily and continuous water level, 3) discharge measurement, and 4) suspended sediment load sampling. The discharge measurement activity includes those by using floats and measuring surface water profile reading staff gauges.

(2) Gauge Distribution

Kali Gandaki River basin (basin area 7,110 km^2)

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

Twelve (12) new recording raingauges were installed at Yaragau, Samargau, Dhagarjong, Beghara, Muna, Kuhun, Bega, Doban, Sallyan, Pamdur, Sirkon, and Tisedi as shown in Fig. 5.2. These gauges are distributed considering phenomena of south east monsoon which induces heavy rainfall in the southern area of the Annapurna and Dhaulagiri and conveys dry air mass to Mustang, spatial and vertical uniformity of distribution, and steady operation by village people. Total rainfall gauging stations become 34 in number and density of the raingauge distribution is around 210 km^2/gauge on an average. This average density may lead to approximate areal rainfall judging from the study on point and areal rainfall relationship based on the existing record.

Three (3) new recording water level gauges were installed at Tatopani, Kalleri and Setibeni as shown in Fig. 5.2. Total water level gauging stations become 10 in number. Tatopani was selected because it is located at a changing point of runoff, upstream of which is the arid Mustang area. Kalleri was chosen as important point in terms of river management, where a big tributary, Modi river joins just downstream. A new gauge was added in the existing Setibeni station in order to obtain continuous data because the existing recording gauge was interrupted sometimes due to sedimentation and scouring of riverbed.

Jamuni River basin (basin area 110 km^2)

The Jamuni River is the biggest tributary of Thali River in the Terai plain. No water level gauge or rain gauge were installed in the Jamuni River at the planning stage. 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. 5.3. The selected water level gauge site at Chyuntaha is much upstream of the Gandak Eastern Canal and not affected by backwater due to this canal.

(3) Observation Instruments

14 sets of recording raingauges with ordinary ones, 4 sets of recording water level gauges with staff gauges, 5 sets of current meters and 3 sets of cableways were introduced in the Model System.

The selected types of raingauge are as follows:

1) Weighing-type recording raingauge — 13 sets
2) Tipping bucket-type recording raingauge with a data logger at Pamdur — 1 set
3) Ordinary (Manual) raingauge — 14 sets

The weighing type raingauge has advantages of simple measurement of snowfall and easy operation. The DHM has long operational experience of the weighing type. The tipping bucket type is preferable to apply in combination with a data logger. The recording chart is one week recording type since observers are forced to inspect gauges at the time of chart change, one week chart is available in Nepal and frequent processing with checking is possible. The data logger is introduced to attain prompt and correct data processing.

The selected types of water level gauge are as follows:

1)	Pressure-type recording water level gauge with horizontal chart recorder at Tatopani and Setibeni	2 sets
2)	Pressure-type recording water level gauge with a data logger at Kalleri	1 set
3)	Float-type recording water level gauge at Chyuntaha	1 set
4)	Staff gauges for all sites including staff gauges for slope-area method in Setibeni	L.S.

The pressure type is selected to monitor availability on severe sedimentation and scouring river condition. This type is preferable to be installed in remote area with less amount of construction material. The float type water level gauge installed in Chyuntaha has outer steel pipe for float, which is vertically movable and adjustable to riverbed fluctuation. The recording chart is of one week type.

The selected types of current meter are as follows:

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

The price type current meter is chosen at Setibeni, since the existing cableway to connect to this type is well operated. The pigmy price type current meter is necessary to measure lowflow discharge at Chyuntaha in dry season. The propeller type is recommended in the upper reach of the Kali Gandaki river, because this type is preferable to use for the turbulent flow and to connect with the double winch cableway.

The following cableways are selected:

1)	Bank operating double winch system at Tatopani, Kalleri and Chyuntaha	3 sets
2)	Sounding reel with existing single winch system for Setibeni	1 set

The double winch system is recommended because of safe discharge measurements and easy operation of heavy weight.

(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 traces. In case that there is no water, record of 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. In flood time, hourly observation is required.

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 from 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-area method

This measurement method is one of the most common types 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.

Continuous maintenance is required for stable and reliable operation of the observation system. Failure to periodical maintenance will cause frequent troubles and these systems will finally fulfill no functions. Therefore, continuous maintenance is essential for satisfactory observation system.

(5) Civil Work Design

Design work of civil structures was carried out, which included raingauge basement, concrete abutment of steel pipe for float type water level gauge, protection pipe of pressure type water level gauge, and observation house. The raingauge basement is proposed to keep a space to measure rainfall without obstacles such as trees and crops. The concrete abutment of the pipe was designed to set deep foundation level preventing from future scouring. The protection pipe of the pressure gauge should be of dismantling type for future adjustment of zero level. The observation house was built in each water level gauge site for easy operation and instrument storing.

5.2.3 Study on Model Data Management System

(1) System Design

A certain trial actions of the data collection, processing, and registration are included in the operation of the Model Data Management System. The main items of the trials are 1) Method of data management, 2) Schedule of data management, 3) Organization of data management, and 4) Training for the DHM staff.

The Model Data Management System has been operated under the following basic policy and conditions:

1) The operation term is from April to December, 1992.

2) The System is mainly operated by the staff of the DHM with guidance and instruction of the JICA experts.

3) A total of seven (7) sets of new computers and their accessories are introduced in each Regional Office and the Central Office.

4) The existing database softwares are utilized basically for the processing work.

The items being observed and managed in the Model System are daily and continuous precipitation, daily and continuous water level, discharge measurement and suspended sediment. The precipitation data observed at the existing 22 stations in the Kali Gandaki river basin were mainly dealt with as well as 14 new model stations. As hydrometric data, those of four model stations and 46 priority stations were principally utilized.

The main work components of the Model Data Management System are 1) data collection, 2) data processing at the Regional Office, 3) data transfer, 4) data processing at the Central Office, 5) data storing, and 6) data dissemination. These components are supported by the activities of management, supply of consumables, maintenance, and training. The following are description of the above components:

1) Data Collection Method in Regional Office

In the Model System, two methods of data collection from gauging stations to the Regional Offices are applied, one is common collect system and the other is special collect system.

The common collect system consists of the following methods:

a) Precipitation and water level records observed by ordinary/staff gauges are sent by mail or wireless facility once a month. The wireless facility is set at Kathmandu, Pokhara and Tatopani to collect data and monitor data collection activity.

b) Precipitation and water level records observed by chart recording gauges are collected by the staff of the Regional Office every three months during trip of inspection.

c) Precipitation and water level records observed and stored in the data loggers at Pamdur and Kalleri are collected by taking ram card from the data logger by the staff of the Regional Office once a month.

d) Discharge measurement records are brought by the staff of the Regional Office after measurements.

e) Suspended sediment sample is carried by staff of the Regional Office or bottle runners once a month.

The special collect system is adopted in case that data do not reach the Regional Office within one month, of which the procedures are:

a) Issuance of request letter to observers to urge them to send data, and

b) Data collection by the staff of the Regional Office on the way to station inspection.

All the above data and sample are registered just after arrival at the Regional Office with filling in monitoring sheets shown in the General Manual of Model Data Management.

2) Data Processing Method in Regional Office

The data processing activity in the Model System consists of sediment analysis, data entry and data processing.

The suspended sediment sample is analysed at the existing laboratory of each Regional Office. The value of suspended sediment concentration and problem on the analysis are obtained.

The collected data are entered into the model data base installed in each Regional Office within one month after data arrival in the following manner and using check list attached in the General Manual of Model Data Management:

a) Continuous precipitation and water level record charts are duplicated by hand with carbon papers for future reference in the Regional Office. On the other hand, hourly values are read from the chart and entered into computer through key board.

b) Continuous precipitation and water level records stored in the data loggers are transferred to the computer from ram cards of the data loggers directly.

c) Precipitation and water level records observed by ordinary/staff gauges, discharge measurement records and suspended sediment concentration values are entered into the computer by key board.

Verification of the above data entered is made by visual checking and checking by totalling. The visual checking is conducted by the experienced staffs such as the Regional Chief, Hydrologist or Meteorologist. The checking by totalling is carried out by the staff of the Processing/Observation Unit. The data error is corrected in the Regional Office.

The data processing work is made by using newly introduced computers shown in Fig. 5.4, in which daily precipitation, water level, discharge and suspended sediment transportation values are calculated with quality checking;

a) The precipitation data are processed and total, average, maximum, minimum and the other values are computed.

b) The water level data are processed by the UNDP/WMO software and average, maximum minimum and the other values are computed. Hydrographs of the daily mean water level are also made by using the computer and printer in order to verify data quality and find extraordinary values.

c) The discharge measurement records are processed and rating curves and tables are developed applying least square method to quadratic equations.

d) Daily mean discharge values are estimated from the water level records and rating tables. Using the above discharge values, the suspended sediment amount is computed.

The above mentioned processed values are examined by the experienced staff such as the Regional Chief, Hydrologist or Meteorologist.

3) Data Transfer from Regional Office to Central Office

The input and processed data which are duplicated on floppy disks in the Regional Offices are sent to the Central Office by the staff of the Regional Offices. The original record books and charts are also carried to the Central Office by the staff.

4) Data Processing in Central Office

The data transferred to the Central Office from the Regional Offices are checked, corrected and registered into the data base of the Central Office in the following manner:

a) The overall checking including check of discharge rating curves is made by the staff of the Data Checking Section.

b) In case some obvious mistakes or considerably unbelievable figures and their reasons are found in the data, they are corrected in the Data Checking Section.

c) The data are registered to the data base, and output. The corrected data are informed to the Regional Offices.

The historical data recorded in 1991 are processed in the Data Entry Section for training purpose.

5) Data Storing in Central Office

In the Model System, the data are stored in the Central Office as follows:

a) The original record books, sheets and charts are kept in the present store house.

b) The computer output lists are kept in the present Computer Unit.

c) The data entered into the computers and processed are stored in the data base. All the above data are also duplicated to newly installed optical disk for the purpose of backup.

6) Data Dissemination in Central Office

The data are offered by floppy discs or computer output lists.

In order to operate the Model System more systematically, the tentative organization was set up as given in Fig. 5.5. This organization was made up of Sections and Units in the Central Office, Regional Offices, and the Study Team. In the Central Office, four (4) sections of Negotiation Section, Central Management Section, Data Checking Section and Data Entry Section were established. In each Regional Office, Processing Unit and Observation Unit were set up under the control of the Regional Chief. Especially, the Central Management Section was to perform management works such as preparation of data processing schedule, monitoring of data processing, evaluation works of the Sections/Units, supply of consumable and maintenance of computer facilities. Through monitoring works in the Model System, the effectiveness of branch office was examined.

(2) Installed Computer System

The following computers and data transfer devices were installed in the Central and Regional Offices in order to operate the Model System:

Instrument	Quantity	Office
Laptop type computer	6 sets	Regional Office
Desktop type computer	1 set	Central Office
Reader for data logger	2 sets	Western Regional Office

All the existing computers in the DHM are of IBM or IBM compatible machines, and the DHM staffs are familiar with these machines and softwares. The newly introduced computers listed above were determined, then, to be of IBM machines from the viewpoints of smooth and interchangeable operation and maintenance. The desktop type was selected for the Central Office considering easy operation, maintenance and system expansion. The laptop type was proposed to all the Regional Offices including two offices in the Eastern Office since these can be forwarded to Kathmandu easily for repair in case of getting damage or out of order. Beside the above computers, 3 sets of wireless equipment were introduced to try data transfer by voice communication.

5.3 Establishment of Model System

5.3.1 Establishment of Model Observation System

The Model System has been established in two selected Model Basins, the Kali Gandaki river basin in the western development region and the Jamuni river basin in the central development region. Twelve (12) new raingauges and three (3) new recording water level gauges have been installed in the Kali Gandaki river model basin. In the Jamuni river basin, two (2) new raingauges and one (1) new recording water level gauge have been provided.

Civil construction works for installation of the above gauges were carried out by dividing the works into the following three lots:

Lot I : civil construction works in the Jamuni river basin,

Lot II : civil construction works in the northern part of the Kali Gandaki river basin, and,

Lot III : civil construction works in the southern part of the Kali Gandaki river basin.

The civil construction works in the Lot I cover civil works of station for and installation of:

1) two (2) raingauges at Kolbhi and Chyuntaha,

2) one (1) recording water level gauge with staff gauges at Chyuntaha,
3) one (1) cableway facility at Chyuntaha,
4) including levelling survey at the above raingauge sites and river cross sectional survey at Chyuntaha.

The civil construction works in the Lot II comprise civil works of station for and installation of:

1) seven (7) raingauges at Yaragau, Samargau, Dhagarjong, Bega, Beghara, Muna and Kuhun,
2) one (1) recording water level gauge with staff gauges at Tatopani,
3) one (1) cableway facility at Tatopani,
4) including levelling survey at the above raingauge sites and river cross sectional survey at Tatopani.

The civil construction works in the Lot III consist of civil works of station for and installation of:

1) five (5) raingauges at Pamdur, Sallyan, Sirkon, Tisedi and Doban,
2) two (2) recording water level gauges with staff gauges at Kalleri and Setibeni,
3) one (1) cableway facility at Kalleri,
4) including levelling survey at the above raingauge sites and river cross sectional survey at the above water level gauge sites.

Design of the above civil works and preparation of the tender documents were performed in October and November, 1991. The tender for the civil construction works was called on November 20, 1991 in Kathmandu and nine (9) contractors who submitted the tender documents were evaluated on December 03, 1991. The successful tenderers, who were approved by the JICA after evaluation, are listed below.

Lot I	:	Prera Nirman Sewa Pvt. Ltd.
Lot II	:	Engineering Construction and Services
Lot III	:	Rabina Construction Pvt. Ltd.

The contract agreement for each Lot was signed between the Study Team and the selected contractor on December 08, 1991. The contract price of each Lot is shown below.

Lot I	:	NRs. 2,363,810
Lot II	:	NRs. 3,804,555
Lot III	:	NRs. 2,704,524

During the civil construction works, the following design changes have mainly been made:

1) In Chyuntaha water level gauge station, the observation house for the cable way was shifted by around 5 m toward bank side to found on the stable ground.
2) In Kalleri water level gauge station, the cable way was shifted by around 30 m toward upstream to measure discharge under stable flow condition.

Subsequent to the civil construction works, raingauges, water level gauges and cable way facilities were installed as designed. The list of observation instruments is given in Table 5.4.

5.3.2 Establishment of Model Data Management System

The proposed computers and peripheral have been installed in the Central Office and all the Regional Offices in 1992. The list of the installed equipments is given in Table 5.5.

5.3.3 Manual and Training

(1) Manuals for Observation

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:

Observers Manuals

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.

(2) Manuals for Data Management

In order to process and manage hydro-meteorological data observed in the existing and model observation stations smoothly and systematically with high accuracy, operation and maintenance manuals of data processing and management systems were provided for the technical staffs of the DHM. The manuals for the data management include:

1) General Manual of Data Management
2) Procedure Manual of Data Management
3) Operation Manual of Data Management

The General Manual presents mainly organization, general flow and schedule of data processing and management. The Procedure Manual states detailed work flow and methods of data processing and management. Several forms of data checking, data sending, and monitoring of activities are included in the Manual. The technical papers to approach to methods on data processing are also associated. The Operation Manual consists of two parts, one is Computer Operation Manual and the other is Manual of Data Base. The existing User's Manual of Hydrological Data Base is included in the latter Manual, which was prepared during the UNDP/WMO Project.

(3) Training

The following trainings were performed by the Study Team for the DHM junior staffs:

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 objectives of the introduction training were 1) introduction of the Model System, 2) training of data processing including derivation of discharge rating curves and 3) guidance of operation method of newly introduced observation facility and computer. Eleven trainees attended this training, who were chosen from the Central and Regional Offices.

In the field observation training in June and July 1992, some discharge measurements by using a current meter and floats were carried out as well as water level gauge reading and operation in the Kali Gandaki river model basin. Intensive suspended sediment sampling was also conducted.

Computer trainings in June and July 1992 consisted of two programmes. One was training on the computer softwares including MS-DOS and computer virus checking programme, which was held in Kathmandu. The another was training of smooth data processing in the Regional Offices using newly introduced computers. The computer training in December 1992 was for data checking by using computers, which was held in Kathmandu. Twelve trainees attended this programme, who were selected from the Central and Regional Offices.

5.4 Operation of Model System

5.4.1 Operation of Model Observation System

(1) Rainfall Observation

Almost the weighing type recording raingauges were operated relatively well. However some weighing type recording raingauges were not calibrated correctly due to inadequate checking of instrument. One gauge at Muna was damaged by the observer. All of them were already re-calibrated or repaired at the end of 1992 and June 1993. The field adjustment of weighing type raingauge such as time setting and zero adjustment was not conducted properly at most stations due to insufficient technical level of observers. The weighing type raingauges were affected by vibration of heavy wind and evaporation. Proper observation of ordinary raingauges was not carried out at some stations showing extraordinary values. In spite of the above mentioned inadequate operation, prompt repair or calibration was not conducted. The data logger with the tipping bucket type raingauge was operated with good data recording though it suggested a disadvantage that stored data were invisible at site for checking.

Almost all the recording cards of ordinary raingauges and recording charts of automatic raingauges until April 1993 were collected in the Regional Offices as of June 1993 as seen in Fig. 5.6.

(2) Water Level Observation

The basic operation such as time setting and water level adjustment was not conducted correctly at some stations due to less capability of observers. Proper observation of staff gauge reading was not carried out at some stations in which extraordinary data were included. At Tatopani in the Kali Gandaki river, the installed pressure sensor was washed away due to attack of big boulders in August 1992 in spite of careful site selection and installation. At Chyuntaha in the Jamuni river, the steel gauge well did not work due to shift of river course and a lot of sand deposit around the well during low water level for a few weeks in August 1992 and for three months from April 1993. Despite the above accidents and troubles, no immediate repair/rehabilitation work was conducted. The former station was recovered. The latter was supplemented by temporary staff gauges installed on the left bank.

Records of staff gauge reading and recording charts of automatic water level gauges observed until March or April 1993 were collected in the Regional Offices as of June 1993 as shown in Fig. 5.7.

(3) Discharge Measurement

The installed bank operating cableway with double drum winch functioned well with safe and easy handling of equipments except for heavy winch operation by manual. At Tatopani, however, propeller type current meter was slightly damaged due to attack with big boulders during a measurement in rapid flow. A protector for the propeller was attached. For high flood measurement, the float method and the slope-area method are also useful and some trials of these methods were carried out at Setibeni in the Kali Gandaki river.

(4) Suspended Sediment Sampling

The suspended sediment sampling was made in Setibeni using the depth integrated sampling method and investigation was carried out for distribution of suspended sediment concentration with some parameters such as flow velocity, water depth and sampling section.

(5) Station Description

Station descriptions of fourteen (14) raingauge stations and four (4) water level gauging stations were prepared after construction and installation. The station description includes basic information on historical and current condition and instrument list.

5.4.2 Operation of Model Data Management System

(1) Data Collection in Regional Office

The situation of data collection in the Model Data Management System was investigated by referring to register books in the Western and Mid Western Regional Offices, of which the former is rather developed and the latter has wide less-developed remote area in terms of transportation and communication.

For both the above Regional Offices, around 58% of data of daily precipitation and staff gauge reading were collected within one month after observation and around 86% of the data within three months as shown in Table 5.6, though the data should be gathered to the Regional Office within one month. One of the dominant reasons of the above delay is irregular data sending such as once in five months by some observers. The other reasons are that 1) the register mail service is not available in some remote areas which induces data loss sometimes, 2) post offices are located far from stations, and so on. The trial of wireless communication in the Kali Gandaki river basin showed noisy and unstable transmission and suggested inadequacy of data sending by this communication method.

Information were delivered by observers to the Regional Offices on damage or trouble of gauging stations in the Model System twice. One was the information of loss of pressure sensor in Tatopani and the another was that of sand deposit around the gauge pipe in Chyuntaha. No reaction was made for both cases.

(2) Data Processing in Regional Office

The laptop computers newly introduced in each Regional Office were operated well by staffs of the Regional Office. In the Model System, some computer trainings were performed and the staffs could understand general knowledge and operation method of the computer hardware and its programmes easily. However some future supports are required for them to guide and help for unexpected troubles.

Almost staff gauge reading records until 1990 were entered in the Regional databases except for data in the Eastern Regional Office for the priority stations as seen in Table 5.7. The staff gauge records observed in the Model Observation System were not entered at the end of 1992 since the stations were not registered in the DHM. The entry work of these data just started after registration. The recording charts of water level gauges remained unprocessed. The daily rainfall data observed in the Model System were entered in the

Regional database progressively. However, the rainfall recording charts were not processed. The number of discharge measurement is not enough to develop discharge rating curves in the Model System. Some sediment concentration was analysed in the Western Regional laboratory, though the data entry into computer was not yet done.

The data checking consists of 1) visual check, 2) check by totalling, 3) check by graphs and 4) overall check in the Model Data Management System. The visual check and check by totalling were not carried out in the Regional Offices due to less understanding of necessity. The other check works were scheduled to be done in the Central Office. The data check list was not used due to complicated form. No monitoring form or report was prepared in the Regional Office, which was to be sent to the Central Office.

(3) Data Transfer and Processing in Central Office

Some daily precipitation and water level data observed in the Model System and processed in the Regional Offices were transferred to the Central Office occasionally. On the other hand, no continuous data were processed and sent.

The data check by graphs and overall check were performed in the operation of the Model Data Management System. Especially, the graphical checking for water level data was useful. The precipitation data were checked by the overall checking method using isohyetal map or double mass, which was useful.

The temporary organization for the Model System did not work well, especially in the Central Office because of insufficient number of the staffs and huge amount of works in preparation of the DHM data books.

5.5 Evaluation of Model System

5.5.1 Evaluation of Model Observation System

Through monitoring of the Model Observation System, the following are revealed:

(1) Observation

The tipping bucket type raingauge is recommendable from the viewpoints of stable operation and easy connection with data loggers. The weighing type raingauge is usable in snowfall area though careful calibration is required. The data logger is applicable and efficient for reliable data recording. The logger should have monitoring function to confirm exact data storing at site. The pressure sensor should be installed with careful site selection and designing of strong protection. The adjustable pipe well in Chyuntaha was attested to be available following riverbed fluctuation. The bank operating cableway is recommended to be applied for safe and smooth discharge measurement. The float method and the slope-area method are also effective for discharge measurement to supplement current metering method. The proper sediment sampling should be incorporated with discharge measurement, point/depth integrated sampling, appropriate sampling section and frequent flood sampling.

(2) Operation and Maintenance

Proper and regular calibration is required for the weighing type raingauge by technicians. The daily inspection and maintenance are also essential for this raingauge as well as water level gauges by the part-time observers. The operation and maintenance manuals should be modified and updated. Immediate repair of the station is also requisite to minimize data missing by improving managerial system.

(3) Training

Adequate training is necessary in the field for observers to operate raingauges and water level gauges accurately. Training on calibration of the weighing type raingauge and operation of data logger as well as regular field observation is also important for technicians.

5.5.2 Evaluation of Model Data Management System

Through monitoring of the Model Data Management System, the following are found:

(1) Data Collection

Data collection by mail and manpower of the Regional Office staff is easy and reliable. The data collection to the Regional Office within one month may be achieved by further guidance and instruction to the part-time observers and effective scheduling of site visits. The wireless communication is not recommended.

(2) Data Entry and Processing

Computer equipment is powerful for data entry and processing. Continuous data entry is proposed to be carried out by using data loggers, digitizers, image scanners, etc. Some computer softwares to support processing works such as rating curve derivation and checking will be useful.

(3) Data Check

Precipitation data could be checked by comparing with those of adjacent stations and preparing isohyetal maps or double mass. The discharge measurement data can be checked by graphical method of stage-area or stage-velocity relationships or calculation of uniform/non-uniform flow. Water level and discharge data may be checked by hydrographs or runoff coefficient.

(4) Data Storing

The original data and other important information should be stored orderly for future reference in conformity with manual and schedule.

(5) Computer

Computer equipment is very useful for data processing, storing and dissemination. The on-line system between the Central Office and the Regional Offices will induce efficient data management and smooth activity control. Computer training is essential for the young engineers. One week computer training for one fundamental software may be required.

(6) Others

Manuals and work schedule for data processing and management activities should be prepared and modified. The responsibility of each work is also clarified by the manuals. The monitoring and evaluation work should follow.

6. LONG TERM PROGRAMME

6.1 Observation

6.1.1 Precipitation Observation System

(1) Observation Network

The minimum network of precipitation observation is proposed containing a total of 470 stations within the area of Nepal below the altitude of EL. 4,000 m with the density of 250 km^2/gauge in the mountainous area and 900 km^2/gauge in the Terai plain. Precipitation is able to be observed in the form of rain below the altitude of EL. 4,000 m for more than 6 months in a year. Almost all the villages and towns are also located below EL. 4,000 m. The density of gauge distribution conforms to the WMO norm. A study result of relationship between point rainfall and areal rainfall suggests the appropriateness of the norm. The selected 470 raingauging stations consist of 252 existing, 14 model and 204 newly proposed stations, among which the recording stations are 60 in number,14 existing , 14 model and 32 new stations, following the WMO norm. All the existing gauges remain. New gauges are to be distributed near villages uniformly in terms of area and altitude in the northern and southern slopes of ridges on which the monsoon crosses. The list of the selected 470 raingauge stations is tabulated in Table 6.1 and the network is shown in Fig. 6.1.

(2) Observation Instrument

Point rainfall measurement is recommended instead of area rainfall measurement in the Programme using ordinary and recording raingauges, since the area measurement by radar and satellite shows some disadvantages such as sensitive observation accuracy, complicated maintenance and high cost. Two types of recording raingauges, tipping bucket type and weighing type are proposed. The weighing type gauge is to be installed in high mountainous area above the altitude of EL. 2,000 m owing to its advantage of easy snowfall measurement. The tipping bucket type gauge shows stable operation and easy connection with the data logger. The data logger is also recommendable for accurate recording and smooth data processing. The following table shows a summary of raingauge installation:

Instrument	Recording Method	Number of Station
(1) Ordinary raingauge only	Once a day at 8:45	410
(2) Tipping bucket type recording raingauge*	Data logger	40
(3) Weighing type recording raingauge*	Weekly drum chart	20
Total number of gauging station		470

* Each station is to be equipped with an ordinary raingauge.

(3) Observation Method

Ordinary raingauge measurement is to be conducted by part-time observers without any change from the present DHM procedure: twice a day at 8:45 and 17:45 in the synoptic, aeronautical, agrometeorological and climatological stations, and once a day at 8:45 in the other stations. In the weighing type recording gauging stations, recording charts are to be replaced by part-time observers once a week. Digital data stored in data loggers of the tipping bucket type gauge are to be collected by field technicians every three months. In case that troubles on the above recording instruments occur, hourly measurement by observers must be started. The observation manual should be reviewed and all the works should follow the observation manual.

(4) Observation Staff

The present system to employ part-time observers is proposed to continue to apply in the Programme. Since qualification of present observers is mostly in low level, training for them is essential to familiarize with observation technique, to understand importance of accurate observation and to improve data quality.

6.1.2 Water Level Observation System

(1) Observation Network

The minimum water level observation network, which consists of three types of gauging stations, basic, primary and secondary hydrological stations, is formulated with consideration of hydrological need, water usage/control aspect and the WMO norms for minimum density. Locations to fulfill the hydrological need are 1) the border with maximum basin area, 2) confluence of major tributaries, 3) topographic change point, 4) downstream of snow and glacier areas, 5) geological fault zone, and 6) rainfall regime changing point. Locations selected from the water usage/control aspect are near the prospective development project sites such as hydropower, irrigation, water supply, flood control, glacial lake burst and soil conservation. The WMO norm recommends the minimum density of 300 to 1,000 km2/gauge in mountainous area and 1,000 to 2,500 km^2/gauge in flat area such as the Terai plain. This network includes the following 110 stations:

Number of basic hydrological station	10
Number of primary hydrological station	38
Number of secondary hydrological station	62
Total number of water level gauging station	110

The basic hydrological station is the key station located downstream of the basin and performing accurate and continuous observation with trained staffs and standard instrument and the base point for water resources development planning and river managing. The basic stations are as listed below.

River Basin	Station No.	River Basin	Station No.	River Basin	Station No.
Mahakali	150	Tinau	390	Kamala	598
Karnali	280	Gandaki	450	Koshi	695
Babai	289.95	Bagmati	589	Kankai	795
West Rapti	350				

The primary stations are selected in order to observe discharge at major tributaries, prospective sites of water resources development projects and near the border with China. The secondary stations are supplemental ones to the primary station.

The selected 110 stations include 86 existing, 3 model observation and 21 newly proposed stations. Here, two present priority hydrometric stations, No. 536.2 and No. 640, are discarded due to limited requirement for water resources project and small drainage area. The list of the selected stations for the Programme and location are shown in Table 6.2 and Fig. 6.2.

(2) Observation Instrument

Both of staff gauges and water level recorders are proposed in the Programme. Water level recorders are to be installed in the basic and primary stations which consist of 44 existing and 4 new recorders. Commonly used float type recording water level gauge and pressure type recording water level gauge are recommended. The float type gauge works well with high accuracy and its operation and maintenance are easy. In case that construction of gauge well of the float type is difficult, the pressure type gauge is applied from the viewpoint of easy transportation to remote area and easy installation and replacement in high siltation or scouring rivers. Both of the float type and pressure type gauges are proposed to be connected with data loggers for accurate recording and smooth data processing. The following table and Table 6.3 give the gauges proposed in the Programme. Fig. 6.3 shows a general idea of the observation:

Instrument	Recording Method	Number of Station
(1) Staff gauge only	Three times a day at 8:00, 12:00 and 16:00	62
(2) Float-type recording water level gauge*	Data logger	33
(3) Pressure-type recording water level gauge*	Data logger	15
Total number of gauging station		110

* Each station is to be equipped with staff gauge.

The stilling well for the float type gauge requires adequate design and construction for riverbed degradation and quick desilting action to cope with sedimentation inside the well. The smooth operation of the data logger should be considered since the Model System revealed that data transfer from the logger is apt to fail and data overflow occurs due to rare collection. The data logger is to be equipped with large memory size and monitoring function to trace memory status. Introduction of data logger with chart recorder in the Immediate Programme is one countermeasure, of which the extra cost is not so much.

Installation of the water level gauge is very difficult work in such mountainous countries as Nepal. Further and continuous study on selection of the gauge is expected.

(3) Observation Method

Staff gauge reading is to be conducted by part-time observers three times a day at 8:00, 12:00 and 16:00. In addition to this regular reading, temporary staff gauge reading of flood is recommended with every hour reading and observation of water surface profile. Recording charts are to be replaced once a week and simple checking of instrument and facility is to be made at that time by the observers. Digital data stored in the data logger are to be collected by field technicians at the time of discharge measurement or station inspection. In case that troubles on recording gauge occur, hourly measurement should be started by the observers. The observation manual should be reviewed and all the works should follow the observation manual. The general idea of the observation method is given in Table 6.4.

(4) Observation Staff

In each basic hydrological station, it is recommended to assign two DHM staffs, one Junior Hydrometeorological Assistant and one Field Assistant, and make them stay in a whole year so as to conduct sufficient, effective and accurate observation and maintain the station in best condition. For the other stations,part-time observers are continued to be employed. Proper training for operation and maintenance is essential for the above observers and technicians.

6.1.3 Discharge Measurement System

(1) Measurement Instrument

The following instruments are recommended for the discharge measurement in the Programme:

1) Cableway:
   40 bank operating double drum winch cableways are to be installed in the basic and 30 primary stations in mountainous area for safe and steady operation, and single drum winch cableways with a cable car are to be provided in 7 primary in Terai and 53 secondary stations for simple operation as seen in Table 6.3. Current meter measurement from boat is recommended to be applied to the station near the Indian border in which a cableway is not installed due to wide river.
2) Current meter:
   25 Propeller-type current meters are to be used in the river with turbulent flow and 15 price-type current meters in gentle flow.
3) Flood Measurement Instrument:

The bank operating cableway is efficient for safe flood measurement as well as ordinary discharge measurement. Three sections of staff gauges are to be provided at the basic and primary stations for float method and slope-area method. The peak water level gauges are proposed in the secondary stations to observe maximum water level in flood time.

Fig. 6.3 gives a general idea of the observation.

(2) Measurement Method

Improvement of the current metering method such as angle correction and proper procedure, and introduction of high flood measurements by float method and slope-area measurements are proposed in the Programme. The cableways are to be used commonly except for the stations near the Indian border, where boats are to be provided for current metering.

The following number of discharge measurement is recommended through consideration of the WMO recommendation and importance of station:

1) a minimum of 36 times per year in the basic hydrological station by stationed staff,
2) a minimum of 10 times per year in the primary station,
3) a minimum of 6 times per year in the secondary station.

Temporary high flood measurement is also required in all the stations. The observation manual should be reviewed and all the works should follow the observation manual.

(3) Measurement Staff

The following staffs are proposed to participate in the discharge measurement:

1) field technicians to make discharge measurement for the primary and secondary stations with efficient schedule,
2) full-time DHM technical staffs staying in the basic hydrological stations for continuous discharge measurement,
3) a measurement group with 5 persons to take high flood measurement by using float method,
4) part-time observers to read staff gauges for slope-area measurement.

6.1.4 Sediment Sampling System

(1) Observation Network

Twenty stations are selected and proposed as stations of the minimum sediment sampling network for the Programme, which include 10 basic stations and 10 primary stations. This is the result of the following considerations: 1) the network includes all the basic hydrological stations, 2) sampling should be made at the stations of which upstream basins are less forested or heavily eroded, and 3) sampling should be made at the prospective water resources development project sites. In these stations, sampling of suspended sediment and riverbed material, and river survey are proposed. The list of the selected stations and location are shown in Table 6.2 and Fig. 6.2.

(2) Sampling Instrument

For sampling of suspended sediment and riverbed material, the following instruments are recommended to be installed in the Programme:

1) 10 point integrated samplers in the basic hydrological stations for more accurate observation,

2) 5 depth integrated samplers in other sediment sampling stations,

3) 5 pit sampling apparatus for sampling of undisturbed riverbed material,

4) 10 turbidity meters in the basic hydrological stations, which are convenient to field job and do not need transportation of heavy sampling bottles.

(3) Sampling Method

For suspended sediment sampling the point integrated method and indirect field measurement by using turbidity meters in the basic stations, and depth integrated method in the other stations are introduced. Regular measurement of once a week during dry season and once a day during monsoon season is proposed. Hourly sampling during floods is also proposed.

For riverbed material sampling, the pit method is recommended because of economical and simple one. The WMO recommends the following minimum number of sampling points:

Width of main channel (m)	< 500	500-1000	> 1000
Minimum sampling points	3	3-5	5-7

The sampling of riverbed material is to be made at least once a year in all the sediment observation stations. The sampling section is taken along the section of discharge measurement.

River profile and cross section surveys are recommended to be made once a year in representative sediment observation stations located in mountainous area. This river survey covers area between 1 km upstream and 1 km downstream from each station with spacing intervals of approximately 200 m. The observation manual should be prepared and all the works should follow the observation manual.

(4) Sampling Staff

Sampling of the suspended sediment and riverbed material is to be made by part-time observers of the water level gauges or the technical staffs of the DHM in the basic hydrological stations regularly. Field technicians are also responsible to take sediment sampling at the time of site visit for discharge measurement.

6.1.5 Water Quality Sampling System

(1) Observation Network

Water quality observation is proposed to be conducted in 10 basic hydrological stations and one primary station in the Kathmandu Valley, total in 11 stations. These stations are selected to form the minimum network for the purpose of collection of nationwide and general data on river water quality. The list of the selected stations and the location are seen in Table 6.2 and Fig. 6.2.

(2) Sampling Method

The collection of depth integrated samples in a single vertical is recommended. Daily and monthly samplings are proposed as routine observations. The observation manual should be prepared and all the works should follow the observation manual.

(3) Sampling Staff

Technical staffs who will stay continuously in the basic hydrological stations take water samples for quality analysis. Technical staffs who will work in the water quality laboratory of the Basin Office also take samples.

6.2 Sediment and Water Quality Analysis

6.2.1 Sediment Analysis System

(1) Suspended Sediment Analysis

The evaporation method and the filtration method are recommended for concentration analysis of suspended sediment load. These two methods cover all the range of sediment concentration. The field measurement of sediment concentration by turbidity meter is to be introduced. The particle size analysis of suspended sediment load is newly to be introduced by applying visual accumulation (VA) method, sieve method and hydrometer method. The setting velocity and specific gravity are also analyzed.

(2) Riverbed Material Analysis

Sieve analysis and some physical property analyses of riverbed material such as specific gravity and unit weight are to be included in the Programme.

(3) Sediment Laboratory

The existing sediment laboratories are to be strengthened and expanded in the Central and Basin Offices. In each Basin laboratory, two DHM staffs, one laboratory Chief and one Assistant are to be assigned. The existing laboratory equipment such as electric oven and balance should be repaired and strengthened. Guidance of proper sediment analysis by foreign experts and preparation of procedure manual are requisite.

6.2.2 Water Quality Analysis System

(1) Water Quality Analysis Parameter

The following 11 parameters are proposed to be analysed in the Programme: 1) Water temperature, 2) pH-value, 3) Conductivity, 4) Dissolved oxygen (DO), 5) Nitrogen Ammonia, 6) Nitrogen Nitrate, 7) Ortho-phosphate, 8) Turbidity, 9) Chlorine ion, 10) Biochemical oxygen demand in 5 days (BOD), 11) Chemical oxygen demand (COD). These parameters are selected by considering basic physical and chemical property, basic environmental item and eutrophication item.

(2) Analysis Instrument

Most of the above water quality parameters are measured in the field. Only samples for BOD and COD are transported and analysed in the laboratory. The following instruments are recommended in the Programme:

1) Test kits applied for colorimetric analysis are proposed to be used for measurement of Nitrogen Ammonia, Nitrogen Nitrate, Ortho-Phosphate and Chlorine Ion in the field.
2) Portable probes applied for electrode method are proposed to be used for measurement of Water Temperature, pH-value, Conductivity, Dissolved Oxygen and Turbidity which are to be installed at each basic station.
3) Containers for transporting samples of BOD and COD are to be provided.

(3) Analysis Method

The samples of BOD and COD must be transported to the laboratory within 24 hours after sampling and be kept at a temperature of 3° to 4°C to slow down the biochemical oxidation processes. Routine observations are recommended with the frequency of daily observation for Water Temperature, Ph-value, Conductivity, Dissolved Oxygen (DO) and Turbidity, and monthly observation for Nitrogen Ammonia, Nitrogen Nitrate, Ortho-phosphate, Chlorine ion, BOD and COD. The procedure manual should be prepared and all the analyses should follow the manual.

(4) Analysis Staff

The water quality analysis will be carried out by:

1) Technical staffs, who will stay continuously in the basic hydrological stations and take routine water quality analysis including Water Temperature, PH-value, Conductivity, Dissolved Oxygen and Turbidity every day,
2) Technical staffs, who will work in the water quality laboratory of the Basin Office and take field water quality analysis such as Nitrogen Ammonia, Nitrogen Nitrate, Ortho-Phosphate, and Chlorine ion and sampling for BOD and COD once a month.
3) One laboratory Chief and one Assistant in the laboratory.

(5) Water Quality Laboratory

The water quality laboratory is to be newly established in the strengthened sediment laboratories in the Central and Basin Offices. In the new laboratory, the following are provided:

1) Preparation of laboratory space and equipments such as BOD meter, COD meter and incubator in the Central and Eastern Laboratory.
2) Test kits for the field measurements in each Basin Laboratory,
3) Guidance of proper analysis by foreign experts and preparation of procedure manual.

A tracer laboratory has been operated in Kathmandu under the Snow and Glacier Hydrology Project. The tracer technique is one of the effective discharge measurement methods for turbulent flow in the mountainous area, then it is recommended to continue the operation of this tracer laboratory.

6.3 Establishment, Inspection and Maintenance of Facility

6.3.1 Establishment System

Establishment work of gauging stations and laboratories consists of network design, selection of instrument, structural design, civil construction work and its supervision. The Establishment System includes structural design, civil construction work, instrument installation and their supervision. The network design and instrument selection will be conducted in the Data Quality Research System which will be discussed in the following Section. In the Programme, the Establishment System is to be strengthened. The Establishment System will function in the Basin Office and technical staffs of the Basin Office will be responsible for structural design and construction/installation works. The procedure manual should be prepared and all the works should follow the manual.

6.3.2 Inspection and Maintenance System

(1) Basin Office

The main inspection and maintenance activity of observation stations should be born by the Basin Office due to prompt and easy access. The following staff and schedule are proposed for inspection and maintenance in the Long Term Programme:

1) The daily/weekly inspection, which is general checking, is required to be performed by the part-time observers. This inspection is very important to keep stations in good condition in remote areas. The weekly inspection is to be made at each recording station at the changing time of recording chart. In the basic hydrological station, stationed DHM staffs are to inspect all instruments and facilities.

2) The several monthly inspection is to be made by the well trained field and mechanical technicians of the Basin Office. Workshop mechanics are recommended to carry out periodic inspection for recording stations and mechanical facilities. Field technician is to conduct inspection at the time of discharge measurements. In addition to the regular inspection, an inspection is required to check the stability of the observation station just after severe flood.

3) The annual inspection for overall checking of stations is required by the Hydrologist or Meteorologist.

4) The adjustment and calibration of instruments are to be conducted by the well trained workshop mechanics in the field once a year. The minor adjustment may be performed by observers or field technicians.

5) In each Basin workshop to be established in each Basin Office, two(2) mechanics (chief and assistant)are recommended to be employed.

The workshop in each Basin Office is proposed to be established in the Programme for prompt repair and proper management of the station. The workshop should have enough space, repair equipments and tools, spare parts and spare instruments. The procedure manual and record form of the inspection and maintenance are required to be provided for efficient and standardized work. Recommended field maintenance schedule of precipitation and hydrometric stations is given in Table 6.5 and 6.6.

(2) Central Office

Good and effective communication between the Central Office and each Basin Office is quite important for smooth inspection and maintenance work. The Central Workshop shall give proper and timely advice and suggestion to the Basin Workshop. The Basin Workshop should inform activities and condition of all stations every year. Staffs of the Central Workshop will make inspection upon request.

The existing instrument workshop in the Central Office is to be reinforced by repairing machines and tools, supplying sufficient spare parts and spare instruments and reinforcing staffs. A full fledged standard current meter calibration facility is also recommended to be established for accurate discharge measurement. Timely calibration for damaged current meter as well as regular calibration will be made easily and economically by using this facility.

6.4 Data Processing and Management

Conforming to the purpose of the Programme and basic concept of the data processing and management discussed in the preceding Chapters, the basic structure of the data management system is prepared and shown in Fig. 6.4. The data and information flow of the data management system is illustrated in Fig. 6.5. The annual schedule is briefly explained in Fig. 6.6 for the activities of the observation and data management.

6.4.1 Data Collection System

Objective of the Data Collection System is to collect observed or analysed hydro-meteorological data and information on observation station and equipment, and to send them to the Data Processing System after registration. The data and information to be collected are summarized in Table. 6.7.

The data and information are to be collected by mail, staff, telemeter and /or telephone. The records observed by ordinary/manual gauges are transferred by mail, within one month after observation which is useful, economical and easy according to the operation of the Model System. The records on charts and data loggers are collected by the DHM staffs as well as discharge measurement, survey and inspection records at the time of station visits. The data observed at three basic stations in Karnali, Narayani and Koshi rivers are to be transmitted through telemetering system for more accurate observation and proper maintenance. The data collected in the Branch Offices should be sent to Basin Offices after preliminary checking. Inventory of data collection is to be provided by using computer for monitoring present status of collection in the Basin Offices and Central Office. The Basin Offices should request urgent data sending to observers who do not transfer them within one month after observation on the basis of the monitoring.

Emergency information on stations, equipment, observers or others is also collected by mail, telephone or telegraph, which should be transferred to the Inspection and Maintenance System and Progress Control/Quality Control Systems. All the data mentioned above are to be transferred to the Data Processing System by the DHM staffs. The procedure manual should be reviewed and all the activities should follow the manual.

6.4.2 Data Processing System

Objective of the Data Processing System is to process collected data to the figures of user's need with entire checking, and to convey them including collected information on station and equipment to the Data Storing System.

Before entering hydro-meteorological data into computer collected data are to be checked primarily in the Basin Office. The check items are station number, observation date, station name, data themselves and data missing.

The data and information in paper form, chart, ram card of the data logger or of analogue/digital sign of the telemeter system are to be entered into computer with simple and easy operation method in the Basin Offices. Table 6.8 shows the summary of the data entry work. After data entry, they are to be checked to the full extent by printout/display monitoring check, check by computer verification software, limit check, total value check or double entry check.

After the above data check, data processing is to be made by using computers with three processing levels: the first level processing is independent one of each data such as mean or total value calculation of respective data, the second is processing by using two or more kinds of data such as discharge calculation or suspended sediment transportation, and the third is data book compilation. This data processing work is to be followed by further data checking in the Basin Office. The data check is to be carried out by comparison with historical data or adjacent data, comparison of data between recording and manual gauges, use of hyetographs, isohyet, hydrographs, or double mass curves, calculation of discharges or runoff coefficient.

The processed data and information are to be transferred from the Basin Office to the Central Office through on-line system as well as original data to be sent by staff and final data check is carried out by the experienced staffs in the Central Office. In case some data errors are found, information on it is sent to the Basin Office and data are corrected in both of Basin and Central Offices. The data book is actually compiled after this error correction. All the data mentioned above are to be transferred to the Data Storing System.

The computer equipments are to be used to the full extent for accurate and prompt processing as seen in Fig. 6.7 and 6.8. Both of the Central Office and the Basin Offices should have their own databases to process and disseminate the same data. The databases consist of permanent and temporary databases. The database of precipitation data and that of hydrological data are to be combined and one database will function. The procedure manual including check forms should be reviewed and all the activities should follow the manual. The following are the number of computers proposed in the Long Term Programme which consist of 19 new and 7 model computers:

Office	Purpose	Number of Computers
Central Office	Database with server	1 set
	Management	1 set
	Data dissemination	1 set
	Data entry	1 set
	Quality control	4 sets
	Training	5 sets
	Backup in optical disk	1 set
Basin Offices	Database with server	4 sets
(total)	Data entry	4 sets
	Data processing	4 sets

6.4.3 Data Storing System

Objective of the Data Storing System is to store original and processed data and collected information safely and systematically and to convey the data and information to the Data Dissemination System.

The original and processed data and collected information are to be stored once a year after registration with identification number in the Central Office. The System will store the original data and information in the storeroom and processed data in the database. Back-up for original and processed data is also to be kept in the optical disk. The list of data to be stored and their storing terms are proposed as indicated in Table 6.9. Nobody will be allowed to take the stored original data out of the storeroom except for duplicated one. The duplicated data are to be submitted to the Data Dissemination System on request. The Data Storing System monitors the storing term and the data of which the storing term is expired will be abandoned. The procedure manual should be prepared and all the activities should follow the manual.

6.4.4 Data Dissemination System

Objective of the Data Dissemination System is to disseminate necessary data to data users and also to the Data Quality Research System.

The data dissemination is to be made in the form of data book, on-line means, floppy disk and photocopied list. Before dissemination, the System will survey registration of user for on-line contact, user's request and also storing status of required data. The data book is one of the most suitable dissemination methods. The annual data book publication is recommendable. The contents of the data book are proposed as shown below.

	Data	Data Items
1.	Common Item	• location map of stations • code number for stations • summary of station description
2.	Precipitation	• summary of precipitation condition in Nepal • isohyetal map in Nepal • continuous precipitation • daily precipitation • monthly precipitation • annual precipitation • hydrograph • rainfall intensity
3.	Discharge	• summary of stream flow condition in Nepal • daily mean discharge • monthly mean discharge • annual discharge • hydrograph • flow duration curve • specific discharge • extreme values
4.	Sediment and Water Quality	• Summary of sediment and water quality condition in Nepal • daily suspended sediment concentration • monthly suspended sediment concentration • daily suspended sediment transportation • monthly suspended sediment transportation • annual sediment transportation • grain curve • specific gravity • percentage of voids • water quality index

The on-line connection should be applied to only the governmental agencies for maintaining the database in safe condition. The reasonable cost will be charged to the users for requested data.

The Data Dissemination System will function in both of the Central Office and the Basin Offices. To keep the common data, the computers in the Central and Basin Offices are to be connected by the global area network.

6.5 Data Quality Improvement and Training

6.5.1 Data Quality Research System

Objective of the Data Quality Research System is to improve quality of the hydro-meteorological data by proposing improvement plan based on related studies such as observation network study, investigation of modern instruments and other hydrological studies, and monitoring and investigating activities of current observation and data management.

The System will include the following functions:

1) Review on present observation activity including review work of observation item, network, instruments, method and organization,
2) Review on present data management activity including data processing and checking method, instrument and organization,
3) Hydrological analysis such as depth area duration analysis, low flow and flood analysis or sediment yield and transportation analysis, and examination of data reliability,
4) Modification and improvement of operation, inspection and maintenance manuals of all the activities,
5) Preparation of proposals for future improvement to raise data quality and annual reporting.

6.5.2 Training System

Objective of the Training System is to train the DHM staff to achieve smooth operation of observation and data management system and to obtain accurate data.

In the Programme, regular and systematic training courses are to be introduced as given in Table 6.10 aiming at the following main targets:

1) to understand fundamental knowledge on hydrology and meteorology,

2) to understand mechanism of observation instruments and to master proper observation procedure,

3) to master procedure of appropriate data processing including data checking,

4) to familiarize with computer operation.

The above training to be introduced is formulated to train the following five staff groups; newly employed staff, field assistant, junior hydro-meteorological assistant, senior hydro-meteorological assistant, and engineer.

Not only on-the-job training for the observers and field technicians also the training in the Training Center is proposed, which is recommended to be established in the Central Office for efficient and intensive training. Foreign and local experts are also recommended to be despatched to the Training Center for effective operation. The System should review and improve the training menu. Besides the above local training, the System will send some trainees and trainers to participate in international training courses, seminars or study tours relevant to hydrological and meteorological activities. The joint operation of the training is also recommended with the DPTC, Research and Training Branch of the DOI, Research and Training Unit of the Tribhuvan University and others.

6.6 Monitoring and Evaluation of Activities

6.6.1 Progress Control System

Objective of the Progress Control System is to monitor and control the progress of all the activities in order to keep the specified annual schedule and disseminate data within next year.

The Progress Control System will receive reports of present work status of all the other Systems every month and prepare monitoring report compiling the above reports in the Basin Office and the Central Office. The report transmitting is to be made by on-line means between the Basin and Central Offices.

The System will control the progress of all the other Systems every month by comparing the actual work condition shown in the monitoring report and the schedule with giving necessary instructions. And the System will modify the annual schedule of all the activities when some defects or discrepancies occur. The annual report on the progress of all the System is to be prepared and submitted to the Evaluation System.

6.6.2 Quality Control System

Objective of the Quality Control System is to monitor and control the quality of data and activity to disseminate reliable hydro-meteorological data.

The Quality Control System will receive reports on present work method and condition of all the other Systems including data checking every month and prepare monitoring report in the same manner as the Progress Control System. The System will, then, control the quality of data and activity on the basis of the prepared monitoring report and recommendation from the Data Quality Research System.

The System will revise check list of quality control monitoring including data check list. The annual report on the quality of data and activity of all the Systems is to be prepared and submitted to the Evaluation System.

6.6.3 Evaluation System

Objective of the Evaluation System is to evaluate the current activities and to improve them. The evaluation is to be conducted on the basis of the monitoring reports prepared in the Progress and Quality Control Systems, user's demand obtained through dialogue and others. The System is organized as the independent Division in the DHM. This evaluation may be accompanied with reward and punishment. The evaluation report will be distributed to all the other Systems through the Central and Basin Offices and to the MOWR.

6.7 Organization and Staff

6.7.1 Organization and Roles

There are mainly two data processing modes, one is the centralized data processing mode and the another is the decentralized mode. Seven alternatives of the centralized or decentralized processing organizations are studied as seen in Table 6.11 and compared each other. Finally, the Case 6 is selected as the most suitable organization, in which 1) the Branch Office will collect data and send to the Basin Office, 2) the Basin Office will collect, process data and transfer to the Central Office, and 3) the Central Office will manage the data. This selection is made through the following considerations:

1) According to the present situation of the DHM, it is difficult to collect, process and manage the nationwide data by the Central Office only.

2) The Basin Office will collect and process data by the unit of river basin for efficient data management. Nepalgunj, Pokhara, Kathmandu and Biratnagar are selected as the locations of the Basin Offices to process data in the Karnali, Narayani, Bagmati and Koshi river basins as well as the adjacent basins respectively. The above locations are the traffic center and have good transportation condition.

3) The Branch Office will support the Basin Office to collect data especially in the northern part of the country. However, it is difficult for the Branch Office to share the data processing function due to unstable power supply and lack of well trained staff.

In the Long Term Programme, a Central Office, four Basin Offices and ten Branch Offices are recommended as a new organization of the DHM from the viewpoints of more consistent, efficient and easy observation and data management as illustrated in Fig. 6.9. The Central Office will function in mainly management field to make progress and quality control, evaluation of system, data dissemination and staff training. The Basin Offices, which are to be located in Nepalgunj, Pokhara, Kathmandu and Biratnagar, will function to operate stations and process data. The Branch Offices will maintain stations and collect data. The location of the proposed offices is given in Fig. 6.10. The following are summary of the above offices:

Basin Office	Basin Office Site		River Basin to be Managed	Branch Office
Far Western	Nepalgunj	I.	Mahakali River	Bangga
		II.	Southern Border River Group No. 1	Chainpur
		III.	Kamali River	Simikot
		IV.	Babai River	Jumla
		V.	Southern Border River Group No. 2	Musikot
		VI.	Rapti River	
		VII.	Southern Border River Group No. 3	
Western	Pokhara	VIII.	Narayani River	Jomsom
Central	Kathmandu	IX.	Southern Border River Group No. 4	Simara
		X.	Bagmati River	
		XI.	Southern Border River Group No. 5	
Eastern	Biratnagar	XII.	Kamala River	Okhaldhunga
		XIII.	Southern Border River Group No. 6	Khandbari
		XIV.	Sunkoshi River	Taplejung
		XV.	Southern Border River Group No. 7	
		XVI.	Kankai River	
		XVII.	Southern Border River Group No. 8	

The organization and role of each office are briefly explained below.

1) In the Central Office, two Divisions, Data Management Division and Evaluation Division are proposed. The Data Management Division will observe, process and manage the data including quality and progress control. The Evaluation Division will evaluate all the other systems by operating the Evaluation System.

2) The Data Management Division will consist of Management Section and Data Arrangement Section. The Management Section will manage the systems through Progress Control Unit and Quality Control Unit. The proposed training center, workshop and laboratory will belong to the Quality Control Unit. The Data Arrangement Section will process and manage the data through Data Processing, Data Storing and Data Dissemination Units.

3) The Basin Office will establish and maintain stations, collect and process data and send them to the Central Office. The Basin Office will consist of Data Arrangement, Observation, Laboratory and Workshop Units. The number of observation stations is tabulated for each Basin Office in Table 6.12.

4) The Branch Office will be established in the northern part of Nepal to operate and maintain stations, collect data and send them to the Basin Office.

6.7.2 Staffing

Under the new organization, engineering staff of 138 persons are recommended as shown in Table 6.13.

6.8 Implementation Schedule

The Long Term Programme consists of three stages. The first stage is a programme up to 1995, which is considered as the Immediate Programme. The second stage is to be implemented between 1996 and 2000 and the third stage is from 2001 to 2005. Table 6.14 and Fig. 6.11 and 6.12 show summary of the implementation schedule.

6.9 Project Cost

The total project cost for the Long Term Programme is estimated to be around NRs. 878 million including price escalation. Out of the total project cost, NRs. 633 million will be needed in foreign currency and the rest of NRs. 245 million in local currency.

The following are the conditions and assumptions on which the cost estimate is based:

1) The direct cost of the project is estimated by CIF at Kathmandu based on the price level in February, 1993.

2) The following exchange rates are applied, which were the rates on February 15, 1993:

   1.0 US Dollar = 46.4315 Nepali Rupees = 121.05 Japanese Yen

3) Unit prices of instruments for observation and computer system and unit prices for each work item are mainly referred to the study of the Model System.

4) Local currency is required for the labour cost, purchase of domestic materials such as timber, bricks, fuels, cement, reinforcing steel bar, etc., and the transportation charge in the territory of Nepal.

5) The general administrative expenses of the HMG/N and the engineering services for the detailed design and construction supervision to be rendered by a foreign consultant are estimated to be about 10% of the total direct cost.

6) The contingency and reserve to cover possible increasing quantity in the civil works are estimated to be about 15% of its total direct cost. Those on the instruments for

the observation and the computer system are estimated to be about 5% for its total direct cost.

7) The staff training cost for the Central Office and Basin Office is estimated to be about 1% of the total instruments cost for the observation and the computer system.

8) The operation and maintenance cost to cover annual expenditures for maintenance materials, spare parts and calibration costs are estimated to be about 3% of the total instruments cost for the observation and the computer system. It includes the replacement cost for the observation instruments.

9) The annual price escalation of 4% for the foreign currency is assumed. For the local currency, the escalation of 9% up to 2000 and 6% after 2001 are assumed.

The estimated project cost is summarized below and the breakdown is given in Table 6.15.

(Unit: 1,000 NRs)

Item	Foreign Currency	Local Currency	Total Amount
- Observation	128,690	87,066	215,756
- Analysis of Sediment and Water Quality	3,056	0	3,056
- Management of Facilities	23,293	6,663	29,956
- Data Processing and Management	38,783	637	39,420
- Data Quality Improvement and Training	190,935	42,217	233,152
- Computer System	58,109	5,500	63,609
Sub-Total	442,866	142,083	584,949
- Administration and Engineering Service	75,107	4,032	79,139
- Contingency and Reserve	13,306	20,562	33,868
- Staff Training	0	2,424	2,424
Grand Total	531,278	169,102	700,380
- Price Escalation	101,611	76,130	177,741
Grand Total incl. Price Escalation	632,889	245,231	878,121

The annual disbursement schedule for the implementation of the Long Term Programme is tabulated below.

(Unit: 1,000 NRs)

Stage		Investment			Operation and Maintenance	
		Foreign Currency	Local Currency	Total Amount	Foreign Currency	Local Currency
First Stage (Immediate Programme)	1993	16,928	0	16,928	0	0
	1994	160,794	66,989	227,783	2,326	997
	1995	96,976	23,599	120,575	3,267	1,400
Second Stage	1996	57,426	20,242	77,668	4,122	1,767
	1997	37,013	16,283	53,296	4,645	1,991
	1998	31,863	17,624	49,487	5,168	2,215
	1999	31,620	19,196	50,816	5,714	2,449
	2000	27,818	13,621	41,439	6,192	2,654
Third Stage	2001	23,363	6,792	30,155	6,546	2,805
	2002	20,730	6,301	27,031	6,873	2,945
	2003	19,236	17,816	37,052	7,215	3,092
	2004	91,428	19,495	110,923	8,585	3,679
	2005	17,696	17,274	34,970	8,947	3,834
Total		632,889	245,231	878,121	69,601	29,829

The annual operation and maintenance cost is estimated to be around 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.

6.10 Evaluation of Proposed Long Term Programme

(1) Impact on Data Analysis and Development Project

The hydro-meteorological observation and data management systems improved and expanded by the implementation of the Long Term Programme will surely contribute to serve more accurate, nationwide and long term hydro-meteorological data. The quantitatively and qualitatively improved data will induce more reliable hydro-meteorological analysis which leads to raise the academic level in the field of the hydrology and meteorology. The improved data will also enable to grasp national water resources potential and to plan and design water resources development project properly and more economically. Moreover, the increase of the available data may accelerate the development activities of the water resources projects.

(2) Realistic Programme Formulation

The Long Term Programme is formulated to apply the most practicable and reasonable observation instruments and computer equipments in order to form the realistic programme. The size of the project cost NRs. 878 million is also verified in terms of the operation, maintenance and replacement cost. The operation, maintenance and replacement cost is estimated to be NRs. 12.8 million in the year 2005, which is about 16% of the projected annual budget of the DHM in the fiscal year of 2005/06. This percentage may be judged not to be large and it is concluded that the DHM could maintain the system after completion of the Programme.

(3) Case Study on Economic Evaluation

The economic benefit of the Programme is evaluated as an economic effect which is produced by raising an accuracy of hydrological data. A more accurate hydrological data will be brought from increase in number of the hydrological stations. Then a case study on the economic evaluation of the Long Term Programme is carried out by making a comparison between incremental benefit and incremental cost due to increase in discharge and rain gauging stations.

In a hydrological network, the increase in number of gauging stations will generally shorten the average distance between gauging stations, and as a result the calculation error of hydrological value at any stations other than observation stations will be reduced. In the rain gauging network in the river basin also, an increase in number of the gauging stations will lead the network to a higher density distribution of the gauging stations, and will reduce the calculation error of discharge, when the discharge is calculated from rainfall data in the basin.

Error of estimated discharge is examined using the monthly discharge and rainfall data for the period 1963-1986 in the Karnali river and Sun Koshi river basins in terms of average distance between discharge gauging stations or density of raingauging stations. On the other hand, the discharge gauging stations and rain gauging stations are planned to be increased from 46 to 110 and from 252 to 470 respectively in the Long Term Programme. As a result, it is indicated that the error of estimated discharge will be reduced ranging from 10% to 30% in case of the above mentioned station increment. The 20% of reduction in error is assumed in this case study.

Taking the historical development budget of Nepal into account, it is assumed that the water resources projects will be executed taking 10 years per case at a rate of 2 cases per annum.

The average construction cost of future water resources projects is estimated to be US$300 million and it is assumed that the cost related to the water discharge is estimated at around 40%. Under the foregoing conditions and assumptions, the average annual benefit is estimated to be NRs. 223 million as a reduction effect of 8% of the project cost. The total construction cost amounts to NRs. 700 million for the Long Term Programme without price escalation. The annual OM cost increases year by year and after the year 2005, the cost of NRs. 8 million are required. The economic evaluation of the Long Term Programme is made by making a comparison between two present values of the total cost and benefit for the project life period of 50 years after commencement of the Programme. As a result, IRR of the Programme is estimated to be 30.2 %. This indicates that the Long Term Programme has a high feasibility economically. In case where the reduction effect of discharge error comes half of the above case, that is 10 %, the IRR will come to 14.5 %. This figure also shows that the Programme is feasible economically.

7. IMMEDIATE PROGRAMME

7.1 Purpose and Basic Policies of Immediate Programme

7.1.1 Purpose of Immediate Programme

As set forth in the preceding Chapters, the present observation and data management systems have not furnished the hydro-meteorological data with enough quality and quantity for evaluation of nationwide hydrological phenomena and characteristics. The first priority should be put on the quality of the data instead of the quantity in stepwise improvement programme of the systems. The Immediate Programme, thus, concentrates to improve quality of the hydro-meteorological data urgently by strengthening the existing hydro-meteorological observation and data management system without a large physical expansion of the system.

7.1.2 Basic Policies of Immediate Programme

In order to attain the purposes to improve data quality as mentioned above, the Immediate Programme was formulated conforming to the following basic policies:

1) to focus on four existing observation items to take in the Immediate Programme, precipitation, water level, discharge and sediment observation.

2) to reinforce existing observation stations and laboratories with those operations by:
   - repair and replacement of existing gauging stations and instruments with a certain addition,
   - reinforcement of existing sediment laboratories,
   - reinforcement of existing inspection system and workshop including establishment of current meter calibration facility,
   - improvement of observation and operation method with revision of manual.

3) to reinforce and improve existing data management system by:
   - reinforcement and improvement of work procedure for data collection, processing, storing and dissemination including introduction of data check system and revision of manual,
   - expansion of computer system and other equipment.

4) to reinforce systems for data quality improvement and monitoring of observation and data management activities by:
   - establishment of training center with training programmes,
   - invitation of foreign experts,

- introduction of study system to improve data quality including revision of manual,
- reinforcement of procedure and method to monitor and evaluate all the observation and data management works.

5) to reorganize a part of the structure of the DHM to enable and smoothen all the above works by introducing 16 systems among 18 systems proposed in the Long Term Programme.

7.1.3 Improvement Items Selected for Immediate Programme

The following items are selected as the reinforcement and improvement work items to be included in the Immediate Programme to achieve the targets to raise the quality of the hydro-meteorological data:

(1) Observation

The Programme includes:

1) repair and replacement of existing raingauge stations with addition of recording gauge,
2) repair and replacement of existing water level gauge stations and cableway facilities with addition of recording gauge and cableway,
3) establishment of basic hydrological stations,
4) improvement and addition of discharge measuring instruments,
5) improvement of existing sediment sampling system with repair and addition of sampling instruments, and
6) review and modification of manuals.

(2) Sediment and Water Quality Analysis

The Programme includes:

1) repair and reinforcement of sediment analysis instruments, and
2) review and modification of manuals.

(3) Establishment, Inspection and Maintenance of Facility

The Programme includes:

1) repair and reinforcement of existing workshop in the Central Office,
2) establishment of calibration facility for current meter, and
3) review and modification of manuals.

(4) Data Processing and Management

The Programme includes:

1) reinforcement and improvement of data collection system,
2) reinforcement and improvement of data processing system with introduction of check system,
3) reinforcement and improvement of data storing system,
4) reinforcement and improvement of data dissemination system,
5) expansion of computer system with local area network, and
6) review and modification of manuals.

(5) Data Quality Improvement and Training

The Programme includes:

1) establishment of a training center in the Central Office with training programmes,
2) invitation of foreign experts, and
3) introduction of investigation and study system to improve data quality.

(6) Monitoring and Evaluation of Activities

The Programme includes:

1) reinforcement of monitoring system for all the activities,
2) introduction of evaluation system for sections and staffs, and
3) review and modification of manuals.

7.2 Proposed Plans of Immediate Programme

7.2.1 Precipitation Observation System

The Immediate Programme concentrates to reinforce and repair existing precipitation observation system without expansion of the network. Precipitation network of the Immediate Programme, which is the first stage of the Long Term Programme consists of 266 existing stations including 38 recording stations, which are 14 existing, 14 model system and 10 newly proposed stations. The number of recording raingauges is determined according to the norm of the WMO that at least 10% of raingauges are to be equipped with recorder in the network.