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DATA PROCESSING AND HYDROLOGICAL ANALYSIS

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PREFACE

Data processing and analysis are important tools for the development, planning and management of advanced technology related to Water resources. The comprehensive use of data processing and analysis systems for water resources, specifically for problems related to hydrology, has been widely recognised and is considered to be an objective for all agencies involved in data collection and analysis.

In India, with the improvement in the modern needs and multi-purpose use of hydrologic events data processing and analysis is of utmost importance. A number of organizations dealing with hydrologiucal data are attempting to develop some computer techniques for data storage and retrieval ffor hydrological modelling and further studies.

The report entitled DATA PROCESSING AND ANALYSIS prepared by Sri Ramakar Jha, Scientist'B', under the guidance of Dr. S.M. Seth, Scinetist'F' incorporates various data processing techniques, its background, mechanics of data processing and agencies involved in data processing in India. The report also indicates the usefulness of Data processing in problems related to Hydrology.

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ABSTRACT

Data processing and hydrological analysis is related to well established principles of hydrodynamics and thermodynamics. The central problem is the application of these principles in a natural environment which is irregular, sparsely, and only partially known. The event samples are usually unplanned and uncontrolled. Analysis are performed to obtain average aerial values of certain elements, regional generalization, frequency distribution, and relationships among variables, often the potential elements are not or cannot be measured directly.

Organisation and analysis of hydrological data are fundamental parts of development, planning and the associated tasks of project design and operation. The consequent needs for comprehensive data processing systems for hydrological data has been widely recognized, and is invariably stated as an objective of all agencies involved in data collection and analysis.

The study reported herein indicates the data processing storage media, machines, development, analysis, and a case study of data processing and hydrological analysis is also reported.

1. INTRODUCTION

Advances in scientific hydrology and in practice of engineering hydrology are dependent on good, reliable and continuous recording, processing and analyzing the measurement of hydrological variables. An engineer may find it difficult to use the information assembled by any of the different methods but the hydrologist often finds his first job entails the organization of a data receiving and processing system. Organisation and analysis of hydrological data are fundamental parts of development, planning and the associated tasks of project design and operation. The consequent needs for comprehensive data processing systems for hydrological data has been widely recognized, and is invariably stated as an objective of all agencies involved in data collection and analysis. In the developing nations, the successful design and implementation of such systems has been relatively limited.

Concept of hydrologic cycle forms the basis for the engineering hydrologists to understand the source of water (at or under the earth's surface) and its consequent movement by various pathways back to the principal storage in the ocean. In the process of hydrologic cycle two of the greatest problems for the hydrologists exists : (1) Amount of water in the different phases in the cycle; and (2) Evaluating the rate of transfer of water from one phase to another within the cycle.

Earlier, the hydrological variables such as rainfall, streamflow, or groundwater have been measured for many years by separate official bodies and private organizations but it could serve only single and simple purpose. Now-a-days, with the improvement in communication to serve modern needs, hydrometric schemes are tending to become multipurpose. These measurements are recorded by a wide range of methods, from a simple writing down of a number by a single observer to the invisible marking of electronic impulse on a magnetic tape. A hydrologist often finds that his first job is to receive and process informations assembled by any of the many different methods, to correct and warn the personnel involved in recording different hydrological measurements. Once data are collected, the next important and necessary step is their proper storage. In the conventional ways, the data are mostly kept in manuscript form in register or files. With the advancement of technology, computer memories, magnetic tapes, microfilms etc. have replaced this conventional storage media. In the modern procedure, the data are stored only after a particular level of processing.

Most countries have well established and expanded hydrological networks, producing correspondingly increasing quantity of data. However because of the shortage of suitably trained personnel and inevitable pressure to perform urgent work at the expense of routine data processing, much of the collected data remains unprocessed. The larger the backlog of raw data, the more difficult is the task of data storage and analysis. This results in manual processing technique which is becoming totally impractical, except for limited individual studies. Thus the introduction of automated or electronic data processing is essential where this situation exists but is equally valuable in preventing it in places where significant amounts of data are only now become available.

Data processing covers data preparation, data entry and transfer to the data base, data validation, data correction, filling-in of missing data, data compilation and analysis, data retrieval, and data dissemination/publication of yearbooks.

Data processing may be defined as any systematic procedure through which basic information is transposed into more accessible or more directly usable forms. It comprises editing and organizing functions (detecting and correcting errors, classifying and indexing records, sorting and collating data prior to use, etc.), carrying out necessary calculations and transcribing both data and results in prescribed format to a suitable storage and processing medium.

The data have first to be recorded at source, dispatched to a collecting centre and finally distributed to the users. Nowadays data production and transmission are becoming so bound up with data processing, both on the organizational and on the equipment sides, that it is sometimes difficult to differentiate between them at all clearly.

1.1 Definition

Data are any collection of facts. Thus, sales reports, inventory figures, test scores, customers' names and addresses, and weather reports, are all examples of data. Note that the data may be numerical or they may be nonnumerical.

Data processing is the manipulation of data into more useful form. Data processing includes not only numerical calculations but also operations such as classification of data and the transmission of data from one place to another. In general, these operations are performed by some type of machine or computer, although some of them could also be carried out manually. 1

1.2 Categories

Modern data processing with machines falls into two broad categories, punched card data processing and electronic data processing. Punched card data processing systems consist of various electromechanical devices, such as sorters, collators, reproducers, calculators, and tabulators, which operate on punch cards. Electronic data processing systems consist of various input and output devices connected to an electronic computer. The latter systems can process very large amounts of data in very little time.

1.3 Cycle

The component of data collection enclose the capturing of data and the transmission of data. Data processing covers all the activities after transmission up to and inclusive data dissemination. It comprises editing and organizing functions (i.e. detecting and correcting errors, classifying and indexing records, sorting and collecting data prior to use etc.), carrying out necessary calculations and transcribing both data and results in prescribed format to a suitable storage and processing medium.

Basically data processing consists of three steps- (1)Input (2) Processing and (3) Output. The flow chart is as follows:

```
Data Collection--->Input--->Processing--->Output--->Dissemination
                                ¦¦
                                ¦¦
                                ¦¦
                                ¦¦
                               \¦¦/
                                \/
                              Storage
```

1.3.1 Input-

In this step the initial data, or input data, are prepared in some convenient form for processing. The form will depend on the processing machine.

1.3.2 Processing-

In this step the input data are changed, and usually combined with other information, to produce data in a more useful form.

1.3.3 Output-

Here the results of the preceding processing step are collected. The particular form of the output data depends on the use of the data.

1.4. Expanded Cycle

Three more steps are added to the basic data processing cycle to obtain expanded data processing cycle shown as below:

```
Origination
     |
    \|/
   Input
     |
    \|/
Processing----------> Storage
     |
    \|/
   Output
     |
    \|/
Distribution
```

1.4.1 Origination-

This step refers to the process of collecting the original data. An original recording of the data is called a source document.

1.4.2 Distribution-

This step refers to the distribution of the output data. Recording of the output data are often called report documents.

1.4.3 Storage-

This step is crucial in many data processing procedures. Data processing results are frequently placed in storage to be used as input data for further processing at a later date.

1.5 Data Processing Operations and Concepts

A data processing procedure normally consists of a number of basic processing operations performed in some order. They are as follows:

1.5.1 Recording-

Recording refers to the transfer of data onto some form or document. It occurs not only during the origination step(on the source documents) and during the distribution step (on the report documents) but throughout the processing cycle.

1.5.2 Duplicating-

This operation consists in reproducing the data onto many forms or documents. Duplicating may be done while the data are being recorded manually, or it may be done afterwards, by some machine. On the other hand, one may record a sales transaction by punching the data onto a card, and may then duplicate the card using a duplicating machine.

1.5.3 Verifying-

Since recording is usually a manual operation, it is important that recorded data be carefully checked for any errors. This operation is called verifying.

1.5.4 Classifying-

This operation separates data into various categories. Classifying can usually be done in more than one way.

1.5.5 Sorting-

Arranging data in a specific order is called sorting. This operation is familiar in everyday life.

1.5.6 Merging-

This operation takes two or more sets of data, all sets having been sorted by the same key, and puts them together to form a single sorted set of data. When one deck is empty, the cards in the other deck are put at the end of combined deck.

1.5.7 Calculating-

This is performing numerical calculations on the (numerical) data.

1.6 Need for Automation

Data processing may be defined as any systematic procedure through which basic information is transposed into more accessible or more directly usable forms. It comprises editing and organising functions (detecting and correcting errors, classfying and indexing records, sorting and collating data prior to use etc.), carrying out necessary calculations and transcribing both data and results in prescribed format to a suitable storage and processing medium.

The data have first to be recorded at source, despatched to a collecting centre and finally distributed to the users. Nowadays data production and transmission are becoming so bound up with data processing, both on organisational and on the equipment sides, that it is sometimes difficult to differentiate between them at all clearly.

Throughout the world an immense amount and variety of meteorological data have been accumulated over the years. Moreover, the rate of production is rising steadely because of ever-growing demands both practical and Scientific, and because of the invention of new recording and observing devices. The old processing and retrieval problems remain and intensify while many additional applications and more searching statistical techniques have been evolved to deal with them.

Climatological information is a heritage which is not lightly to be discarded. However, no country need to process all the world's data. At most a selection, largely consisting of observations produced within its own frontiers, is required and after a time some condensation even of this may be possible. For the smallest countries "hand and eye" methods of processing may still suffice. Such methods, however, have for some years proved impractical and uneconomic for most countries where a measure of automation has been introduced, more usually through the agency of punch card machines. These in their turn are now being supplemented or supereseded in the largest countries by still more powerful and efficient techniques based on electronic computers.

1.7 Data Processing Systems and Centres

A few or many of the large range of data processing devices and machines are available can be variously combined so as to constitute a system designed to carry out one or more specific tasks, simultaneously or in succession. The combination may be a loose one comprising a number of independently operated units as in a conventional punch card installation; or it may be more rigid as in some of the smaller paper tape business accounting machines or electronic computers on which several different functional units are assembled together under single operator control.

By merely multiplying machines and operators, a large elaborate system capable of a heavy complicated schedule of work can be built up. But then, apart from considerations of space economy, the problem of management and control tend to grow disproportionately. Modern electronic data processing (EDP) systems are designed to overecome these difficulties by concentrating a number of highspeed ancillaries (printers, tape and card readers etc.) round a single central computer, capable of carrying out several functions and several programmes concurrently. The problem of utilising the extremely flexible resources of the system with max. efficiency, weather the work load is known well in advance or is largely unscheduled, is left to a "master" supervisory programme. Human intervention by way of maintanance, programme writing and console operating can not be eliminated, of course.

Although such systems vary considerably in size and can be expanded by degrees from quite modest beginnings, even the smallest are fairly expensive and their use presupposes a large workload concentrated at a data processing centre. The size and composition of any installation will depend also on where it is expedient to carry out the work.

2. DEVELOPMENT IN DATA PROCESSING

2.1 Introduction

From antiquity, man has invented devices to assist him in calculating and processing data. There are three types. A manual mechanical device is a single mechanism powered by hand. An electromechanical device is usually powered by an electric motor and uses switches and relays of the type found in household appliances. An electronic device, such as an modern computer, has its principal components transistors, printed circuits, and the like.

2.2 The Dark Ages (5000 B.C. - 1890 A.D.)

The earliest data processing equipment were all manual mechanical devices. We refer to the era when these machines were used exclusively as the Dark Ages of data processing.

2.2.1 Abacus (c. 5000 B.C.)

Probably developed in China, the Abacus is frame with beads strung on wires or rods. Arithmatic calculations are performed by manipulating the beads. The Abacus is still widely used in Orient. An Adept Abacus operator can calculate faster than a clerk using a desk calculator.

2.2.2 Napier's Bones (1617)

John Napier described this device in the year of his death. His "bones" are set of elevan rods with nos. marked on them in such a way that by simply placing the rods side by side products and quotients of large numbers can be obtained. Napier is best known for the invention of logarithms which is in turn led to the slide rule.

2.2.3 Oughtred's Slide Rule (c. 1632)

Although the slide rule appeared in various forms in Europe during the 17th century, its invention is attributed to the English mathematician William Oughtred. Basically a slide rule consists of two movable rulers placed side by side. Each ruler is marked off in such a way that the actual distance from the begining of the ruler are proportional to the logrithms of the numbers printed on the ruler. By sliding the rulers one can quickly multiply and devide.

2.2.4 Pascal's calculator (1642)

Blaise Pascal invented what may be considered the first adding machine. The device registered numbers by rotating a cogwheel gear by one to ten steps, with a carryover rachet to operate the next higher digit wheel when the given cogwheel exceeded ten units.

2.2.5 Jacquard's Loom (1801)

Jacquard invented the first punched card machine. The pattern woven by the Loom was determined by the placement of holes in a control card: only those threads whose guiding hook encountered a hole in the card could enter the pattern.

2.2.6 Babbage's Difference Engines (1823)

Only part of this machine was ever constructed. It is based on the principle that, for certain formulas the difference between certain values is constant. A machine of this type was later adopted by insurance companies for computing life tables.

2.2.7 Babbage's Analytical Engines

He followed the difference engine with a much deeper and more general conception . This machine never realised owing the limited technology of the time, would have contained many features of presented a computers, including punched card input, storage unit, arithmatic unit, printing unit, and control by a sequential programme.

2.3 The Middle Ages [1890-1944]

The Middle Ages of data processing are said to have begun when Dr.Herman Holleirth, a statistician with the U.S. Bureau of Census,completed a set of machines to help process the results of the 1890 census. Using 3 by 5 inch punched cards to record the data, he constructed a box to sort the data and a manually fed, electromegnatic counting machine to tabulate the data. The 1890 census was processed in one-fourth the time needed for 1880 census. In 1908, Powers patented a 20-column punching machine. In the same year Hollerith developed a vertical sorting machine which processed almost 200 cards per minute. In 1911, Hollerith developed a horizontal sorter whose rate was almost 275 cards per minute.

The speed and capabilities of punched card machines continued to improve. Verifiers were invented to check that the right data were entered into a single sorted deck. Electromechanical accounting machines were developed which could read cards containing both alphabetical and numerical data, perform simple arithmetic operations, and print the results.

2.4 The Modern Ages (Since 1944)

2.4.1 Mark I (1944)

Major innovation. The first computer capable of automatically performing a long sequence of arithmetical and logical operations.

The brainchild of H.G. Aiken, a professor of applied mathematics, the Mark I was built by IBM corporation. It was an electromechanical device, like the calculators which preceded it; subsequent computers were all electronic.

2.4.2 First-generation computers (1946-1959)

Major innovations. Vaccum tubes in place of relays; stored programmes.

The first large-scale vaccum tube computer, the ENIAC (Electronic Numerical Integrator and Calculator), was completed in 1946 by John Mauchly and Presper Eckert at Moore School of Electrical Engineering at the University of Pennsylvania. It could accomplish in one day what the previous computers took 300 days to perform. In 1947 the

ENIAC was moved to the Aberdeen Proving Grounds, a Government Research Centre, where it continued to operate until 1955.

In the mid 1940s, the famous mathematician John Von Neumann, together with H.H.Goldstine and A.W.Burks, developed the concept of the stored programme: the list of instructions(program) which controls the operation of the computer, coded in the same way as the input data, is initially stored in the computer alongwith the data, and then this program is executed automatically. The first computer to use the stored program was EDSAC (Electronic Delayed Storage Automatic Computer), completed in 1941. The first American computer to have the stored program feature was the EDVAC (Electronic Discrete Variable Automatic Computer), which was also built at the Moore school; it was completed in 1952. In the EDVAC, the computer program was fed into the data storage unit by means of a punched paper tape.

In 1946, Eckert and Mcuchly formed their own company, which in 1949 was incorporated as the Univac division of Remington Rand, Inc. In 1951, the UNIVAC I became operational at the Bereau of Census. This computer was self checking and used magnetic tape for data input and output. The UNIVAC I was run 24 hours a day until 1963; it is remembered for having predicted the election of D.D.Eisenhower in 1952.

Another UNIVAC I (this was the first computer to be produced in quantity) was put to business use (the first such application) by General Electric Corporation in 1954.

2.4.3 Second generation computers (1959-1965)

Major innovations. Solid state devices (transistors) in place of vaccume tubes; magnetic core storage.

In this period computers became much smaller in size, faster, more reliable, and much greater processing capacity. Built in error detecting devices were installed and more efficient means were developed to input and retrieve data from the computer. Also more efficient programming methods became available.

2.4.4 Third generation computers (1965-1970)

Major innovations. Integrated solid state circuitry; improved secondary storage devices; new input-output devices.

The new solid state circuitry increased the speed of computer by a fraction of 10000 over the first generation computers. Arithmatic and logical operation were now being performed in microseconds or even nanoseconds. In the third generation, the primary storage unit, or memory, of the computer was greately augmented by secondary storage devices located outside the computer proper. All this together with faster input and output devices, made possible multiprocessing and multi programming, whereby a number of data processing problems from different sources could be run virtually at the same time on a single centrally located computer.

2.4.5 Fourth generation computers (Since 1970)

Major innovations. Microprocessor; further improvement of mass storage and input -output devices.

A microprocesor which in itself is small computer capable of performing arithmatic and logical operations. Because of microprocessors, the fourth generation includes (i) large computers that are much faster less expensive, and of much greater data processing capacity than equivalent sized third generation computers; (ii) a multitude of relatively expensive mini computers; (iii) even further miniaturized computers, called microprocessors.

Among the advanced input-output devices employed in fourth generation computers are optical readers, by which all documents can be fed into the computer; audio response terminal by which an operator can vocally introduce data or instructions; and graphic display terminals, by which an operator can feed pictures into the computers.

2.5 Development of Computer Languages and Softwares

A computer language is the language which is used to write a programme for the computer. When first generation computers were introduced, programs were written in binary based machine language, which is the only language actually understood by the computer. Unfortunately, machine language is very difficult to use and varies from computer to computer. Second generation computers saw the introduction of assembly languages wherein symbolic codes were used instead of binary numbers. One then required an assembler program to translate assembly language programs into machine language. Even so, assembly languages were still too complicated for general use.

The late 1950s saw the development of FORTRAN (Formula Translation) and COBOL (Common Business Oriented Language). These are high level languages, in that they use symbols and words similar to those of ordinary arithmatic and English and are independent of computer on which the programme is to be used. FORTRAN has come one of the most popular languages for general Scientific applications, and COBOL the most popular language for general purpose business applications. Such high level languages require a compiler program which translates programs written in high level language into machine language.

Computer programs are of two basic types. Application programmes are the programs written to solve a particular data processing problem. They are usually written in a high level language by the party who wishes the problem solved. Operating system programs are the programs needed to operate the computer; they are usually supplied by the manufacturer. In second generation computers, operating system programs consisted many of assemblers and compilers. By the time third generation computers appeared, there was a need for manufacturer to provide the user with a varity of system programs. This included program which provided for efficient allocation of computer memory, control of input and output operations and supervision of the computer in a multi programming mode.

A more recent development in packaged programs. These are collections of application programs provided by the manufacturer or some software company, for certain standard computer applications such as payroll etc. The use of packaged programs allows the computer programmer to devote his energies to special applications unique to his company.

2.6 Careers in Data Processing

Data processing has developed into one of the major industries in this country, offering employment in the following categories:

2.6.1 Computer operators-

Handle the devices that feed data into and out of the computer. They are also responsible for keeping the Log books and doing other paper work related to these devices and for the supplies used with these devices. Computer operators usually study at vocational schools and then recieve the rest of their training on the job.

2.6.2 Computer maintanance personal-

They are responsible for on-site servicing on computer hardware. They are much more highly trained than the computer operator, first at a trade school or an Engineering college and then for atleast a year by the manufacturer of the equipment.

2.6.3 Computer Programmers-

They are mainly responsible for writing programs for the computer. Contrary to common belief, programming is a very technical field, and programmers usually have a college degree in computer science or a related field. In addition the programmer will need a year or two of on the job training.

2.6.4 System analyst-

They are responsible for the overall flow of information among the various departments of a large institutions. Working directly under Management, they organize the variuos data processing procedures throughout the institution and guide the programmers as to the type of progrms to be written.A system analyst usually a has graduate degree in either computer science or business management, in addition to several years of on the job training. Skilled analyst are in great demand and are highly paid.

2.6.5 Sales personnel-

Since the modern computer is a highly technical machine and its applications are complex in nature, computer sales personel will usually have a college degree in computer science, engineering, or in business management. The ability to interact in a positive manner with the people is an essential requirement for successful salesmanship. As always, there is a great demand for capable sales representatives.

3. DATA STORAGE AND PROCESSING MEDIA

3.1 Introduction

The data required for data processing have to be recorded on one of the available media in appropriate machine language for PC based data processing. In the conventional way, the data are recorded in field note books, field data sheets and charts and whenever demanded they are transmitted manually or automatically and supplied.

The punched cards, punched paper tape and magnetic tape are used extensively in data processing. Digital coded microfilms, magnetic tape, and punched cards are used for automatic data storage and retrieval. Manuscript records, autographic records, charts and printed paper documents are time honored media for the storage and retrieval of data. Recently equipment has been developed for automatic retrieval from autographic records and printed documents. To ensure better permanence and more compact, cheaper storage and reproduction, the practice of microfilming paper records has grown in importance.

An ideal medium should be : Durable and non-erasable, to ensure the permanence of the data; Flexible, to allow easy arranging,editing and modifying of the data; Versatile, to allow ready use for all purposes and by all means, from visual blowing and manual manipulation, through automatic processing by the entire range of data processing machines, and ; Compact, to allow accumulation and storage over long periods in manageable proportions and at reasonable costs.

3.2 Type of Records-

Records fall into the three broad categories discussed below;

3.2.1 Master records.

Contain data that are reletively permanent.

3.2.2 Detail records.

Contain data corresponding to a single transection or event.

3.2.3 Summary records.

They are those that summarise a number of detailed records; 'they are the records commonly used for reports.

3.3 Types of Storage Media-

Sequential storage media. In this media the records composing a file are sorted in linear fashion, one after another. One obtains information from a particular record by examining each record in the sequence until the desired record is reached. Accordingly for efficient processing a file should by sorted before being commiyted to the medium. The principle subsequential storage media are punched cards, punched paper tapes and magnetic tapes.

Random-access storage media. This media allow direct access to a particular record in a file without any examination of are used ,interchangebly in this context. The principle random storage media are magnetic disks, magnetic drums, and the memory of the computer.

3.4 Comparison of Digital Data Processing and Storage Media

Medium	Storage density characters/ cc	Archieval life and safety of data	Storage requirements
Punch cards	25	poor	compression
Paper tape	125-250	poor to fair	spools
Magnetic tape	6000-60000	fair	1. Spools 2. Magnetic shielding 3. Dust-free 4. Temp.and Humidity control
Microfilm	6000-30000	good	1. Spools 2. Dust-free 3. Temp.and Humidity control
Microfilm	30000-2000000	good	1. Spools 2. Dust-free
Printed Sheets	1000-2000	Fair to good	Little on none

Medium or Rolls	Speed (characters /sec.) Reading	Writing/ Punching	Advantages	Disadvantages
Punch cards	20-2666	20-333	1.Flexible 2.Input-output for all classes of machines	1.Wear & Age rapidly 2.Easily lost 3. Slow 4. Bulky & costly storage
Paper Tape	20-2000	10-1000	1.Data not easily lost 2.Cheap readers & punches	1.Inflexible 2. Slow 3. Wear & age rapidly if poor quality paper 4.Bulky storage

Medium or Rolls	Speed (characters /sec.) Reading	Writing/ Punching	Advantages	Disadvantages
Magnetic Tape	10000-300000	10000-360000	1.Flexible 2.High speed 3.Compact storage	1.Data Signals age & can be erased 2.Costly writing & reading equipment
Microfilm (digitally coded)	133-100000	10-30000	1.High speed 2.Compact storage 3.Long safe life 4.Cheap reproduction	1.Inflexible 2.Costly reading equipment
Microfilm (plain Language)	200-2000	10000-200000	1.Human readable 2.Compact Storage 3.Long safe life 4.Cheap reproduction	1.Inflexible 2.Read automatically only by slow 3.Costly equipment
Printed Sheets or rolls	200-2000	10-60000	1.Human readable 2.With good paper quality, long safe life	1.Bulk storage 2.Read automatically only by slow, costly machines

3.5 The 80-Coloumn card

One of the first and still a popular input output medium is the 80-coloumn or IBM cards. It measures 59/8" long by 13/4" wide by 0.007"thick. The coloumns are numbered 1 to 80 from left to right.

Each coloumn of the card contains 12 punching positions, which form 12 horizontal rows. The top row is called the 12-row, the next row is called 11-row, and they are numbered consecutively from 0-row to 9-row. The top three rows are called the Zone-punch rows, and the bottom ten rows are called the digit-punch rows. Thus the 0-row is both the Zone punch row and a digit-punch row. The top edge of the card is called 12-edge and bottom edge is called the 9-edge.

Each coloumn of the punched card can record a single character as a set of holes punched in the coloumn. A digit is represented by a single hole punched in its corresponding row. Each alphabatic character is represented by two holes, one punched in a zone row and one punched in a digit row. The special characters are represented by other combinations.

3.6 The 96-coloumn cards

A 96-coloumn card, was introduced by IBM in 1969. The card is smaller (2.63 by 3.25 inches) than the 80-coloumn card, yet it can store 20% more information.

A print area occupies approximately the upper 1/3 of the card and a punch area occupies the rest. The punch area is divided into three tiers, with 32 coloumn in each tier. Each coloumn in a tier contains 6 punching positions, forming 6 rows across the card. The top 2 rows of each tier called the A and B rows are the zone-punch rows; the last four rows, called the 8-, 4-, 2-, and 1-rows, are the digit punch rows.

Each colcumn in a tier records a character by having various holes in the coloumn punched. A digit is represented by punching the digit punch row or rows whose digits add upon to the desired digit. The alphabatic and special characters are recorded by holes in both the zone and digit rows.

3.7 Punched Paper Tape

One of the oldest input/output media is punched paper tape.- A continuous strip of paper about 1 inch wide. Characters are recorded on the tape by punching holes across its width. Depending upon its design, the tape has 5 or 8 punching positions, called channels.

Paper tape has never been as popular an input/output medium as the 80-coloumn IBM card. For one reason, the correction or insertion of a single character in the continuous strip is a time-consuming task. Also, paper tape lacks the durability and storage of the punched card. Infact, paper tape is being used less and less in data processing.

3.8 Magnetic Tape

Magnetic tape is widely used when large amounts of data are to be stored sequentially. The magnetic tape used with computers is similar to that used in home Tape recorders. Varying from 1/2 inch to 1 inch in width, it is made of plastic that is coated on one side with a matellic oxide which may be locally magnetised.

Data are usually recorded on the tape in either 7 or 9 parallel tracks (challels).

3.9 Magnetic Disk

Both punched cards and magnetic tapes share a disadvantage in that they are sequential -storage media. The records in a file have to be read one by one until a particular desired record is located; the access time for magnetic tape may be as much as 10 seconds. Magnetic disk, on the other hand , are a random access medium; a particular record in a file can be found directly. The access time for magnetic disk is less than 0.01 second.

A magnetic disk unit consist of 5 to 50 magnetic disks about 1/2 to 3 feet in diameter turned by a single drive shaft at speed upto 2400 rpm. Both surfaces of each disk are coated with a compound similar to that on a magnetic tape, on which the data are recorded. The most common design, for each side of each disk there is reading and recording head that moves in and out between the disk to locate itself next to spot on the disk where the data item is to be read or recorded.

A surface of a disk has 50 to 100 circular tracks along which the data are recorded. Usually data are recorded serially along a single track.

Each disk face is divided into a assigned number of sectors. A storage segment is a specific sector of specific track on a specific disk face. Storage segment will store 1 or several records of a file , depending upon the size of the records. Since each storage segment is uniquely identified by an address, a particular record can be directly accessed.

In some magnetic disk units each track has its own recording head. In this type of unit the record heads are fixed, reducing the access time even further. Also in some models the stack of disk can be removed from the shaft and replaced by a different stack. A removable stack of disk is called a disk pack.

A fourth innovation, called the Floppy disk, is similar to a 45 rpm record stored in an envelope. One disk at a time is placed in an input/output device where it is read or written upon. The storage capacity and access speed of a folppy disk are much less than those of a disk pack. However, the folppy disk is less expensive, easier to maneuver, and is quite suitable for the micro-computers.

The storage of disk unit varies from model to model, but a fixed disk stack can store upto several hundred million characters. A replacable disk pack can store upto 50 million characters, which is about the storage capacity of a reel of high density magnetic tape. A floppy disk can store about 600000 characters.

3.10 Magnetic Drum

A magnetic drum is similar in many respects to a fixed stack of magnetic disks. It is a rotatable whose surface is coated with a magnetically compound. The surface is divided into number of tracks, each track having one or more fixed reading and recording heads. As in the case of magnetic disk, data are recorded serially along the tracks

When a fixed recording head, no time is lost in moving the head, and so access time is negligible. Magnetic drums are commonly used when very fast access and transfer speeds are required.

3.11 Magnetic Strip

A magnetic strip is a plastic strip about 2 by 12 inches on which data are magnetically recorded. Ten of the strips make up a subcell, and twenty subcells are stored on a data cell drive. To read or record data on strip, the cell drive rotates to the subcell containing the strip. Then the drops out of the cell drive, moves under a read/wrute head where the selected record is read or recorded, and then is replaced on the drive.

4. DATA PROCESSING MACHINES

4.1 Punched Card Recording and Processing

4.1.1 Card punching machine

Punching data on to a card, called key punching is accomplished by means of a card punching machine. The list of various parts and their founctions are given as follows:

Key board. When a key is pushed the corresponding character is punched in the card. The key board also contains functional control switches, programme selector, auto feed etc.

Card hooper. It holds the blank cards(about 500 of the blank card). Cards should be put in the hopper with the 9 edge down and facing the operator.

Punching Station. Cards are fed from the card hopper into the punching station, where the data are punched onto them.

Reading station. When a card has been punched, it moves into the reading station. Here the data on the card can be read, and can be duplicated on to the following card in the punching station by depressing the duplication key.

Card stacker. Cards from the reading station are collected in the card stacker. Like the card hopper, card stackers can accomodate about 500 cards.

next to be punched.

Backspace Key. Depression of this key causes the card in the punching and reading stations to be backspaced one coloumn.

Programme control unit. In this unit a programme card, wrapped around a programme drum is used to instruct the machine to perform the operations of skipping, duplicating and shifting.

4.1.2 Verifier

Once data have been punched onto a card, it is essential that the card be checked for accuracy. This task can be done by means of a verifier, a machine which looks very much like a card punching machine. To verify a punched card, the operator feeds the card into the verifier and, reffering to the original source document, strike the same key as should have been struck when the card was orginally punched. If the holes in the coloumn of punched card do not corresponds to the character entered via the key board, the machine locks and a signal is given to the operator. The operator then checks the accracy of the punched card, and punches a new card if indeed there is an error.

4.1.3 Control Pannel

The punched card processing machines can process cards in more than one way. A specific task is programed by means of a wired control pannel that is inserted into the machine.

4.1.4 Reproducer and Interpretor

Reproducer. Since punched cards are subject to wear, one may want to reproduce a deck of punched cards. This task can be accomplished by means of the reproducer. Infact, the reproducer can be reprogrammed, by means of a control pannel, to punch all or part of the data from original cards onto other coloumns of the same cards or onto new cards. Besides card to card duplication, the reproducer can punch the data from a single master card onto a whole deck of detail cards. This process is called gang punching.

Interpreter. As it punches character data onto a card, the key punch normally prints the characters along the top of the card. On the other hand, the reproducers never print the characters that it punches in a duplicating deck. The interpreter is a machine that accepts a punched card and prints on the card the characters that were punched into a cards.

4.1.5 Sorter and collator

(i) Sorter. is the EAM which accomplishes arranging the records in some particular order. Actually a sorter sorts only one coloumn at a time.

Selection sorting. Here certain cards are sent to the corresponding pockets and all other cards are sent to the reject pocket.

Major, intermediate , and minor sorting. Frequmently cards sorting involves more than one field.

Block sorting. Large files of cards might take hours to sort. Rather than sort an entire file before bringing the cards to the next step in the data processing, one sometimes subdivides the file onto blocks and sorts the block at a time. This is called block sorting.

(ii) Collator. The collator is the EAM that merges two sorted files of records(combining the two files into one sorted file of records).

Collators have two input hoppers and several output pockets. The main property of a collator is that it can read two cards at a time and tell if they are punched identically, and if not, tell which precedes the other in some ordering. Thus it merges to numerically sorted decks of cards by reading the two first cards in the decks and sending the lower number to the recieving pocket.

Besides merging, a collator can perform;

Sequence checking. The collator can check if the cards in a sorted deck are in correct order by reading each two successive cards in the deck and seeing if the two cards are in correct order. Note that all cards except the first and last are read twice when the whole deck is examined.

Selecting. The collator can select from a deck whole cards with a specific property without disturbing the rest of the deck.

Matching. Given two sorted decks of cards, the collator can select any pairs of identical cards, one from each deck. This "matched cards" can either be sent to different pockets, or merged into one pocket.

4.1.6 Accounting and Calculating machines.

Accounting machines. The accounting machine is an EAM made up of three following units; the reading unit reads all part of the data on input cards and send this data to the calculating and/or printing unit. The calculating unit performs the opreations of addition and subtraction on the input data, and sends the result to the printing unit. The results may also go to a reproducer, to be punched on cards. The printing unit prints the data from the reading and calculating units in final reports, using print forms (pages) which are contineously fed into the machine.

Calculating Machine. The calculator can also peerform numerical calculations, but it can record its results only on punched cards, not on printer reports as can the tabulator. However, the calculator is superior to tabulator in two respects;

(a) the tabulator can only add and subtract, whereas the calculator can also multiply and divide.

(b) the tabulator can record its results on summary card, whereas the calculator can also record its results on the input cards themselves.

4.2 Punched Tape Machines

4.2.1 Keyboard perforators

The transcription to paper tape in the appropriate code is done on a key punch or key board perforator, as for cards; the equipment is more compact and is invariably electrically powered. Also the key board much more often comprises both alphabatic and numeric characters.

4.2.2 Tape readers and reperforators

Automatic tape readers or transmitters are motor driven devices for translating perforations on tape into electrical impulses. They may either be single wire, producing a single train of impulses in series, or multi wire for parallel reading, one wire per tape channel with possible additional wires for circuit control purposes. In general single wire tape readers are used for telegeaphic or tape editing applications at fairly slow speeds (less than 29 Ch/sec.) whereas multi wire readers are used with computers for which much faster speeds (100 ch/sec.) are required. Both may employee "strikers" or "peckers" for sensing the holes, but for the fastest speeds photoelectric seneing is necessary.

Reperforators automatically reconvert coded electrical impulses back into holes. They two are single or multi wire depending on the speed requirements. Linked to a reader directly or over a land line, they can be used to reproduce a tape. Fitted to teleprinters or accounting machines they can automatically capture data on tape for latter processing or rebroadcasting. They may be adopter to produce fully perforated or chadless tape, with or without interpretation. The fastest typewriting is done by printing rather than perforating, at speed upto 1000 ch/sec.

4.2.3 Tape verifiers.

With manually prepared tape one error may be expected to occur every 200-2000 characters. Some errors are noticed by the operator almost immediately they are made and can be corrected by back spacing until the wrong character is under the punches when it can be removed by means of an erase (all holes punched) character that computers and other automatic machines are designed to ignore.

To dect and eliminate errors later requires a more elaborate procedure and special equipment. A feature of tape editing is that the whole tape is remade irrespective of the number of errors that occur on it, whereas the cards only those containing mistakes are actually repunched.

4.2.4 Other facilities and devices

Although originally developed for the telecommunication field, punch tape units are increasingly being employed on non telegraphic applications. They may be attached to conventional machines of all sorts and in particular provide links to unable data processing system to be built. Card readers and punches are also being used in this way and both classes are used in association with computers, but of the two, punched tape ancillaries are cheaper and more compact.

This is particularly evident in a tape editing equipment which apart from punching and verifying may also serve for reproducing and tabulating, and a certain measure of collation is possible. Composite tape containing data from several tapes source can be made up, and this is practicable even with many fairly short segments. For more detailed and systematic collation, at higher speed special tape merging apparatus comprising two or more readers, one or more reperforators and the necessary electronic circuits for control and comparison will be required.

Tape is par excellence a continuous recording medium and random access to or sorting of data it contains is not feasable without the help of a computer. Althuogh there does exist at least one auotmatic retrieval device where by preselected items on a series of tape reels may be punched or printed out, a complete resorting by such means would be slow and uneconomic. Another rather devious way round this difficulty is to convert to card for sorting followed by conversion back to tape, using automatic converters. The later have many other uses.

4.3 Special and Peripheral equipments

A growing variety of equipments has been developed to operate in association with automatic data processing, (ADP) systems to provide linkage between otherwise incompatible systems. Essentially they are convertors of some kind and often have to be specially made or modified to suit particular applications.

4.3.1 Analogue to digital converters-

Digitizers accept the analogue output from observing instruments in the form of voltages, pressures, temperataures, shaft positions, rate counts, measurement of length or weight etc. This output is converted to digital forms for recording on cards or tape, in print or directly to line. The sampling rate may be as high as several hundred readings per seconds, and a range of different instruments may be tied through one or more convertors to a single recording unit.

4.3.2 Digital to analogue converters-

Numerical data may be required in graphical or line form. There are several automatic line drawing or graph ploting machines commercially available which accept digital inputs from cards or tape or directly from computers. Line drawing speed of 25 cm /sec. or more are not uncommon for mechanical plotters, andf a limited range of symbols may be plotted.

4.3.3 Digital to digital converters-

Converters of digital information from one medium to another (including microfilm) in any medium vary considerably and each converter may have to be specially adapted to its purpose.

4.4 Electronic Data Processing

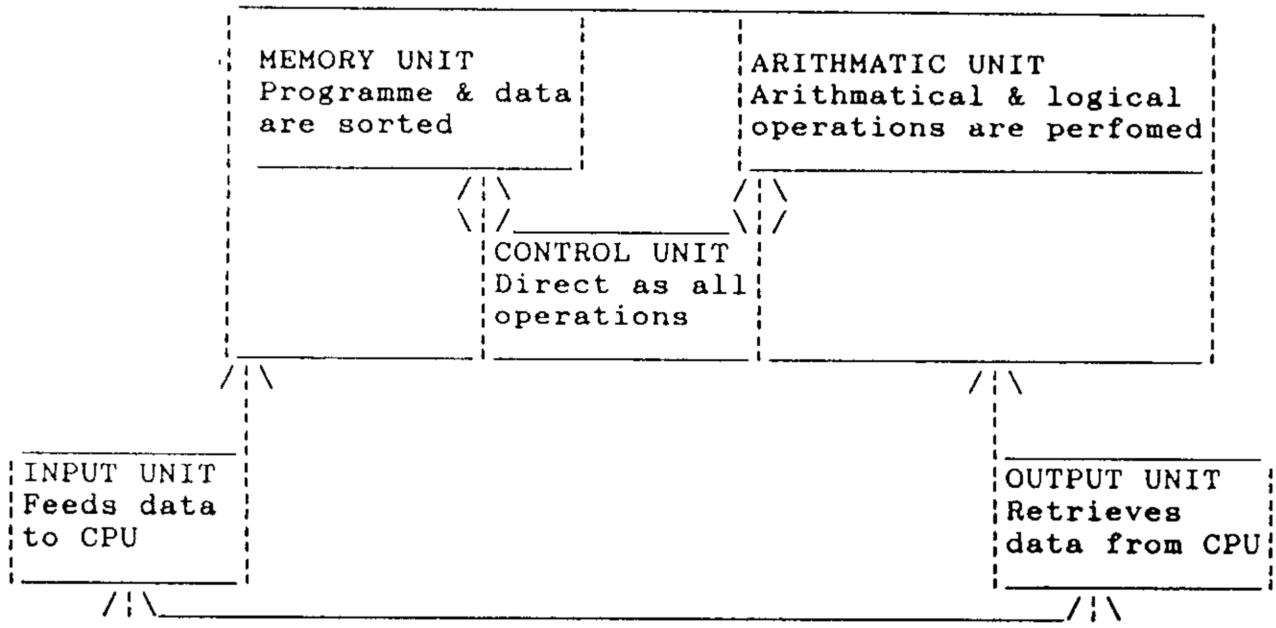
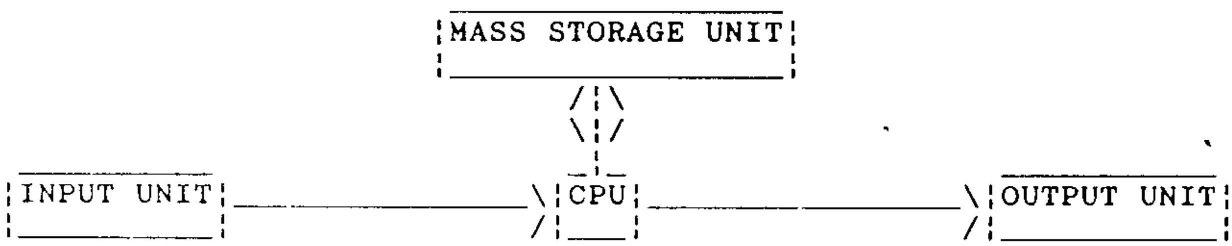


Figure 1 indicate the five basic components of the modern electronic computer. The memory unit is also called the primary storage unit. Together, the memory, arithmatic, and control unit make up the central processing unit (CPU), or processor. Sometimes the input and output units are collectively referred to as the input/output, or I/O, units.

In addition to the five basic units, a large computer will normally have one or more mass storage units, which input and output data that are stored in a compact medium such as magnetic tape or magnetic disks. The relationship between the mass storage units and the five basic components is pictured in fig.2.



Peripheral is the term applied to all devices that are connected to the CPU but are not part of the CPU. These include the I/O and mass storage devices, and other computer devices such as analog to digital converters. The collection of all peripheral equipment is called the computer configuration.

4.4.1 EDP systems

(i) The design and construction of digital computers are still a vigorously expanding technological field with an impressive variety of models at its credit. Improved components and logical designs have resulted in a large reduction in size, weight, power consumption and heat dissipation, and a large increase in speed, reliability and ease of operation. This is in turn has made it feasable to build large multipurpose EDP systems round a single computer.

All computers are now assembled from electronic "package" of high intrinsic reliability, on a building block principle. Thus on the few occasions when a fault in the computer does develop, it is merely necessary to trace the affected package which can be replaced in a matter of seconds so that normal working can be quickly resumed while the faulty component is repaired at leisure. Another advantage of this method of construction is that a minimum system may be acquired initially and extra capacity (memory and ancillaries) can be added as and when required with very little interruption of day to day working.

(ii) Quite small transistorised computers of limited capacity and little or no expandability are, however, also being produced. Logical and arithmatic speeds are more often in the milli second range, but they may be fast enough for many meteorological services. They are similar to the first computers to be produced in that only one programme at a time can be run on them, at least without a prodigious programming effort and prohibitive input and output restrictions. Most of them are able to operate several peripheral units, sometimes simultaneously and parallel with computing. Ususlly only the "slower" media punched tape, cards or possibly low density magnetic tape will be justified.

Although these small machines tend to be exclusively punch tape or punch card systems, there is no inherent restriction. In climatology a card or tape oriênted computer equipped with two readers, a punch and a printer would be capable of carrying out all the collating and sequential processing required, a task normally done by a much larger arrey of conventional card machines. Sorting, in the sense of grouping items or of a limited rearrangement of orderly data, can be done with very little internal storage but a large random sort would require a magnetic drum at least, and it may be more economic to punch and sort on cards for this class of data. Where there are international exchange obligations for card data an extra card punch would be necessary.

5. HYDROLOGICAL DATA TRANSMISSION SYSTEMS

For operational hydrology purposes the need for transmission of hydrological data has evolved from (a) the growing interest in and need for flood forecasting, warning systems and water management; (b) increasing demand, particularly in developing countries, for transmission of data from manned or unmanned stations for real time as well as archieval purposes; (c) expanding international exchange of subregional and inter-country data in common river basins. There is little apparent need in operational hydrology for the global exchange of observational data.

5.1 Automatic Transmission System

5.1.1 Collection of data

The collection of hydrological data is time consuming and basically a manual task. The vast majority of data i.e. relayed involves voice transmission, either by telephone or radio over the past quarter of a century, efforts have been made by countries to accelerate data collection. The increased use of telemetering was made possible by advances in and sensing and communication technology. Observing and recording of the elements pose problems for the acquisition process; transmission of the data from the sensor to the user was another problem. Sensors were designed with cams, coded discs, weighing mechanisms, potentiometers, shaft encoders, and other apparatus that would transform analog data into an electrical signal, permitting data to be transmitted from the remote sensor to a collecting office by hardware, telephone and radio.

5.1.2 Transmission methods

Some of the more commonly used transmission methods of hydrological services are listed below:

Direct wire

This system involves a hardware connection or dedicated telephone line between the sensor and the central read-out device. The read out device provides instant display of the sensor reading. An interrogator can also be used, programmed to interrogate automatically anyone station, group of stations or the entire network at a variety of time intervals. An interrogator can be a teletypewriter or small computer terminal. The system may accommodate more than one parameter at each site and can relate the data to another location.

Low voltage direct wire systems are used to relay water level recorder information from the gauging station to a convenient nearby location for ready access by the observer. The system have a good history of reliability. The observer generally uses other means, such as the telephone, to relay the observation over longer distance to a collection centre.

These systems are not costly and are relatively easy to maintain. They are particularly useful in a remote areas if the observer has a radio transceiver, whereby he can be in direct contact with a collection centre, relay point or forecast centre, depending on distance.

Direct dial telephone

This system utilizes commercially available telephone circuits. Either a manual, automatic dial or computer assisted dial system can initiate the outgoing call. Upon connection the observational site responds and transmits current observational data and any data held in memory if the station is so equipped.

With the availability of relatively inexpensive many computer systems, the use of commercially available telephone circuits provides a rapid means automating data collection directly at the observing site. This presupposes the availability of telephone circuits at or near the observation point and certain degree of reliability of the telephone system, particularly in periods of storms and floods.

This system involves a minimum of investment in communication equipment. The major components are a mini computer or specially configured tele typewriter at the collection centre or forecast centre and a communications interface at the sensor sites. Communication costs are the monthly tariff of telephone company and the maintenance of the line is their responsibility.

Line-of-sight radio

This system depends on VHF line-of -sight transmission (usually less than 50 km) and does not therefore require relay stations. Greater distances can be achieved if the remote stations are elevated such as on a mountain side.

The network of remote stations can be designed to initiate a transmission whenever an event occurs. The receiving station can be equipped to process the data or relay them to a central processor.

Line-of-sight radio systems are less costly than radio relay primarily because they are not dependent on relay towers but offer benefits as well as limitations. The benefits are that the system is not compromised by the possible failure of a relay tower facility through which all or parts of the data flow. One limitation is that transmissions are usually restricted to line-of-sight distances,generally less than 50 km. on level terrain. This approach, however, has particular value and application in relatively small basins where data may be collected from within the basin at a collection centre or the forecast centre.

Radio relay

This system features radio equipment that includes the use of high frequency, very high frequencies,ultra high frequencies and super high frequencies.

Super high frequencies are generally used where multiplexed channels are required for data transmission such as from an Earth command station to a Satellite. Ultra high frequencies are used between earth orbiting satellites and a data collection platforms as well as between relay stations.

In such a systems the computer initiates an identifying signal which is transmitted from the data control unit over a multi channel microwave link to a relay station. The signal is then carried over a VHF link from the relay stations, to repeater station and finally to remote reporting station.

The remote station responds to the proper identifying signal and transmits observational data to its assigned repeater station. The repeater station relays the data to the relay station and then to central control.

Radio relay provides a range of system to meet particular needs of users. This capability requires an extensive maintenance program of electronics technicians either in- house or under contract with a radio maintenance company where UHF and SHF are employed such as with computer controlled interrogation systems. Both VHF and HF are used in the basic collection of data and are the least expensive radio systems.

Satellite

Two types of satellites are employed for data collection: polar orbiting and geostationary. A polar orbiting satellite circles the earth once about every 90 minutes and is therefore available for use as a relay station only while passing overhead with in view of the earth platform. A geo stationary satellite is in a fixed location in space relative to the earth above the equator and as it always views the same area of the earth is therefore available for continuous data relay. Smaller antenna and less power are required to transmit data to a polar orbiting satellite because it is closer to earth (about 1000 km altitude). A larger antenna and more power are required to relay data to a geostationary satellite because of its higher altitude (about 30000 kms.).

Two basic types of data collection platform radio sets are most commonly used with geostationary satellite interrogated and timed. With the interrogated type a call up demand can be initiated. With the timed platform, reporting intervals are preselected and remain fixed at the site until changed. All data collection platforms communicate with the satellite in the UHF band.

Data are received directly at the central read out facility and may be relayed over other communication facilities to various users.

Meteor burst

Meteor scatter, or more commonly, Meteor burst communications rely on the ionization in Meteor trails to re-radiate or reflect radio waves in the low VHF frequency range for distance upto 2000 kms.

The Meteor trial characteristics dedicates the techniques for utilizations of the medium as a communication path. As these Meteor trials only exist for a few seconds, a burst (very short) transmission mode must be used. Also, the availability of ionized meteor trails varies with the time of day and month of the year, requiring proper selection of operating frequencies.

The Meteor burst transmission system consist of two master poling stations plus the remote stations where the hydrological observing sites are located. The master station can be linked to a central computer over dedicated telephone circuits if required. The system can operate unattached and interogating can be made for any one remote station or group of stations.

5.2 Requirements for Hydrologic Data Transmission

5.2.1 Long term needs

It is anticipated that present day techniques of data acquisition and transmission will be inadequate to meet the needs for services expected from organizations in the next decades. For a newly established service where flood warning are the only immediate demand to be satisfied, rainfall reports following heavy rains may be quite adequate for many years. However, demands will steadily increases requiring definition of the complete hydrograph expanding to extended outlooks for weeks in advance. Requirements for river rainfall, and related data will grow to the point at which the observation and data collection system is inadequate. Daily reports will not define a hydrograph except on the largest of rivers. Multiply this by other demands for data concerning irrigation, navigation, power reservoir regulation, and population abatement where hrly. data are often needed, and a full hydrological service organization will have evolved. Many of the longer term needs make use of satellite imagery and related technology.

5.2.2 Special requirements

Extremes in the hydrological cycle- too much or too little water at a given time and place- produces the long term disasters of drought and the seasonal disasters of flooded river valleys. Data transmission systems are vital to monitoring and predicting these events.

One of the prime requirements of a national hydrological service is an adequate network of observing stations to provide data and on elements that characterize the physical environment of the basin and are vital to the river, flood, and water supply forecasting and advisory services. Types of data collected vary with climate, geographical location, season of year and other factors but may include any or all the following parameters:

1. amount, character, and time of occurrence of precipitation;

2. elements determining rate of snow melt and evaporation- solar radiation, air temp., humidity and wind;
3. areal extend and water equivalent of snow cover;
4. river conditions-gauge height, tendency, rate of rise or ice cover, reservoir outflow, etc.

As an integral part of data collection, a radar surveillance is being used increasing to determine areal extent and intensity of rainfall. Use of radar greatly enhances conventional observations and, in many instance, provides the only observation of precipitation. The use of satellite-derived imagery is also being studied for operational hydrological application, particularly for better determining precipitation conditions and the extend of snow cover in addition to data collection. These data need to be considered in data transmission planning.

5.2.3 Data transmission in support of operations of a hydrological service

In operational hydrology it is essential that information be received speedily and in a coordinated fashion. For real time forecasting, data must be received in real time. Real time users are those operations where the information must be received and/ or processed within a few hours. Hydrological data transmission in support of operations concerns real time requirements.

If the basic levels of the systems were categorized, they might be grouped as follows:

a) manual;

b) mix of manual and semi-automated;

c) semi-automated (man/ machine mix);

d) semi-and fully automated;

e) fully automated (computer controlled);

f) a combination of any of these.

Undoubtedly, there are numerous sub-categories and combinations of these arbitrary levels. One area not mentioned, but of major consideration, is the size of the network and environmental extremes under which such networks must operate and maintenance of the sensors and the telecommunication equipments- the large the system and more severe the weather extremes, the more costly the original system and its maintenance.

5.2.4 Coordination of meteorological and hydrological data transmission

There is an increasing need in meteorology and hydrology for automatic observing stations at manned and unmanned sites, particularly where the two disciplines have common elements to be measured. In some countries, where there are combined hydrological and meteorological services, hydrological and meteorological data are exchanged on common communication network. In other countries the exchange of hydrological data is quite distinct from the meteorological telecommunication system.

In addition, processed meteorological observational data available under the WWW have application in hydrological forecasting. Similarly, meteorological forecasts are an important input for hydrological forecasting. Here, the problem of communication arises in ensuring that this information can be made available for day-to-day operations. While forecast of specific elements may be available from the meteorological centres, the most important feature is often the interpretation at the national level of prediction charts from these centres in terms of the expected occurrence, intensity and duration of weather elements. Hydrological forecasting offices need meteorological warnings and forecast, calling for communication links between these offices and weather forecasting offices. It is considered that the whole question of coordinating hydrological and meteorological communication systems is worthy of detailed examination primarily at the national and regional.

It is not unusual for imposed problems to be the impetus required to set needed change in motion. Similarly, new methods and techniques of observing and forecasting can bring about change. Primary among these will be the introduction of new procedures for data observation and forecasts such as:

a) radar estimated rainfall in digital form for specified basins;

b) satellite -derived digital data;

c) hydrological models for forecasting streamflow.

These data will create new or additional demands for computers and automated data acquisition systems to maintain effective and efficient operations. Similarly hydrological sensors will be designed to interface with a wide variety of telemetering devices. In countries where telemeters or computers have not been introduced for lack of resources or need, careful consideration should be given to planning improvements. Actual need, including the time line of the data, must be defined to help in deciding the most cost effective system. Consideration must also be given to real time as opposed to non real time data need and to manual as opposed to computer reduction of data as this consideration affects hydrological instrumentation requirements in several ways.

5.3 Use of Global Telecommunication System (GTS) for hydrological data transmission

The GTS primarily provides the telecommunication facility and arrangements for the rapid and reliable collection, exchange and distribution of the required observational data particularly from the Global Observing System (GOS), and also for processed information available from the World Meteorological Centres (WMC) and regional meteorological centres (RMC) operating within the Global Data Processing System (GDPS) of the World Weather Watch (WWW). Thus the GTS would meet the need of members for optional purposes and those research purposes which necessarily involve the exchange of information in real time. The GTS also gives telecommunication support for the implementation of all other environmental programmes in so far as its principle objectives allows.

Meteorological and environmental satellites can be expected to perform an increasingly important role within the GTS. Data collection platforms (DCP) will constitute an integral part of the GTS for collection of inside observation from fixed and mobile platforms. Further more, the low resolution analogue direct broadcast channel of geostationary satellite, known as WEFAX, is an important part of the GTS for the distribution of pictorial information directly to users. Therefore, both the data collection and distribution capabilities of meteorological satellites will be integrated into the GTS, as far as possible.

The GTS is organized on three levels:

a) the main trunk circuit (MTC) and its branches;

b) the regional meteorological telecommunication networks;

c) the national meteorological telecommunication network.

5.4 New Technologies for Hydrological Data Transmission

5.4.1 Satellites

The WWW space based subsystem includes 6 geostationary satellites, some of which are fully operational. The satellites have a data collection capability facilitating the collection of observational data from ships, island stations, ocean buoys and other platforms. Furthermore, the satellite provides a data relay facility for the broadcasting of processed information in pictorial form. The near-polar orbiting and geostationary satellites also form part of the integrated global observing system to provide reasonably complete coverage of the world taking observations between about 50 degree North and 50 degree South on a near continuous basis by day and night.

Geostationary operational environmental satellite (GOES)

In some countries, the use of satellite data collection systems may be as important or perhaps more important than remote sensing for hydrological purposes. Techniques for using geostationary and polar orbiting satellite communication system to collect ground based meteorological and hydrological data have been developed and field tested. Data received from these sensors telemated to fixed data acquisition sites. Requirement for rapid, broad scale disseminations of data may increases if satellite systems are used widely for data collection.

The DCS includes a command and data acquisition station (CDAS), the space craft which collects information from radio equipped data collection platforms and confirms to the applicable standards and regulations established by the international telecommunication union(ITU). The use of DCS is limited to the acquisition of environmental data defined as observations and measurements of the physical, chemical or biological properties of the oceans, rivers, lakes, solid earth, and atmosphere (including space).

Design characteristics of the DCS on the space craft require that user conform to specific technical standards. An arrangement is required that includes statements as to

(a) a period of time of the arrangement is valid and procedures for cancelling it.

(b) conformity with ITU agreements and regulations;

(c) required equipment standards;

(d) standards of operation;

(e) properties for use ;

(f) reporting time and frequencies;

(g) data formats;

(h) data delivery systems and schedules;

(i) user-borne costs.

Geostationary meteorological satellite (METEOSAT)

The METEOSAT project was conceived to meet the requirements of the European meteorological community and to constitute Europe's contribution to the global atmospheric research program and in particular to the first GARP global experiments (FGGE) and the WWW program of WMO.

The ARGOS system

In addition to the GOES and METEOSAT geostationary data collection system experiences, users have reported on the polar orbiting TIROS-N satellite with its ARGOS systems.

The ARGOS on-board data collection system is equipped to receive data transmitted by DCPs (fixed or moving) within the satellite's radio viewing range. Data are received on a random access basis. Under this arrangement the DCP in effect transmits its signals continuously (about every 100 to 200 seconds for fixed DCPs). As each message is acquired the time and the data are recorded, the DCS measures carrier frequency a demodulate the platform identification number and sensor data.

These data are then formatted and stored by one of the on board magnetic tape recorders. Each time the satellite passes over the telemetry station, the data recorded on tape are read out and transmitted to the ground receiving station. All DCPs transmit on the same frequency (401.650 MHz). Duration of the message is less than one second.

The space craft transmits data in real time on 136.770 or 137.770 MHz. Users can receive sensor data from platforms at the time of transmission by providing a demultipexing and reconstruction program.

5.4.2 Meteor burst

A Meteor burst communication system is designed to use the ionized Meteor trials in the upper atmosphere as reflectors to transmit digital data intermittently over non-line-of-site paths up to 2000 km long.

A Meteor burst communication system must take into account the characteristics of Meteor trials. Some of this characteristics include diurnal and seasonal fluctuations, density, duration and length of the trials.

Master station

The master station consists of a transmitter, receiver, duplexer, antenna, and a processor. A call-up message on a frequency in the VHF band is initiated to call remote stations. The master station can call any remote station or group of remote stations on command. In addition, the system can be instructed automatically to perform system-wide calling daily in the absence of other instructions and store data on line as a back-up feature in the event that land line outages prevent the forwarding of data. The master station can be computer controlled and commanded over telephone circuits for unattended operation. The master station transmitter power output may be as low as 100 w but other systems indicated that power requirements of

1000 w or higher may be needed, depending on weather one antenna for one quardarent coverage is used or four antenna for 360 degrees coverage are used.

Remote Station

The occurrence of a Meteor trail in the correct geometric orientation, and of sufficient duration to allow the remote station to recognize its signal and transmit its data, is a random event. In the worst case, successful calling of a particular site can be expected to occur several times an hour, assuming the remote station is probed continuously. When a path has been established between the master station and the remote station, the remote station replies in the VHF band. Response time is about 100 ms. The remote station is controlled by a timer which activates the station at a predetermined time following a call-up message transmission.

The antenna system is a YAGI array, horizontally polarized , and vertically mounted. The antenna has a wide horizontal and vertical beam-width. Frequency shift keying (FSK) modulation is employed and the data are transmitted to BCD format at a clock rate of 2000 bit/s.

The number of times a day the remote station transmits a data message is determined by how often a valid call-up message is received and decoded by the remote station. The remote stations can be powered by batteries charged by solar panels. System design permits operation for up to a year without servicing depending on the type and variety of sensors employed.

System applications

The Meteor burst telemetry technique has many features which make it uniquely responsive to remote environmental requirements. The long range paths which it creates will allow coverage of vast areas. Also, the use of Meteor trials for signal reflection creates an ultimate number of potential paths for transmission. This minimizes, and in most cases eliminates, blockage problems due to terrain obstacles. Meteor burst also affords greater flexibility from the stand point of expanding the data site population. The addition of a site requires only the installation of the remote station equipment and the updating of computer tables in the master polling station. No hardware changes of any kind are required.

Another facet of the Meteor burst technique is that it allows complete control over which stations are probed at which times. This control is effected by governing the scheduling and content of the master station probes.

The overall reliability of the system can be enhanced by the use of two master stations. Drying an outage of either master station, the system will collect data from all data sites, although significantly less efficiently. The second purpose of two master stations is to provide better quality paths for communication. In cases where a data site location is disadvantageous relative to one master station, the other master station, or a combination of both master stations, will then yield the desired performance.

Data gathered show that Meteor burst is suitable for hydrological data acquisition from remote location. It may provide significant economic benefits, especially where conventional line-of-site radio links would require one or more repeaters. Some refinements and modifications to the prototype hardware must be accomplished before it may be considered a suitable operational system.

6. HYDROLOGICAL DATA PROCESSING

Hydrological data processing is related to well established principals of hydrodynamics and thermodynamics. The central problem is the application of these principles in a natural environment which is irregular,sparsely,and only partially known. The event samples are usually unplanned and uncontrolled. Analysis are performed to obtain average aerial values of certain elements, regional generalization, frequency distribution, and relationships among variables, often the potential elements are not or cannot be measured directly.

Evaporation from a lake is an element which cannot be measured directly,it cannot be caught in gauges,nor concentrated in a channel as with streamflow. The problem of aerial sampling is exemplified by estimating rainfall over a drainage area where only a small portion is caught in gauges and actually measured. The problem is to interpolate the rainfall between gauges. In relating rainfall to runoff, the hydrograph of runoff is divided into components, so that the portion associated with a particular rain event is repeated from the rest of hydrograph. The separation is achieved by computation based on analytical models rather than by a physical measurement.

The analysis,therefore,includes:

(i) Hydrological data storage & retrieval system for the data collected from the network of the representative catchment.

(ii) Network design for a representative catchment.

(iii) Use of remote sensing techniques for estimation of geomorphological parameters.

(iv) case studies & statistical examination of masses of data, which include fitting of data to frequency distribution and to theoretical models by regression or time series analysis methods.

(v) Evaluation of control measures.

(vi) Development of PC based software for data processing .

(vi) Estimation of different components of water balance.

6.1 Processing of Precipitation Data

The precipitation data usually, in its raw form would contain many gaps and inconsistent volumes. As such preliminary processing is essential before it is put to further use in analysis. The methodology of executing the various steps involved in the analysis are briefly described.

6.1.1 Preliminary scrutiny

The reports received from manually observed stations by telephone or other communication channels are checked by repeat back system. Improper registering of data includes entering data against wrong time & date, alteration of figures, etc. The official at receiving station could check the reasonableness of report by judging the report base on past experience and statistics of the station &region to which the station belongs.

6.1.2 Quality control

It is essential to guide, correct errors in the observational data of the earliest stage. The errors could be classified as systematic errors and random errors. Systematic errors are essentially due to malfunctioning of instrument, wrong exposure conditions and /or lack of knowledge of observed data. Random errors could arise due to spilling of the water when transferring it to the measuring far, leakage into or out of the receiver, observational error, etc.

6.1.3, Data validation

Data validation could comprise following steps:

(i) Flagging suspect values by absolute range check for the individual series.

(ii) Flagging suspect values by relative range check using.

- -Comparison of data in tabular summaries of selected stations.
- -Plotting of data of neighboring stations.
- -Comparison of values for the station under investigation with its near neighbors equally distributed in space.

(iii) Checking the long term rainfall stations consistency by double mass plots.

6.1.4. Filling in missing data

Data for the period of missing rainfall data could be filled using estimation technique. The length of period up to which the data could be filled is independent on individual judgment. Rainfall for missing period is estimated either by using the Normal Ratio Method or The Distance Power Method.

6.1.5, Adjustment of data

To obtain homogeneity among & within measurement of precipitation, adjustment becomes necessary, Adjustments for these errors is made by "Double Mass Analysis.

6.1.6. Data computation

Analysis of rainfall data after includes the determination of -

(1) For daily series: Daily maximum & minimum values' total per month & year 'the date of occurrence of the extremes as well as the number of wet or dry days;

(2) For monthly and annual series 'basic' statistics' extremes and fractiles

Apart from analysis of point rainfall also aerial rainfall is investigated computed catchment or sub catchment wise. Numerous methods of computing aerial rainfall from point rainfall have been proposed. The most commonly used methods are:

(i) Arithmetic mean method,

(ii) Thiessen polygon method,

(iii) Isohyetal method,and

(iv) Quadrant characteristics method,

For studies of short duration events the regular time series(Mass curve) produced from recording raingauge data must be used. It is obvious that the time interval selected for producing this time series should be compatible with the duration of interest.

6.2. Processing of Streamflow Data-

Design, planing & hydrological modeling are some of the important aspect of the water resources projects where the streamflow data are utilized in one form or other.

The time interval between successive readings depends on the flashiness of the stream and hence varies with location and river runoff.

Generally the streamflow data are required in the following forms for different hydrology studies:

1. Instantaneous discharge (every day or smaller units)
2. 3 days, 10 days, monthly seasonal & yearly mean discharges,
3. Annual maximum flow,
4. Annual minimum flow,

The length of data for use in hydrological stimulation studies varies from 10 years to 40 years depending upon the type of project & their use.

6.2.1. Type of errors

Errors involved with staff gauge readings generally are of the following kind:

(1) Sudden shifts in gauge zero, due to resetting of the gauge without leveling,

(2) overlap between subsequent element due to resetting of the gauge without leveling.

(3) Overlap between subsequent element due to subsidence on one of the elements.

(3) improper scaling due to starting of the staff gauge.

(4) Observation errors often due to missing meter-marks.

(5) Gauge overtoppings.

6.2.2. Validation of data.

It includes;

(1) Inspection and updating of the gauge history

(2) Plotting of bar charts.

(3) Range and rate of change checks.

(4) Plotting of time series.

(5) Plotting of water levels.

(6) Plotting of relation curves.

6.2.3. Filling in missing data.

After the removal of the errors, data gaps could be filled in based on;

(1) Interpolation between reading before and after,

(2) Relation curve determined by regression analysis'

(3) Random choice from values observed for that period,

(4) Correlation with adjoining station either of the same hydrologic element or different hydrologic elements,

(5) Auto correlation with earlier period at the same station

(6) Rainfall-runoff simulation.

(7) Dynamic flow models.

6.2.4. Data processing

Specific tests in data processing includes;

(1) Calculation of mean velocity and discharge based on stream gaugings.

(2) analytical fitting of stage-discharge relations, Preparation of regular time-series containing monthly tables of hourly values with means and extremes; annual tables of hourly values with means and miscellaneous graphs showing variations with time.

(3) Preparation of chronological tables with elementary statistical parameters, daily data tables for spatial comparison, multi annual summary tables of monthly and annual value with elementary statistical parameters, discharge classified into ranges and probability envelope curves and characteristics discharge and probability envelope curves,etc.

The following analysis are normally performed with the processed data;

(1) Computation of flow duration curves,

(2) Computation of summation & regulation curves,

(3) Computation of natural runoff from a regular reservoir,

(4) Computation of the inflow to a reservoir,

(5) Routing of flood through reservoir or river, channels,

(6) Unit hydrograph analysis

(7) Flood forecasting

(8) Low frequency analysis

(9) Computation if flow frequency curves,

(10) Analysis of flood or bow water analysis,

(11) Multiple linear regression analysis,

(12) Time series analysis.

6.3. Processing of climatological data-

A large number of climatological data is generally collected;

(1) Daily evaporation from class A pan or from piche's eveporimeter.

(2) Wet and dry bulb temperatures at selected hours,

(3) Pan water & air temperatures at selected hours

(4) Minimum and maximum temperature at selected hours

(5) Pan water & air temperature at selected hours

(6) Soil temperature at selected hours at various depths ground level

(7) Daily windrun from anemometers and wind direction

(8) Short wave radiation

(9) Sunshine duration from sunshine records

(10) Air pressure

(11) Relative humidity

6.3.1. Data validation

It is noted that validation of climatological data by method of intersection,comparison may not be possible in many cases because of the scarcity of the climatological station network. Thus the basic validation techniques applied are range checks, rate of change checks and, of particular importance, consistency checks between related parameters observed at the same site i.e. using plotting techniques. For all climatological data, station & parameter codes should be tested for validity &, where relevant, sensor calibration values and ranges should be output with suspect values.

6.3.2 Data processing

First step in processing of climatological data is to derive average values, usually on a daily basis, for temp., relative humidity, vapor pressure and for some indirect evaporation techniques, the slope of the vapor pressure curve. An important derived factor is the degree day index, the accumulated departure of temp. from a standard reference temp.. The psychrometer constant for the station should be stored in the station description file. Average daily wind speed must also be calculated, or wind run obstructed from integrated totals. These are several climatological parameters which need to be transformed to standard condition for storage and/ or application.

Where direct measurement techniques are used, the computer may be used to verify evaporation estimates by checking the water levels (or Lysimeter weights), and the water additions/ subtraction recorded. Estimate of evaporation (and evapotranspiratiion) should be made over time intervals of sufficient length to minimize heat flux errors.

6.4 Processing of sediment data

Many of the cross section plotting techniques for the gauging are directly relevant to suspended sediment data validation. The two sets of data may be validated together if both sediment and velocity observations were made.

The mass balance calculations may be performed if sufficient quantities of data exists. A useful check where catchment are reservoir is to test that rivers sediment loads within a responsible distance downstream of the reservoir are less than those upstream. If a sediment rating curve exists for section sampled, that departure of the sampled value from curve may be estimated for statistical significance and / or plotted for manual sorting.

6.5 Analysis of Snow and Ice Data

The snow data may be validated alongwith rainfall data even if the water equivalent of falling snow caught in the raingauges, but other snow and ice parameters are more difficult to handle. Data on the extent of snow cover may also be validated by a time consuming manual synthesis of field observations, aerial survey data and satellite imagery. Techniques to perform automated interpretation of satellite imagery for snow extent are being developed. But there are still problems of differentiating between snow and cloud cover, and of insufficient image resolution.

Snow depth and water equivalent data again demand much manual validation and verification, integration from snow courses, snow gauges and conventional precipitation gauges. The large spatial variation in snow cover makes inter station comparison difficult. However, there are techniques to estimate the statistical reliability of snow course observation. Under condition of melting snow, degree day functions are widely used for correlation purpose and, where snow melt represents a significant proportion of river flow, established relationship between runoff and snow water equivalents may be used. Air and water temperature relationships are valuable not only for the computation of the degree day factors, but are also used for assisting in the validation of ice cover and thickness data, and in the forecasting of ice formation and breakup data.

7. DATA PROCESSING FOR REMOTE SENSING DATA

Remote sensing is the art and science of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation. In other words, remote sensing is the observation of a target by a device separated from it by some distance. Thus, it is contrasted with insight sensing, in which measuring devices are either immersed in, or atleast touch, the objects of observation and measurement. Instruments placed in inaccessible locations or are connected to central data processing facilities by automatic data acquisition at a transmission links cannot be treated as remote sensors. While no such type contact exist between a remote sensors and its target, some physical emanations from, or effect from , the target must be found if aspects of its property and / or behavior are to be investigated. The most important of the physical links between objects of measurement and remote sensing measuring devices involve electromagnetic energy, acoustic waves and force fields- especially those associated with gravity and magnetism. For most surface and atmospheric remote sensing, electromagnetic energy is the supreme medium.

7.1 Process and Elements

The two basic processes involved in electromagnetic remote sensing of earth sources are data acquisition and data analysis. The elements of the data acquisition process are ; energy sources, propagation of energy through the atmosphere, energy interaction with earth's surface features, air borne and or space borne sensors, resulting in the generation of sensor data in pictorial and / or numerical forms. In short, the sensors are used to record variations in the way earth surface features reflect and emit electromagnetic energy. The data analysis process involves examining the data using various viewing and interpretation devices to analysis pictorial data and/ or a computer to analysis numerical sensor data. Reference data about the resources being studied, such as soil maps, crop statistics, or field check data are used when and where available to assist in the data analysis. With the aid of the references data the analyst extracts information about the type, extent, location, and condition of the various resources over which the sensor data were collected. This information is then presented generally in the form of maps, tables and written discussion or report. Typical information products are such things as landuse maps and crop area statistics. Finally, the information is presented to users who apply it to there decision making process.

7.2 Digital Image Processing

Digital image processing involves the manipulation and interpretation of digital images with the aid of computer. This form of remote sensing actually begun in 1960s with a limited number of researchers analyzing air-borne multispectral scan of data and digitized areal borne multispectral scan of data and digitized areal photographs. However, it was not the launch of Landsat -1, in 1972, the digital image data became widely available for land remote sensing applications. At that time not only was the theory and practice of digital image processing in its infancy, the cost of digital computers was very high and their computational efficiency was very low by modern standards. Today access to low cost efficient computer hardware and software is common place and the source of digital image data are many and varied. These sources range from commercial earth resource satellite systems, to the meteorological satellites, to air-borne scanner data, to air borne solid state camera data, to image data generated by scanning microdensitometer and high resolution video camera . All of this forms of data can be processed and analyzed.

Digital image processing is an extremely broad subject and it often involves procedures which can be mathematically complex. The central idea behind Digital image processing is quite simple. The digital image is fed into a computer one pixel at a time. The computer is programmed to insert these data into an equation, or series of equations, and then store the results of the computation for each pixel. These results form a new digital image that may be displayed or recorded in pictorial format or may itself be further manipulated are literally infinite. However, virtually all this procedures may be categorized onto one of the following for broad types of computer assisted operations.

7.2.1 Image rectification and restoration.

This operation aim to correct distorted or degraded image data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometerically, to eliminate noise present in the data. Thus the nature of any particular image restoration process is highly dependent upon the characteristics of the sensors used to acquire the imaged data. Image rectification and restoration procedures are often termed preprocessing operations because they normally proceed further manipulation and analysis of the image data to extract specific information.

7.2.2 Image enhancement

These procedures are applied to image data in order to more effectively display or record the data subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in a scene. The objective is to create" new" images from the original image data in order to increase the amount of information that can be visually interpreted from the data. The enhanced images can be displayed interactively on a monitor or they can be recorded in a hardcopy format, either in black &white or in color. There are no simple rules for producing the single best image for a particular application. Often several enhancements made from the same"row" images are necessary.

7.2.3 Image classification

The objective of this operation is to replace visual analysis of the image data with quantitative techniques for automating the identifications of features in a scene. This normally involves the analysis of multi spectral image data and the application of statistically based decision rules for determining the land cover identity of each pixel in an image. When these decision rules are based slowly on the spectral radiance observed in the data, we refer to the classification process as spectral pattern recognition. In contrast the decision rules may be based on the geometrical shapes, size and patterns present in the image data. These procedures fall into the domain of special pattern recognition. In either case, the indent of the classification process is to categorize all pixels in a digital image into one of the several land cover classes or "themes" . This categorized data may then be used to produce thematic maps of the land cover present in an image, and / or to produce summary statistics on the area covered by each land cover type.

7.2.4 Data merging

These procedures are used to combine image data for a given geographic area with other geographically reference data sets for the same area. These other data sets might simply consist of image data generated on other dates by the same sensor, or by other remote sensing systems. Frequently, the indent of data merging is to combine remotely sensed data with other sources of information in the context of a geographic information system (GIS).

7.3 Indian Remote Sensing (IRS) Mission

An optimum and effective management of natural resources calls for through and routinely updated information about the environment and associated dynamic phenomenon. Recognizing the potentials and importance of systematic and periodic environmental data collection using space instrumentation, in Indian Space Research Organization (ISRO) has conducted the variety of extensive and intensive nature of activity in the last decade using areal flights and experimental satellite missions like Bhaskara I and II, besides interacting with various user agencies in the form of joint experimental programmes.

The experience gained in conceptualizing and implementing a space based remote sensing system with necessary exposure to ground based data reception, processing and interpretation system through the LANDSAT series of satellites paved the way for initiating the IRS program in the early eighties. In order to integrate the satellite based remote sensing with conventional data system for resource management, ultimately leading to an operational geographical information system for the country, the NATIONAL NATURAL RESOURCE MANAGEMENT SYSTEM (NNRMS), using a series of IRS satellites has been evolved.

7.4 World Remote Sensing Experiment Program

S.No.	Space-craft	Bands	Altitude	Remarks
1.	Landsat I (U.S.A.) (23.7.1972)	4,5,6,7	910 km.	worked upto Jan'1978
2.	Landsat II (2.1.1975)	MSS 4,5,6,7	---do---	worked upto Feb'1982
3.	Landsat III (5.3.1978)	--do---	---do---	worked upto March'1983
4.	Landsat IV (16.7.1982)	MSS 1,2,3,4	705 km	in operation
5.	Landsat V (1.3.1984)	--do---	---do---	----do----
6.	SPOT- I (France) (22.2.1984)	3 bands	833 km	----do----
7.	IRS- IA (17.3.1988)	4 bands	904 km	----do----

8. HYMOS- A DATABASE MANAGEMENT AND PROCESSING SYSTEM

8.1. General Overview

HYMOS is a database management and processing system for hydrometeorological quality and quantity data, designed for use on personal computers. It arranges a convenient structuring of data in a data base and provides an extensive set of tools for data entry, validation, completion, analysis, retrieval and reporting.

HYMOS is comprehensive, well tuned and easy to use via full screen menus with on line help to guide the user. The package includes many tabular and graphical options facilitating efficient reporting. HYMOS runs on stand-alone computers, but can also be used in a network system. Securities have been built into restrict the access for certain activities to qualified staff only.

HYMOS is developed to streamline the storage and processing of (geo) hydrological and meteorological data. It is tailored for use by hydrological and meteorological data processing branches, water resources management authorities, water boards , water engineering consultants and hydrological advisors.

HYMOS data are to a large extent typically time oriented. Together with a space oriented Geographical Information System, it covers all data storage and processing requirements for planning, design and operation of water management system.

8.2 HYMOS in a nutshell

8.2.1 Structure of HYMOS

HYMOS integrates the distinctive phase in the processing of hydrological data. The activities are carried out in specific processing modules; each module consist of a number of program enclosing particular compilations/ computations. The modules are structured according to a logical sequence of activities in data processing. All modules are linked to the HYMOS data base, structured and controlled by a data base management system. Different data base can be operational under HYMOS.

HYMOS comprises following systems:

A. a data base management system to create a data base, to structure the data base and to define user identifications;

B. a data storage and retrieval system, covering data entry editing, reporting in tabular and graphical form as well as the transfer and retrieval of data;

C. a data base processing system, including validation, series completion by interpolation, simulation and regression techniques,elaboration of flow measyrement, data compilation, statistical analysis and time series analysis.

HYMOS allows user program to communicate with the data base. For that purpose the FORTRAN subroutine library HYSUB is enclosed with the package. HYSUB comprises an extensive set of subroutines to store and retrieve data and to carry out statistical analysis.

8.2.2 Data Types

The types of data, handled by HYMOS, can be categorized in the following groups:

1. Space oriented data, covering:
   - catchment characteristics
   - station particulars
   - station histories
   - geo-hydrological profiles

2. Time oriented data, including:
   - equidistant time series
   - non-equidistant time series

3. Relation oriented data, divided in:
   - stage-discharge data
   - relation or rating curves parameters, valid for a period

8.2.3 Database management

Database management deals with the creation and structuring of data based and with the definition of user identifications.

Structure of databases

A HYMOS created database comprises the hydrometeorological data of one or more catchment, or sub-catchment. As many databases are required can be used. Each database is stored in a separate directory.

In a particular database the data are, except for the catchment characteristic, structured station wise. Data type and and time interval are used for further identification of station data. The overall structure is shown in the following scheme:

```
                                      Station particulars
                                      Station history
                                      geo-hydrological profiles
                       Station b      Equidistant time series
Catchment  -----       Station c------Non-equidistant time series
                       Station d      Stage discharge data
                                      Relation curve parameters
                                      Rating curve parameters
```

Definition of users

User Id's can be categorized into three parts:

a) group name,
b) user name, and
c) password.

The access to a particular database is reserved to specified groups. Within a group user are defined with different levels of authority, ranging for access to all facilities to data retrieval operations only. Each user must enter a unique password, which can only be changed by the System Manager.

8.2.4 Data Storage and Retrieval

Under HYMOS the data are sorted in DBASE look alike files (space oriented data, non equidistant time series and relation oriented data) and in dedicated direct access files (equidistant time series). Hardly any limits exist to the size of a database.

To store data in, and to retrieve data from the HYMOS database, the following modules are available:

1. data entry and editing:

HYMOS provides three ways to load the database, viz.:

- via data files on diskette or in EPROM,
- manually, via the screen and
- via one of the HYMOS processing options, in case of computed data.

Full screen editors are available under HYMOS for all data types to add, edit, display and delete data. Codes are generated by HYMOS and stored in database to distinguish among original, corrected and filled in data.

2. reporting and retrieval:

Various entries can be used to retrieve data from the data base, for purpose of transfer to ASCII file or other databases either or not under HYMOS. Ready-made monthly or annual reports can be produced by HYMOS; and many tabular options and powerful graphics are available to support the reporting.

8.2.5 Data processing

The validation, completion and analysis of hydrometeorological data under HYMOS is logically structured in the following data processing modules;

1. data validation: tabular, graphical and computational procedures are available for proper screening of various types of data.

2. data completion and regression: a number time and spatial interpolation techniques, as well as powerful

regression and rainfall-runoff simulations (Sacramento model) are included for series completion.

3. flow measurement: procedures are provided for elaboration and checking of current metering data, stage-discharge analysis and conversion of stage into discharges.

4. data compilation: including aggregation and dis aggregation of series, series transformation, computation of average and extreme values, catchment rainfall and evapotranspiration computation.

5. statistical analysis: computation of basic statistics, fitting of distribution functions, statistical tables, random data generation, computation of IDF curves and frequency and duration of curves.

6. time series analysis: covering correlogram and spectral analysis, range and run analysis and computation of storage requirements.

8.2.6 Special features

To facilitate the use of HYMOS special function keys are available for on line help, display of temporary output files, use of text editors, change of database and packing of database files.

The station and series selection is enhanced by selection from displayed tables or catchment maps on the screen.

Finally keys are available to set the screen colors and hardwork configuration and to switch to DOS during a HYMOS session.

8.2.7 Database limitations

Some limitations exist as to the amount of data, the number of series and the length of the series that can be stored in these files. The following limitations apply to a particular database:

- the amount of data is at maximum 1.8 billion
- the amount of equidistant time series is at maximum 32767
- all series can have a length of atleast 54500 data but, in addition some 40 million data positions are available for extension of one or a number of series

If the above limits are exceeded, more database have to be defined.

8.3 Data Types

8.3.1 Space oriented data

The space oriented data cover:- catchment characteristics,

- station particulars,
- station histories,
- geographical profiles

Catchment characteristics

The catchment data comprise typically time-independent characteristics like area, river length, slope, course, (sub-) rivers and topography. Catchment boundaries and features can be displayed for graphical series selection.

Station particulars

The station particulars stored in HYMOS include:

- data on the location of the station, river basin, district, geographical latitude and longitude (UTM may be used), altitude, catchment area and data collecting agency
- extremes of climatological parameters, water level and discharge.

Station history

Station history data consist of free text covering. Since most commercially available text editors can be linked to HYMOS for the entry of station history information.

Geo-hydrological profiles

Groundwater-well data, including filter dimensions and a full description of the geo-hydrological profile can be stored under HYMOS.

8.3.2 Time oriented data

Time series are, with respect to interval, distinguish in equidistant time series, i.e. series with regular time interval, or non equidistant time series, i.e. series with irregular time intervals.

Time series types

Time series represents various types of data (rainfall, temperature, water levels, chlorinity, sediment concentrations, etc.). A two letter combination is used in

HYMOS for identification. A maximum of 675 different data types can be defined.

A data type prefers either to equidistant or to non equidistant series and has two attributes: a unit, or an observation code, to distinguish among instantaneous, accumulative, averaged and interval constant data. The definition of data types can only be extended or altered by the system manager.

Equidistant time series

Various time intervals for a particular data type can be applied. The intervals can vary from 1 minute to 1 year (quarterly, hourly, daily, monthly, and annual rainfall). The equidistant time series are identified by a combination of station code, data type and interval code. This leads to the following data structure for the equidistant time series:

```
                                                interval ax
                         data type ab           interval cy
station a                data type ax           interval xx
station b ---------- data type ba --------- interval xy
station c                data type bb           interval xz
                         data type ba           interval yx
                                                interval zy
```

Non-equidistant time series:

Non-equidistant time series are identified by: station code plus data type. In deviation from the equidistant time series each series element in the database is stored with a date and a time lable.

8.3.3 Relation oriented data

Relation oriented data are grouped in stage discharge data, and a relation or rating curves parameters, valid for a certain time period.

Stage discharge data

Flow velocity measurements can be stored temporarily under HYMOS for validation and further elaboration in special files. The condensed results of the flow measurements: i.e. sets of water levels, discharge, velocity and crossecstional data are stored in the data base. In case back water or unsteady flow effects, the stage discharge relation , additionally water levels at a second location or gradients are stored as well.

Relation and rating parameters

Sets of coefficients, ranges of applicability and validity period for relation curves, stage discharge relations (with or without unsteady flow and backwater effects) and sediment rating curves can be stored in the database to be used in computations.

8.4 Details of HYMOS components

The following HYMOS systems are discerned:

- the data base management system
- the data storage and retrieval system
- the data processing system

8.4.1 Data storage and retrieval system

Data storage and retrieval activities are compressed in two modules: The "Entry and editing" module and the module"Reporting and retrieval"

Entry and editing

The entry and editing module includes following options:

1. entry and editing of catchment data.
2. creation of stations and series, and entry and editing of station particulars and geo-hydrological profile data.
3. data from user files or manually; direct links with telemetering systems can be established, while also fast data transfer from EPROMs to the data base is possible
4. full screen editors for editing and display of equidistant and non equidistant time series, with on line graphical display.
5. entry and editing of current metering data and discharge and sediment transport rating data.
6. entry and editing of data files for particular analysis (statistical analysis, regression etc)

Reporting and retrieval

The reporting and retrieval modules comprises:

1. preparation of reports on station and series characteristics and time series.
2. preparation of mixed tables of data base quantities.
3. plotting database quantities in a users specified layout.
4. retrieval data stored in database.
5. transfer of data from one database to another.

8.4.2 Data processing system

Data processing system of HYMOS includes following modules:

- data validation
- data completion and regression
- flow measurement
- data compilation
- statistical analysis
- time series analysis

Validation

For data validation use can be made of the following procedures:

1. data screening by flagging, printing and tabular comparison of time series and computation of basic statistics.

2. graphical evaluation of time series (lines or bars), including

   - plotting of time series
   - residual time series graphs
   - residual mass curves
   - moving averages
   - water balances
   - graphical presentation of series availability in the database

3. relation curves analysis to establish relation equations and to investigate shifts in the relationships; it includes:

   - graphical display of relations
   - fitting of relation curves by polynomials
   - storage of relation curve parameters in the data base.
   - comparison of relation curves of different time period

4. investigation of series homogeneity by means of double mass analysis, presented in graphs and tables

5. statistical tests on data homogeneity and randomness

6. special homogeneity test (near neighbor-technique), where data at abase station are compared with weighted averages of neighboring stations, selected on distance and orientation.

Series completion and regression

The completion and regression modules comprises:

1. interpolation techniques for filling in missing data based on time and space interpolations.
2. regression models to establish relationship, or to fill in missing data; the models may vary seasonally (maximum 12 periods), and can be of the following types:

- polynomial equations
- power equations
- logarithmic equations
- hyperbolic equations
- exponential equations
- simple and multiple linear regression equations
- stepwise regressions

3. physically based lumped parameter rainfall-runoff model SAMO, for filling in missing a runoff data. SAMO is derived from the Sacramento Streamflow Simulation Model.

The model is system of parallel and serial reservoirs. In the simulation of runoff process a distinction is made between the land phase and channel phase. The land phase is approached by an explicit moisture accounting lumped parameter model. The catchment area is divided into one or more segments, discharging to a channel. Within every segment areal homogeneity with respect to the rainfall and the basin characteristics is assumed. The propagation and attenuation of flood waves in the channel can be simulated by hydrological routing methods.

Flow measurements

The module comprises a number of techniques for validation and elaboration of flow measurements and rating curves including:

1. entry and editing of flow velocity measurements, stage discharge data and rating curve parameters with cross-sectional parameters.

2. processing of flow velocity measurements by profile and moving boat methods, allowing :

   - various method for measurement in the vertical
   - wet and air line corrections
   - mean and midsection method to compute the discharge
   - graphical and computational validation of measurement
   - transfer of condensed results to the data base

3. computation of stage discharge relations given as parabolic and power type equations with:

   - coeff. for upto three water level ranges per relation
   - correction for backwater effects
   - corrections for unsteady flow
   - detailed error analysis
   - transfer of coeff. with validity period to the data base

4. validation of rating equations for different periods and new measurements.

5. extrapolation of rating curves:

   - computation of cross section capacities and parameters
   - graphs of cross sectional parameters versus stage
   - computation of synthetic stage-discharge data beyond the measured ranges

6. Stage-discharge transformation, using :
   - rating curves stored in the database
   - rating equations of measuring and control structures for critical and sub-critical flow conditions and variable sill level.

Data compilation

The data compilation module comprises:

1. aggregation and dis-aggregation of time series, where accumulative and instantaneous data are treated differently
2. series transformation with various arithmetic transformation potions
3. minimum, mean and maximum series computation for selected time periods and transfer to the database
4. computation of areal rainfall by:
   - (weighted) average of point rainfall data
   - Thiessen method
   - kriging method
5. interpolation and computation of best linear estimates of and uncertainties in areal quantities by point and block kriging method
6. computation of potential evapotranspiration, using:
   - Penman method
   - Pan-evaporation method
   - Christian method
   - Radiation method
   - Makkink method
   - Jenson-Haise method
   - Blaney-Criddle method
   - Mass transfer method

Statistical analysis

The module for statistical analysis includes:

1. Computation of basic statistics and histograms
2. fitting of distribution function of the following type:
   - Normal distribution (with Box-Cox transformation to normality)
   - Log-normal distribution
   - Exponential distribution
   - Pearson-3 and general Pearson distribution
   - Log-Pearson distribution
   - Raleigh distribution
   - Extreme Type 1 (Gumble), 2 and 3 distribution
   - Goodrich distribution
   - Pareto distribution for peaks over threshold

The parameters are estimated using the method of moments and a mixed moment-maximum likelihood method. Once the distribution is fitted extremes for various exceedance probabilities can be computed, binomial, kolmogorov-Smirnov and Chi-square goodness of fit test can be applied and a graphical display can be made of the fit of the distribution with confidence limits.

3. statistical tables, i.e. computation of probabilities and varieties for the various probability distributions
4. generation of normal and gamma distribution random numbers
5. computation of IDF-curves (Intensity-Duration-Frequency curves) from monthly maximum precipitation in short intervals
6. computation and plotting of:
   - frequency curves
   - duration curves
   - average duration curves

Time series analysis

The time series analysis module comprises:

1. auto- and cross-correlation function computation
2. spectral analysis
3. run analysis: computation of up- and down-crossings, run lengths and runsum
4. range analysis:computation of range of cumulative departures from the mean
5. analysis of storage requirements by the sequent peak algorithm.

9. HYDROLOGICAL ANALYSIS

9.1 Catchment Modelling

The advent of high speed digital computer with a large storage for data has stimulated research in many disciplines. Hydrologists are well to the fore in automating the application of existing analytical methods, but they have also used this modern tool to advantage in exploring new theories. Many advances and improvements in the development of rainfall-runoff relation ships appeared in the 1950's and 1960's. However, it is only in last 10 years or so that the practicing Engineer has had ready access to large computers, and therefore many of the advances in hydrological analysis have remained as research tools. Now some of the new techniques are being applied more widely in solving engineering problems.

The principle technique of hydrological modeling make use of the two powerful facilities of digital computer, the ability to carry out vast numbers of iterative calculation and the ability to answer yes or no to specifically designed interrogations. Applying these facilities mathematical models are built up by careful logical programming to describe the land phase of the hydrological cycle in space and time.

9.2 Notable Conceptual Models

Sl No	Name of country	Name of Model	Purpose of Forecast	Number of parameters
1.	Australia	Commonwealth bureau of meteorology model (CBM)	short term forecast of flood heights	9
2.	France	Girard I	various	12
3.	Japan	Serial storage type model (Tank I)	Discharge forecasting for water management	12-24
4.	Japan	Kizugawa Model (Tank II)	Discharge forecasting for water management	3
5.	Romania	The flood forecasting model (IMH2-SSVP)	Rain floods	13
6.	USA	Streamflow synthesis and reservoir regulation (SSARR)	Flood and low water warning for reservoir operation	Several established by trial & error procedures
7.	USA	National water service hydrologic model (NWSH)	Flood & low flow forecasting for water resour.	18
8.	USA	Sacramento river forecast centre hydrologic model (SRFCH)	Flood and low flow forecasting for water management	11
9.	USSR	Rainfall-runoff model of the hydrometeorological centre of the USSR (HMC)	Short term forecast of rain floods	11
10.	ITALY	Constrained linear system (CLS)	Flood forecasting	several est. as those necessary spec. the IUH for a given time increment
11.	UK	Nash Model	Surface runoff forecasting	2

Sl No	Name of country	Name of Model	Purpose of Forecast	Number of parameters
12.		Massachusetts Institute of Technology (MIT)	Flood hydrograph using linear storage & linear channels	2
13.	Australia	Runoff routing model	Floods from ungauged catchments	2
14.	UK	River catchment flood model	Runoff for gaged and ungaged catchments	
15.	UK, France, Denmark	System Hydrologique European	Precp. rate ET loss model Overland channel flow model unsaturated flow saturated flow	4 2 3 3 2 2
16.	Australia	CBM	Flood flow forecasting	
17.	Canada	UBC	Flow forecasting with snowmelt	
18.	France	BILIK	General forecasting	
19.	France	CREC	Forecasting discharge	
20.	France	GIRARD I	Multipurpose	
21.	Isreal	Mero	Cyprus water planning	
22.	Italy	CLS	Flood forecasting	
23.	Japan	TANK 2	Dyscharge for water Resources	
24.	South Africa	HYREUN	Flood hydrograph simulation	
25.	USA	NWSH	Flood and low flow forecasting	
26.	USA	SRFCH	Flood and low flow forecasting	
27.	USA	SSARR	Flood and low flow forecasting	
28.	USA	HEC	Flood and low flow forecasting	
29.	USSR	HMC	Short term forecast of floods	

10. DATA AVAILABILITY AND ORGANIZATIONS INVOLVED IN DATA PROCESSING IN INDIA

10.1 Data Availability

Most hydrological variables such as rainfall, streamflow or groundwater have been measured for many years by separate official bodies and private organizations. In India, with the growth of population and the improvement in communication to serve modern needs, hydrometric schemes are tending to become multipurpose. These measurements are recorded by a wide range of methods, from the simple writing down of a number by a single observer to the invisible marking of electronic impulse on a magnetic tape. A number of organizations dealing with hydrological data are attempting to develop some computer based systems for data storage and retrieval. These attempts are so far limited to only Central Govt. bodies. Regarding State Govt. departments, where bulk of the data lies a perceptible beginning is yet to be made.

The data collection of hydrological parameters on regional basis commenced in 1950's with establishment of hydrograph network stations all over the country. The data collection was limited to 410 hydrograph network stations in the country. The chemical data was being taken for the station.

In India, at present all the precipitation data is collected through Indian Meteorological Department (IMD), State Irrigation Departments, Central Water Commission

(CWC), and other agencies. Raingauge stations are also maintained by State Govt. for the collection of rainfall data. The IMD, State Irrigation Dept., Central government agencies, Universities & Agricultural department, collect meteorological data such as data onevaporation, transpiration, infiltration, wind speed, solar radiation , sunshine duration etc.

The Central Ground Water Board (CGWB) and State Ground Water Dept. are main organizations involved in ground water data collection, which are required for hydrological analysis.

The streamflow data are collected by Central Water Commission and State Govt. Irrigation Departments. The remote sensing data are collected by National Remote Sensing Agency, Hyderabad.

The Physical data of the basin have to be obtained from a study of topographical maps available with the Survey of India. The geological characteristics of the basin under study are available with the Geological Survey of India and the State Geology Directorate.

10.2 Organizations Involved

10.2.1 Indian Meteorological Department

IMD has been storing the meteorological data for the last 40 years of period on punch cards. Till 1970 the daily rainfall were punched on 31 card format where as from 1971 data were punched in 24 cards format. In 31 cards format, each card contains a catchment number, subdivision number, latitude and longitude of station alongwith station no.. For storage of data in 24 card format records are needed for each month. The field in each record are,catchment no.,latitude, station no.,year,month and rainfall values. For hourly rainfall data, the format includes element code,index no. of raingauge station, year, month, date, card number (either 1 or 2) and hourly rainfall values. The second card also has filled for amount and duration of maximum one hour precipitation during 24 hour period.

The need for use of faster methods has been felt with increase in the number of data records for processing and this led to be use of Computers. In 1964 IMD went in for machine processing of rainfall data using Holeritu machine which can sort out, make tables and give printouts in the desired format. The IMD, Pune is equipped with Tape drives and key to tape punch units with the acquisition of Computer system. A program DAILY is developed in IMD to read the daily rainfall data (after identifying the card format and checking the leap year) and writes it into a 12x31 matrix. It also produces long term series of ten daily, monthly, seasonal and annual totals. Another program HOURLY reads the hourly rainfall data and stores the data in a 31x24/ 28x24/ 29x24/ 30x24/ matrix as the case may be. The total of 24 hr. is computed from the hourly data for each day & the maximum hourly rainfall is determined. The computer program RAIN has been developed to distribute the rainfall recorded at the totaling gauges during an observational day (8.30 hr. to

8.30 hr.) into hourly using an average pattern hyetograph derived from a set of representative recording raingauges in the vicinity of the totaling gauges as per a given set of weights. The hourly rainfall pattern thus obtained at each of the totaling gauges is then used alongwith those observed at the recording gauges to determine the average hourly rainfall which eventually could be used as input to the rainfall-runoff models.

10.2.2. Central Water Commission (CWC)

River data directorate and statistics directorate in the headquarters of CWC are primarily responsible for establishing a data bank for systematic collection, processing storage and analysis of hydrological data. The CWC is engaged in computerized storage & retrieval of hydrological data for quite sometime. Data on computer is initially processed mechanically with two fold objectives:(1)Storing of hydrological data on magnetic tape and(2)Processing of data on computer for various hydrological computations. One of these software package processes the gauge & discharge data of the various rivers flowing in the country and produces the reports usually known as"Water year book".The daily gauge and discharge data for all the month for particular site on a river is printed in a tabular format. In case of missing data,the computed discharge is substituted. The maximum & minimum water level/discharge & its data of occurrence are presented month wise. Extract of water level and discharge is further carried out in a stratified spectrum such as monsoon season,non-monsoon season and annual basis. Flow duration of the discharge is further a-analyzed to depict the following water data received from the field units and transferred to magnetic tapes.

10.2.3. State Government Irrigation Departments

The State Govt. departments are collecting the hydrological data through their gauging station located in the vicinity of various river systems in the state. Most of the hydrological data collection activity is still based on manual observations,A perceptible beginning is yet to be made for compu- tation & analysis of available data in the State Govt. Departments.

10.2.4. National Remote Sensing Agency (NRSA)and State Government Remote Sensing Agency (SGRSA)

Remote sensing is one of the most developed Scientific & modern technique which provide a synoptic view of the earth's surface from space. This very technique is synthesis of space segment with ground based data reception, processing, interpretation and integration satellite based remotely sensed data with conventional data.

The National Remote Sensing Agency is collecting the hydrological data from satellite on tape and imageries for various places through Satellite. Various studies are being carried out by different organization utilizing these data. Some of the studies are as follows:

(1) Surveying appraisal and management of natural resources located in the realm of total natural environment (TNE) which consists lithosphere,hydrosphere and biosphere. The very technique is unique,suitable and cheaper for the developing economy and of developing country like India.

(2) Ground water potential zone mapping.

(3) Landuse & land classification maps.

(4) Degraded forest maps,waste land mapping

(5) flood water position during flood year period

10.2.5 Survey of India and Geological Survey of India

The Physical data of the basin have to be obtained from a study of topographical maps available with the Survey of India.

The Geological characteristics of the basin under study are available with the Geological Survey of India.

11. PROBLEM SELECTED FOR THE PROJECT AND THE MODE OF OUTPUT

11.1 Problem Selected

Hydrological data processing is related to well established principles of hydrodynamics and thermodynamics. The study of of Hydrological data processing is ,therefore, of utmost importance. The proble selected for the project ,thus, includes:

1. Evaluation of control measures using various hydrological data processing models.
2. Development and use of PC based softwares applicable in basins and sub-basins of India.

11.2 Mode of Output

The studies to be carried out would be in the form of a Report of National Institute of Hydrology, Roorkee. The copies of the report can be made available to the Central Govt. and State Govt. Organizations of the country whenever required.

12. ECONOMIC EVALUATION

It is important to realize that the use of automated techniques does not necessarily implies the use of highly sophisticated computer installations. The role of micro-computers as a cheap, powerful, and readily available way to introduce computer based technologies and to develop the necessary human skills is very much important.

It has also been shown that distribution data processing systems tend to be more flexible in meetimg changing needs, but that a centralized approach may be necessary where expertise and / or funds are limited. Distribution system may also present some problems or compatibility, praticularly, if several different types of micro-computers are to be linked to the system.

13. CONCLUSION

The following points are concluded under the project-

1. Significant improvements in hydrological data collection, quality control storage, accessibility, preparation of publications and the use of data for analytical studies can be made available with specialized trained persons involved in all phases of work.
2. It has been shown that the decision to automate the data processing function has brought implication in other areas.
3. Computer processing allows the routine management and updating of a wide variety of relationships.
4. The reports could be issued at monthly, 3-monthly, and annual intervals, which may include beside the daily decade, monthly and annual totals, also the minimum and maximum values per month and year, no. of rain/flood days. Derivation from the average year could be indicated as well.
5. The monthly rainfall distribution in time for a particular year can be plotted together with frequency curves.
6. Isohyetes for monthly, seasonal, and annual values can also often be presented in the reports.

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