CASE STUDY

CS-(AR) 179

PROCESSING OF HYDROLOGICAL DATA FOR MANOT SUB-BASIN USING HYMOS

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PREFACE

Processing of hydrological data, in general, is a very difficult task to perform. It becomes even more so when the handling of huge amount of data, which is associated with hydrology, is to be done manually. In country like ours, the computerization in the field of hydrology is yet very far from being adequate. Much of the hydrological data management is done in the conventional way by keeping hand written records. Also, the preliminary analysis which should be done simultaneously while storing the data is being done manually at a later date. This makes the task very tedious and difficult and therefore the hydrologists tend to ignore the much needed aspect of data processing. Only in few cases, like the Central Water Commission or some state governments, the use of computers has recently started. Even these agencies, where the data handling is being done by computers, are not having efficient hydrological database management softwares by which the data may be processed with ease.

In our country, there have been some efforts, though mutually un-coordinated, to develop the hydrological database management softwares but till now there has been no satisfactory software produced indigenously. At the international level, there are some sophisticated softwares being produced by different agencies related with hydrological database management. However, it is to mention here that these softwares have also not achieved a level of perfection and are continuously being upgraded. HYMOS is one such software which is used for storage, processing and retrieval of hydro-metereological data. This software has been

developed by the DELFT HYDRAULICS of The Netherlands. The National Institute of Hydrology, India has received a copy of this software under a bilateral Indo-Dutch Training Programme on Water Management (WAMATRA) in the year 1992. Shri, Hemant Chowdhary, Scientist undertook a two months training on this software at the DELFT HYDRAULICS. This study has been carried out Shri Hemant Chowdhary, Scientist under the guidance of Shri R D Singh.

In this study, the illustration of the capabilities of this software is made by taking a real case study. The catchment of the river Naramada upto Manot gauge-discharge site is taken for this study. Various options of data storage, processing and retrieval are demonstrated with the help of the available hydrological data for this catchment. It is to emphasis here that the illustrations of the capabilities of the software made in this report do not in themselves suggests the real value of the software. The most important thing here is that all these operations are performed in practically no time and the database is so structured that there is little chance of confusion anywhere which is the main hurdle otherwise.

(S M SETH)
Director

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ABSTRACT

Processing of hydrological data is the first task which a hydrologist has to undertake before starting up any hydrological study. The amount of data needed for most of the hydrological studies is enormous. It is very difficult to handle huge amount of data when it is to be done manually. With the help of ever increasing computing facility the processing is not so tedious now. In our country, however, the introduction of computers in the agencies related with hydrology is yet far from adequate. Only in few cases, like the Central Water Commission or some state governments, the use of computers has recently started. Even these agencies, where the data handling is being done by computers, are not having efficient hydrological database management softwares by which the data may be processed with ease.

There are some good hydrological database mangement softwares available in the world market but till now there has been no satisfactory software produced indigenously. HYMOS is one such software which is used for storage, processing and retrieval of hydro-metereological data. This software has been developed by the DELFT HYDRAULICS of The Netherlands. The National Institute of Hydrology, India received a copy of this software under the bilateral Indo-Dutch Training Programme on Water Management (WAMATRA) in the year 1992.

There is a need to develope a good software indegenously so that its country-wide demand may be met. In this study, the illustration of the capabilities of HYMOS software is made by taking a real case study. This would make us aware of the type of software available in the market and the importance of using such

a software. The catchment of the river Narâmada upto Manot gauge-discharge site is taken for this study. Various options of data storage, processing and retrieval are demonstrated with the help of the available hydrological data for this catchment.

In the chapter on introduction all the capabilities of the software are highlighted in brief. Second chapter gives a brief description of the study area and the availability of the data. The next chapter gives a complete idea of how the data files are to be prepared for making the data acceptable to HYMOS. Fourth chapter deals with the different options for validation of the data. The chapter on completion and regression illustrates how the gaps in the data may be filled-up using various techniques. Handling of the flow data which is a very important processing activity is covered in chapter six. Options of aggregation and dis-aggregation of series, series transformation and computation of areal rainfall by different procedures are explained in the next chapter. The capabilities for the statistical and time series analysis are demonstrated in subsequent chapters. In the last chapter various facilities for reporting and retrieval of data are explained. All the operations in the software are done with the help of menu driven selection procedure and thus avoids the difficult problem of file management and data entry and retrieval actions. It has been tried to explain the features of the software by taking suitable examples where ever relavant data was available.

1.0 - INTRODUCTION ABOUT HYMOS

1.1 GENERAL

HYMOS is a database management and processing system for hydro-meteorological quality and quantity data, designed for use on personal computers (pc's). It arranges a convenient structuring of data in a database and provides an extensive set of tools for data entry, validation, completion, analysis, retrieval and reporting. It 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. It runs on stand alone computers, but can also be used in a network system. Securities have been built in to 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 advisers. 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 systems.

In this introduction an overall view of HYMOS is given, the type of data it can handle, the way the data can be stored and processed and the hardware required to run the system successfully.

1.2 COMPUTER CONFIGURATION REQUIREMENT

The HYMOS software package is written in the programming languages FORTRAN 77 and C.

The HYMOS version 3.0 runs on computer systems of the following specifications:

- IBM XT, AT or compatible personal computer, with:
  - 640 kb core memory,
  - ≥ 20 Mb hard disk,

. EGA or VGA graphics card,
. MS-DOS 3.* (or higher) operating system,

.Printer
.HP or Calcomp compatible plotter;
.tape streamer (recommended for back-up purposes):
.protection key HASP II (Supplied by the developer)

For fast and pleasant operation an AT computer with color monitor is preferred but not strictly necessary, nor is a co-processor required. Graphics cards less advanced than EGA or VGA do not support all HYMOS graphics, but they will be acceptable for common data processing activities.

1.3 HYMOS IN A NUTSHELL

1.3.1 Structure of HYMOS

HYMOS integrates the distinctive phases in the processing of hydrological data. The activities are carried out in specific processing modules; each module consists of a number of programs 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 database, structured and controlled by a database management system. Different databases can be operational under HYMOS. In summary, HYMOS comprises of following systems:

A. a database management system, to create databases, to structure the database 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 processing system, including validation, series completion by interpolation, simulation and regression techniques, elaboration of flow measurements, data compilation, statistical analysis, and time series analysis.

The structure of HYMOS is shown schematically in Fig.1.1.

1.3.2 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, i.e. series with regular time intervals
   - non-equidistant time series, i.e. series with irregular time intervals.

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

1.3.3 Database management

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

Structure of databases:

A HYMOS created database comprises the hydro-meteorological data of one or more catchments, or sub-catchment(s). As many databases as required can be used. Each database is stored in a separate directory.

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

```
                                            Station particulars
                                            Station history
                        Station a           Geo-hydrological profiles
Catchment j ------      Station b  ------   Equidistant time series
...                     Station c           Non-equi. time series
...                     ...                 Stage discharge data
...                     ...                 relation curve parameter
                        ...                 rating curve parameter
```

Definition of users:

User identifications can be categorized into three parts:

1. group name,
2. user name, and
3. password.

The access to a particular database is reserved to specified groups. Within a group users are defined with different levels of authority, ranging from 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.

1.3.4 Data storage and retrieval

Under HYMOS the data are stored 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 as may be seen under section of 'Data Limitations'.

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

* data entry and editing:

HYMOS provides three ways to load the data base, 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 the data base to distinguish among original, corrected and filled-in data.

* reporting and retrieval:

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

1.3.5 Data processing

The validation, completion and analysis of hydro-meteorological data under HYMOS is logically structured in the following data processing modules:

* data validation:

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

* data completion and regression:

a number of time and spatial interpolation techniques, as well as powerful regression and rainfall-runoff simulation (Sacramento model) are included for series completion.

* flow measurement:

procedures are provided for elaboration and checking of current metering data, stage discharge analysis and conversion of stages into discharges.

* data compilation:

including aggregation and dis-aggregation of series, series transformation, computation of average and extreme values, catchment rainfall and evapotranspiration computation.

* statistical analysis:

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

* time series analysis:

covering correlogram and spectral analysis, range and run analysis and computation of storage requirements.

1.3.6 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 data base and packing of data base 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 colours and hardware configuration, and to switch to DOS during a HYMOS session.

1.3.7 Database limitations

It was mentioned earlier that the equidistant time series are stored in special direct access files. 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 data base.

- the amount of data is at maximum 1.8 billion (i.e. 7 Gigabyte);
- the amount of equidistant time series is at maximum 10,000;
- all series can have a length of at least 54,500 data (e.g. about 150 years of daily data) but, in addition, some 40 million data positions are available for extension of one or a number of series.

The last observation allows one to use for a limited number of series a length far beyond the standard of 54,500 data, e.g. 25 series of 1.6 million data (i.e. 45 years of 15 minute data) can be used additionally. For non-equidistant and non time series data no limits exist, but the size of the disk. If the above limits are exceeded, more databases have to be defined.

2.0 - DATA AVAILABILITY

2.1 GENERAL

The Narmada is a major west-flowing river in Central India running through the states of Madhya Pradesh, Gujarat and Maharashtra. The basin is bounded on the north by the Vindhyas, on the east by the Maikala range, on the south by the Satpuras and on the west by the Arabian Sea and has a catchment area of 98,796 Sq. Kms. (Fig. 2.1). From its source to its outflow in the Arabian Sea the mainstream stretches 1312 Kms. and is joined by 41 tributaries, oriented in the north-south direction. For the present study the catchment upto Manot gauge-discharge site is taken which is shown shaded Fig. 2.1.

2.2 LOCATION OF NARMADA (UPTO MANOT) BASIN

The Narmada basin (upto Manot) lies between east longitudes 80° 24' to 81° 47' and north latitudes 22° 26' to 23° 18', most of the part lying in Mandla district and some part in Shahdol district of Madhya Pradesh. The basin comprises the 4980 Sq. kms. head water catchment of the Narmada defined by the Central Water Commission gauging site at Manot, where the river length is about 269 kms.. It flows in a generally northwesterly direction but turns in a loop to the south upstream of Manot. At present the upper Narmada is not subject to any major development. Nearly 90 percent of the total rainfall is received during the five monsoon months from June to October.

2.3 AVAILABILITY OF DATA

Eleven years of daily rainfall data for twenty stations is presently used for this study. The gauge-discharge at Manot gauging site for one year is presently fed on the computer. However, more gauge discharge data would be fed alongwith the hourly gauge data.

The boundary of the catchment and the location of various stations is given in Fig. 2.2. Fig.2.3 gives the availability of the raw data available at the Institute for the period 1981 to 1991.

3.0 - DATA TYPES IN HYMOS

3.1 OVERVIEW

The type of data that can be stored in HYMOS include:

(i) Space oriented data:
-catchment characteristics,
-station data: characteristics, log-book and histories,
-series characteristics, and
-geo-hydrological profiles.

(ii) Time oriented data:
-equidistant time series, and
-non-equidistant time series.

(iii) Relation oriented data:
-stage-discharge data
-rating curve parameters, and
-relation curve parameters.

The contents of the various types of data are presented in the sections from 3.2 to 3.8.

3.2 CATCHMENT DATA

3.2.1 General

Catchment data comprise:

1. latitude and longitude of local origin of catchment data,
2. catchment layout data, and
3. (sub-) catchment characteristics.

3.2.2 Local origin

The local origin represents the lower left corner of the catchment map and is given in geographical coordinates. Catchment layout-data, see section 3.2.3, are entered in kilometers east (x-coordinate) and north (y-coordinate) of the local origin. There is only one local origin for a particular data-base, valid for all catchments or sub-catchments in the database!

3.2.3 Catchment layout

Catchment layout data includes:

- -catchment boundaries,
- -plan form of river(s),
- -location of cities,
- -network of roads, and
- -catchment topography

3.2.4 Catchment characteristics

In a database, data of one or more catchments or sub-catchments can be stored. For each catchment or sub-catchment this comprises the following characteristics:

- -(sub-)catchment name,
- -name of the river,
- -(sub-)catchment area
- -stream order,
- -length of the river, and
- -slope of the river.

3.3 STATION DATA

3.3.1 General

Station data covers:

1. station code,
2. general station data,
3. station log-book,
4. station history, and
5. series characteristics.

3.3.2 Station code

The station code is a unique set of 1 to 10 characters (letters, digits or symbols) to identify a station. The easiest way of coding a station is by using the station name or an abbreviation of it.

Example

For Githori rainfall station in Manot sub-basin ($22^{o}43'30"$, $80^{o}59'15"$) in Madhya Pradesh, India, e.g., the following station codes could be used by HYMOS.

GITHORI
GITHOR
22438059
etc.

3.3.3 General station data

General station data include:

- station name,
- name of the river (for streamflow stations),
- district and country,
- station latitude, longitude and altitude,
- catchment area upstream of the station, and
- agency, responsible for the station.

3.3.4 Station log book

The log book contains user remarks on series of the station. These remarks typically refer to processing instructions. The information stored includes:

- the remarks,
- period, the remarks refers to,
- series it concerns,
- status of execution of the remark,
- additionally required action,
- date of the remark, and
- name of the person who made the remark.

3.3.5 Station history

The station history is a text file with user specified information about the station. There is no restriction on the layout or contents of the history file. Typically, the station history comprises information on the establishment of the station, access to the station, benchmarks, gauge particulars, repairs, etc.

3.3.6 Series characteristics

Series characteristics refers to data type and time interval parameters, which are required to organize the storage and retrieval of data from the database.

With respect to series a distinction is made between:

1. equidistant time series,
2. non-equidistant time series, and
3. special time series.

The equidistant time series characteristics include:

- data type, unit and type of observation,
- time interval,
- basic time interval,
- time shift,
- missing value,
- likely minimum and maximum value, and
- likely maximum rate of rise and of fall (when relevant).

The equidistant time series characteristics are discussed in detail in section 3.5.

The non-equidistant time series characteristics include : (see also section 3.6).

- data type, unit and type of observation,
- missing value,
- likely minimum and maximum value, and
- likely maximum rate of rise and fall (when relevant).

The special time series, refer to monthly maximum rainfall amounts and annual exceedances of fixed durations. These series are exclusively applied for Intensity-Duration-Frequency analysis, (see section 9.5).

The characteristics of special time series include:
- fixed data types and unit, and
- missing value.

Basically, these special time series are stored as ordinary equidistant time series, but a different interpretation is given to the time interval.

3.4 GEOHYDROLOGICAL PROFILES

3.4.1 General

The geo-hydrological station data comprise information on filters and layers. The overall data include:

-ground level (GL)	(m+MSL)
-number of filters, and	
-number of layers.	

3.4.2 Filter data

The filter data comprise:

-measuring height	(m+GL)
-upper side of filter	(m+GL)
-lower side of filter	(m+GL)
-diameter of well, and	(m)
-length of well + filter	(m)

3.4.3 Layer data

For each layer the following data are stored:

-depth	(m+GL)
-thickness	(m)
-layer code,	-
-geological information,	-
-type of material,	-
-availability of sieve analysis	(Y/N)
-porosity	(%)
-specific yield/storage coeff.	-
-hor. and vert. permeability	(m/day)

3.5 EQUIDISTANT TIME SERIES

3.5.1 Definition

A time series is a collection of data, ordered sequentially in time, representing the behaviour of a process at a fixed position in space.

An equidistant time series is a sequence of data with a fixed time interval. A time series may be divided into sub-series. Sub-series are not necessarily sequential in time. Time gaps of any size may be present between the subseries.

To specify equidistant time series (series code) following elements are used in HYMOS.

- station code,
- data type, and
- time interval

Additionally, following characteristics are stored

- data unit,
- type of observation,
- basic time interval,
- time shift,
- missing value,
- data limits.

The time labels of the data are derived from the time interval and are based on calendar and time units.

3.5.2 Data type

The data type is a two character specification of the type of data. Any combination of two characters (if not used for non-equidistant time series and not equal to AE or AM) is permitted and can be added to the available set.

EXAMPLE

PH	-	historical precipitation
PG	-	generated precipitation
H1	-	water levels upsteam of structure
H2	-	water levels downstream of structure
QH	-	historical discharge

To each data type belongs a data unit and a type of observation, (e.g. accumulative or instantaneous).

3.5.3 Units

The data unit is a characteristics of the data type. For a specific data type one and only one unit applies. Any unit can be used for the data in HYMOS, however, the use of SI-units is strongly recommended.

3.5.4 Type of observation

The type of observation is another characteristic of the data type, and it refers to the sampling or computational procedure used to obtain the data. Following types of observations are distinguished for equidistant time series, see also Fig. 3.1.

- -instantaneous observations,
- -accumulative observations, and
- -average observations

Instantaneous observations:

The observation is made at a certain point in time within the time interval Δt; it produces one instantaneous exposure of the process in a time span Δt, like e.g. water level time series, discharge time series.

Accumulative observations:

The observation is the integral of the continuous process in the time interval t to $t+\Delta t$, like for example rainfall amounts. Accumulative observations produce volumes rather than intensities. For example runoff expressed in mm is accumulative, whereas runoff expressed in m^3/s is instantaneous.

Average observations:

Average observations are computed quantities, obtained e.g. by aggregation of instantaneous observations over a larger time interval. Average observations are treated in HYMOS as instantaneous observations since in common mathematical operations they are equivalent. (From a view-point of information content they are, however, different: by averaging, information about the process is lost!).

The type of observation has important consequences for aggregation of time series (i.e. averaging versus summing) as well as for dis-aggregation of time series.

3.5.5 Time and calendar units

To define time intervals between and times of occurrence of series elements use is made of the following time and calendar units in HYMOS:

* time units -minutes
  -hour.
* calendar units -day
  -month
  -year

The Calendar units vary with time according to the Gregorian calendar. This implies:

1. months of 28, 29, 30 or 31 days; January 31 days, February 28 or 29 days, March 31 days, April 30 days ,etc.

2. non-leap year:28 days in February and 365 days in a year,
   leap year :29 days in February and 366 days in a year.
   a Leap year is defined as follows:
   - for non-secular years : a year divisible by 4,
   - for secular years : a year divisible by 400.

Secular years are the years at the turn of the centuries, e.g. 1800, 1900, 2000,2100. So, the year 2000 is a leap year, but 1900 is not.

3.5.6 The time interval

The time interval Δt represents:
-the time distance between successive series elements of instantaneous observations, or
-the time span of an accumulative observation

The time interval may be year, month, day or hour or a part thereof. Generally ,

Δt = (time interval unit, divider)

where:

time interval unit = year, month, day or hour (i.e. a calendar or a time unit), indicated by an integer:

Year = 1, day = 3
month = 2, Hour = 4

divider = Division factor (integer : 1-99) applied to the relevant time interval unit.

This definition provides a very flexible method of specifying time intervals. Practically all commonly used intervals between one minute and one year fit in the definition.

EXAMPLES

To demonstrate the use and flexibility of the time interval inspect the following .

Interval	HYMOS	Explanation	Interval	HYMOS	Explanation
(Year,1)	(1,1)	Year	(day,1)	(3,1)	Day
(Year,4)	(1,4)	season	(day,3)	(3,3)	8 hours
(month,1)	(2,1)	month	(hour,1)	(4,1)	hour
(month,3)	(2,3)	decade	(hour,4)	(4,4)	quarter
(year,52)	(1,52)	week	(hour,60)	(4,60)	minute

NOTES

1. For some intervals there is no unique combination of unit and divider, e.g. month may be specified by (2,1) but also by (1,12): in such cases preference is to be given to the definition with the lowest divider.

2. Some combinations of time interval units and dividers lead to non-equal time intervals (e.g.decade and week).
   -decade :if the number of days in a month ≠ 30, then one of the decades ≠ 10 days
   -week : a year is not exactly divisible by 52, hence one of the weeks ≠ 7 days, etc.

   To define irregularity, the basic time interval is introduced. It is, in practice, only used when the time interval is a week, a pentad (i.e. a period of 5 days) or a decade. The definition of the basic time interval is explained in the next sub-Chapter.

3.5.7 Basic time interval

In case the user cannot or does not want to divide the time interval unit into equal parts then in addition to the time interval Δt, a basic time interval or basic Δt expressed in numbers of smaller calendar or time units has to be applied. E.g. for decades, which are parts of months, multiples of days are used to specify the interval; similarly for weeks, which are parts of years, multiples of days are used to specify the length of the interval.

The basic Δt is defined as follows:

Basic Δt = (basic time interval unit, replicator)

where:

basic time interval unit -	month, day, hour or minute (calendar or time unit) indicated by an integer: month = 2, hour = 4, day = 3, minute = 5.
replicator -	multiplication factor applied to the basic time interval unit.

Consider e.g. decade intervals, defined as Δt = (month, 3) = (2,3). To specify that a decade consists of 10 days the basic time interval should read: basic Δt = (day,10) = (3,10). Then as much as possible intervals of 10 days will be defined in a month. So the first 2 decades will contain 10 days, while the last decade comprises 8, 9, 10 or 11 days depending on month and year.

This leads to the following generalization. The time interval Δt is built up out of a number of basic Δt's equal to the divider. The last time interval within a time interval unit may contain an amount of basic time interval units, that differs from the replicator. Let the time interval unit, containing n basic time interval units, be divided into K parts and let the replicator in the basic Δt be m. Then the first k-1 time intervals comprise m basic Δt units. The last or K-th time interval contains (n-(k-1).m) basic Δt units, see also Fig. 3.2.

EXAMPLES

Pentad intervals: Δt = (month,6) = (2,6) and basic Δt = (day,5) = (3,5). The first 5 pentads of the month contain 5 days, while the last pentad includes 3, 4, 5, or 6 days depending on the month and year.

Weekly intervals: Δt = (year,52) = (1,52) and basic Δt = (day,7) = (3,7). The first 51 weeks of the year contain 7 days, while the 52nd week includes 8 or 9 days.

3.5.8 Time label

Based on the definition of the time interval Δt, the positioning of a series element in time, i.e. the time label, is expressed in calendar and time units and a subdivision index. The subdivision index determines the position of the series element within the applied time interval unit; its value can be at maximum equal to the divider.

Generally, the time label or date of a series element is given by:

t = (year, month, day, hour, subdivision index)

where :

year	:	>1850
month	:	1-12
day	:	1-28, 29, 30, 31
hour	:	0-23
si	:	1-99 [(s)ub division (i)ndex]

NOTE

The elements of the time label refer to positions in time and not to time intervals; they are only expressed in multiples of time interval units. Only those elements of the time label have to be used which are relevant to position the series elements; if an element of the time label is not in use a zero is entered.

EXAMPLES :

Date		HYMOS Time label
30 January 1989	-	1989, 1, 30, 0, 1
Decade of 11-20 February 1976	-	1976, 2, 0, 0, 2
Quarter 24.00 28/2/1960-00.15 29/2/1960	-	1960, 2, 29, 0, 1
12th week of 1991	-	1991, 0, 0, 0, 12

3.5.9 Time shift

The quantity Δt time shift is introduced to define the position of an observation inside the time interval Δt more accurately, e.g. for a daily rainfall series one wants to specify that the gauge is daily read at 8.00 hrs. This quantity should be considered as a property of a series and as such it has no meaning for the positioning of a series element in time in the database. In the set-up of the database this time shift does not play a role. Only when at a later stage a number of series are mutually compared, the information on a time shift within the time interval may be of importance; for example, daily rainfall totals derived from quarterly or hourly observations often refer to the period 0.00 - 24.00 hrs, whereas daily rainfall totals from non-recording gauges generally refer to days from e.g. 8.00 to 8.00 hrs. the next day and hence are not mutually comparable.

The shift inside Δt (positive only) is expressed in lower order calendar and/or time units with an accuracy not more than 1 hour.

The Δt time shift has 3 elements:

Δt time shift = (number of months, number of days, number of hours)

EXAMPLE

Daily rainfall, measured at 8.00 hours:

Δt	=	(day,1)	=	(3,1)
Δt time shift	=	(0,0,8 hours)	=	(0,0,8)

3.5.10 Missing data

For each series a value is stored in the database to indicate that a data point is missing. Although the choice of this value is free it should always be less than the lower possible value.

EXAMPLE

Typical values for missing data are:

Rainfall	-1.	
Temperature	-99.	
Water level	-1.	provided that no negative levels occur (depends on the zero-level of the gauge)
Discharge	-1.	in non-tidal areas
	-9999.	in tidal areas, provided that the flow is always > -9999.

3.5.11 Data limits

For validation purposes the likely minimum and maximum values of a series as well as the likely maximum rate of rise and of fall are stored as series characteristics. In some validation options the series elements, which exceed these limits, will be flagged.

3.5.12 Series code

The series code is formed by:

-station code	:	1 to 10 characters
-data type	:	2 characters
-time interval	:	2 numbers: a time or calendar unit (1-4) and a divider (1-99).

So the total series code occupies 15 positions. To store and retrieve equidistant time series data the full series code must be applied. Special function keys are available to ease the selection.

EXAMPLES

Code of rainfall, water level and discharge time series of the Manot station could read :

MANOT	PH3 1	=	historical daily rainfall
MANOT	PG1 1	=	generated annual rainfall
MANOT	HH4 4	=	historical 15 minute water levels
MANOT	QG152	=	generated weekly discharges.

3.6 NON-EQUIDISTANT TIME SERIES

3.6.1 Definition

Non equidistant time series are sequences of data unequally spaced in time. This implies that each data point has to be stored with the time label. To specify these type of series following elements are used in HYMOS:

-station code, and
-data type

The station code has been described in section 3.3.2.

3.6.2 Data type

The data type is a two character specification of the type of data. Any two character combination (if not used for equidistant time series and not equal to AE or AM) is permitted and can be added to the available set.

To each data type belongs a data unit and a type of observation, (e.g. instantaneous or constant).

3.6.3 Units

The data unit is a characteristics of the data type. For a specific data type one and only one unit applies. Any unit can be used for the data in HYMOS, however, the use of SI-units is strongly recommended.

3.6.4 Type of observation

Sampling of continuous processes can be done in several ways, leading to different types of observations. For non-equidistant time series following types of observations are relevant:

- instantaneous observations
- constants

Instantaneous observations :
The observation is made at a certain point in time. It produces one instantaneous exposure of the process, e.g. a groundwater level observation. In between two observations the value of the process is uncertain.

Constants :
The process remains constant from one observation until the next. This is typically representative for time series with human interference, like e.g. gate levels fixed for a period of time or pumps in operation.

3.6.5 Data specification

The time labels of data consist of:

-calendar units	:	year, month, day
-time units	:	hour, minute

Only the relevant calendar and time units have to be specified.

3.6.6 Missing data

For each series a value is stored in the database to indicate that a data point is missing. This value is always less than the lowest possible value.

3.6.7 Data limits

For validation purposes (e.g. to flag unlikely data) the likely minimum and maximum values of a series as well as the likely maximum rate of rise and of fall are stored as series characteristics. Series elements exceeding these boundaries are flagged.

3.6.8 Series code

The series code is formed by:

-station code : 1 to 10 characters
-data type : 2 characters

So the total series code occupies 12 positions. To store and retrieve non-equidistant time series data the full series code must be applied.

EXAMPLE

Non-equidistant time series of observed discharge collected at station with code MANOT.

MANOT OQ

here OQ = observed discharge.

3.7 COMBINED DATA AND PARAMETERS

3.7.1 Definition

The combined data and parameters refer to sets of data/parameters of two or more quantities observed irregularly in time or valid for periods of time. These include:

- -condensed current metering data,
- -discharge and sediment rating parameters, and
- -regression/relation curve parameters.

The data comprise observed and computed data/parameters and are entered via the data entry options or created by one of curve fitting options in HYMOS.

3.7.2 Current metering data

Current metering data are condensed results of flow velocity measurements. These data comprise:

-gauge zero	(m above datum)
-water level	(m)
-discharge	(m^3/s)
-gradient or fall	(m/day) or (m)
-river/canal width at the water surface	(m)
-wetted perimeter	(m)
-cross sectional area	(m^2)
-flow velocity	(m/s)
-hydraulic radius	(m)

The original flow velocity measurement data can be entered and stored under HYMOS in dedicated files.

The data are identified by :

-station code
-date (year,month, day) of the measurement
-observation number , and
-type of use

The type of use refers to the application of the flow measurements, either for :

- simple rating analysis, or
- unsteady flow correction (with gradient data), or
- backwater correction (with fall data)

3.7.3 Rating curve parameters

Stage-discharge relations:
Stage discharge relations are described in HYMOS either by :
-a parabolic equation, or
-a power equation.

Where composite cross-sections are present more than one set of coefficients is generally required to describe the stage-discharge relation. HYMOS allows up to 3 sets of coefficients each valid for a specific water level range.

In case of unsteady flow or backwater, a correction is required to arrive at a unique stage-discharge relation. This correction in HYMOS is described as a function of the water level by a parabolic equation and is applied to stages within a certain water level range.

The type of equation, rating curve parameters and the water level ranges are stored in the data base.

The data are identified by :

-station code
-start and end data of the period of validity of the relation

Sediment transport relations:
Sediment transport relations can be described in HYMOS by various equations, e.g. a power equation. The same flexibility exists as for stage-discharge rating curve; also up to 3 ranges on the independent variable can be defined for which parameters can be stored.

3.7.4 Relation curve parameters

Regression and relation curves are described by :
-polynomials
-simple and multiple linear regression equations
-exponential equations
-power equations
-logarithmic equations
-hyperbolic equations

The parameters for these relations with their validity range and period and the series involved can be stored.

The relations are identified by :
-type of equation,
-series combination, and
-validity period.

4.0 - STRUCTURE OF HYMOS DATABASE

4.1 DATABASE DIRECTORIES

A catchment or sub-catchment forms a separate database under HYMOS. The data of a basin may be stored in one or a number of databases depending on the division into (sub-)catchments.

A particular database is stored in files located in a separate catchment directory,which is a sub directory of the HYMOS databases directory HYMOSDB. The name of the database consists of:

-a 1-4 character database name, prefixed by CAT ,and
-a 1-3 character extension.

Under the catchment directory 3 sub-directories are defined:

-DB :which stores the database files
-DATA :which stores particular data files for data processing, and
-FIGURE :which stores plot files

4.2 EXTENT OF A DATABASE

When structuring data into one or more databases, i.e selection of one or more (sub-)catchments, following should be taken into consideration:

1. communication between databases is only possible via series transfer,so
2. all data required for data validation and analysis should be located in to same database, and
3. large database reduce the speed of storage and retrieval operations and require large disks.

The major bulk of the data is generally formed by equidistant time series data. These data are stored in one or more HIS-files located under catchment sub-directory DB. When more HIS-files are used, only the HIS-files, which store the data required for specific data processing activities will have to be loaded.

5.0 - DATA PREPARATION FOR TRANSFER

5.1 INTRODUCTION

Data can be entered in the HYMOS database in one of the following ways:

1. by reading from ASCII-files
2. via the data entry menus from the keyboard, and
3. through the HYMOS system as a result of computations.

In this section the layout of the ASCII-files for transfer of field data or data from other sources or data bases to the HYMOS database is dealt with for the following types of data:

1. equidistant time series,
2. non-equidistant time series, and
3. stage discharge data.

5.2 EQUIDISTANT TIME SERIES

5.2.1 General

Data are read from data files. Data files may consist of one or more data blocks of one or more series. The way the data are structured in the file and in the blocks is either specified in file- and block-headers or is entered via the screen, leading to the following options:

1. data files with headers, and
2. data files without headers.

For reasons of proper file documentation and safety in data transfer the option with header is strongly advocated. Both options are dealt with in this section.

5.2.2 Data files with headers.

5.2.2.1 File and Block Headers

The data in a particular file may be presented either in free or in fixed format and may be read, see Fig. 5.1 :

1. one series per block: time sequentially row-wise, or

2. one series per block:time sequentially column-wise, or
3. multiple series, per block structured parallel, i.e.column-wise

Further details may vary from block to block and are to be specified for each data block. Hence two types of headers must be used in a data file, viz.:

1. a File Header at the top of a data file, and
2. Block Header(s), one above each data block.

In the File Header the user specifies whether the data is to be read in fixed or free format and whether the data are time sequential row by row or column by column as a single or multiple series. The number of series in the data block, series code(s),start date, data block layout, conversion factor and reference level is contained in the Block Header. This leads to the following general file structure:

Data file :

```
                                File Header
        Block 1:                Header block 1
                                Data block 1
        Block 2                 Header block 2
                                Data block 2
        etc. for following blocks
```

File Header:

The File Header comprises 2 lines;

Line 1: the first 4 positions of the line must contain either the word FREE or the word FIXE:
FREE: the data will be read in free format
(data separated by blank(s) or a comma)
FIXE: the data will be read in fixed format
(each value has the same field length)

Line2: the first 3 positions of the line must contain either the word ROW,COL, or PAR:
ROW: one series per block and the data are time sequential row-wise
COL: one series per block and the data are time sequential column-wise
PAR: multiple series per block and the data are time sequential column-wise

Block Header(s)

The layout of the data Block Header depends beside on the layout of the data block, also on the contents of the File Header; following distinction is made:

1. single series row-wise reading,see section 5.2.2.2
   1.a File header = FREE+ROW
   1.b File Header = FIXE+ROW,

2. single series column-wise reading,see section 5.2.2.3
   2.a File Header = FREE+COL
   2.b File Header = FIXE+COL

3. multiple series column-wise reading,see section 5.2.2.4
   3.a File Header = FREE+PAR
   3.b File Header = FIXE+PAR

4. row- or column-wise reading with data conversion by formula,see section 5.2.2.5

5.2.2.2 Row-wise data blocks

1. Block Header for data in free format (File Header is FREE+ROW):

```
First line :   Series code first series (fixed format):
     pos. 1 - 10: station code
         11 - 12: data type
              13:time interval unit
          14- 15:time interval divider
                  (right justified)

Second line :  (NOTE:this line must end with a slash!)
               -start date
               (date in HYMOS format:yyyy, mm, dd, hh, si)
               -number of rows
               -number of columns
               -conversion factor, if required
               (default = 1.)
               -reference level, if required
               (default= 0.)
               -/
```

NOTE :

If the last record of the data block is incomplete (i.e. if the number of values is less than the number of columns), the record must end with a /(slash).

Example 5.1 at page E-1 illustrates the data entry using FREE+ROW format.

2. Block Header for data in fixed format (File Header is FIXE-ROW):

First line: Series code (fixed format):

pos. 1	-	10:	Station code
11	-	12:	data type
		13:	time interval unit
14	-	15:	time interval divider (right justified)

Second line:
- start date (date in HYMOS format: yyyy,mm,dd,hh,si)
- number of rows
- number of columns
- conversion factor, if required (default = 1.)
- reference level, if required (default = 0.)
- start position of first data field
- length of data field (all fields must have the

NOTE :

1. In this FIXEd-format reading one must not apply a"/"to break off an incomplete row at the end of a data block! (This is in deviation from the FREE-format reading case shown above.)

2. Because the start position of the first data field in a row is to be specified, the left side of the data blocks before the start position of the first data field will not be read and may therefore be used for some codes, e.g., dates etc..

Example 5.2 at page E-1 illustrates data entry using FIXE+ROW format.

5.2.2.3 Column-wise data blocks

1. Block Header for data in free format (file Header is FREE+COL):

First line: Series code (fixed format):

pos. 1	-	10:	station code
	11	-	12:	data type
			13:	time interval unit
	14	-	15:	time interval divider (right justified)

Second line: (NOTE: this line must end with a slash!)

- start date
  (date in HYMOS format: yyyy,mm,dd,hh,si)
- maximum number of rows (nrows)
- number of columns (ncolumns)
- conversion factor, if required
  (default = 1.)
- reference level, if required
  (default = 0.)
- /

Third line: number of rows in each column

Next lines: data blocks of size (nrows*ncolumns).

NOTE :

The columns should be completed with some value (e.g. 0) up to the maximum number of rows in a column, (see also columns 2 and 5 in the example shown below).

Example 5.3 at page E-2 illustrates data entry using FREE+COL format.

2. Block Header for data in fixed format (File Header is FIXE-COL):

First line: Series code (fixed format):

pos. 1	-	10:	Station code
	11	-	12:	data type
			13:	time interval unit
	14	-	15:	time interval divider (right justified)

Second line: (NOTE: this line must end which a slash!)

- start date (date in HYMOS format: yyyy,mm,dd,hh,si)
- maximum number of rows (nrows)
- number of columns (ncolumns)
- conversion factor, if required (default = 1.)
- reference level, if required (default = 0.)
- start position of first data field
- length of data field

Third line: number of rows in each column

Next lines: data blocks of size (nrows*ncolumns).

Example 5.4 at page E-3 illustrates data entry using FIXE+COL format.

5.2.2.4 Multiple series data blocks

If data blocks comprise more than one series, each column representing a different series, HYMOS can read the block:

-format free: then all column will be transferred, i.e. number of columns = number of series, or

-format fixed: then not all columns are necessarily transferred to the database, i.e. number of columns ≥ number or series.

This leads to the following Block Headers.

1. Block Header for data in free format (File Header is FREE+PAR):

First line: Number of series N_s in the data block (=number of columns)

Next N_s-lines: Series code(s),(fixed format),one per line:

pos. 1 - 10 : station code
11 - 12 : data type
13 : time interval unit
14 - 15 : time interval divider (right justified)

Next line: (NOTE:this line must end with a slash!)
-start date
(date in HYMOS format: yyyy, mm, dd, hh, si)

-number of rows (nrows), of equal length for all columns in the block
-number of columns (ncolumns), must be equal to N_s, the number of series
-conversion factor (if required), the same for all series (default = 1.)
-reference level (if required), the same for all series (default = 0.)
- /

Next lines: data block of size (nrows*ncolumns).

Example 5.5 at page E-4 illustrates data entry using FREE+PAR format.

2. Block Header for data in fixed format (File Header is FIXE+PAR):

First line: Number of series N_s in the data block to be transferred (≤ number of columns)

Next N_s-lines: Series code(s), start position and field length (fixed format), one per line:

pos. 1 - 10 : station code
11 - 12 : data type
13 : time interval unit
14 - 15 : time interval divider (right justified)
16 - 17: start position of series field (right justified)
18 - 19 : field length (right justified)

Next line: -start date (date in HYMOS format: yyyy, mm, dd, hh, si)
-number of rows (nrows), of equal length for all columns in the block
-conversion factor (if required), the same for all series (default = 1.)
-reference level (if required), the same for all series (default = 0.)

Next lines: data block of size (nrows*ncolumns).

Example 5.6 at page E-4 illustrates data entry using FIXE+PAR format.

5.2.2.5 Transfers with polynomial conversions

A polynomial type of conversion of data in a block, while transferring data to the HYMOS database, can only be applied to data blocks comprising one series, i.e. the cases where the second line in the file header reads ROW or COL. If a polynomials conversion is requested, then the Block Header is as follows:

First line: Series code (fixed format):

pos. 1	-	10:	Station code
11	-	12:	data type
		13:	time interval unit
14	-	15:	time interval divider (right justified)
16	-	22:	the word FORMULA

Second line: as for row-or column-wise time sequential reading with dummies for conversion factor and reference level

Third line: coefficients c_o, c_1, c_2, c_3 and c_4 (all of them and separated by commas) of the 4th order polynomial:

$$Y = c_o + c_1X + c_2X^2 + c_3X^3 + c_4X^4$$

The remainder is as before.

EXAMPLE (Hypothetical)

A data logger at station MANOT stores gate levels with intervals of 20 minutes. To transform the logger units to SI-units in meters above gauge zero a polynomial of the form is used:

$$H_{gate} = 3.675 + 4.354X + 0.3098X^2 - 3.505X^3 + 2.3966X^4$$

The logger units are in fixed format row-wise time sequential, 3285 rows and 8 columns. The first field in a row starts at the first position and the field length is 6. The first value is at 00.00 hrs 1 January 1990.

5.2.3 Data files without headers

Data files without headers requires data block(s):

1. in fixed format, and
2. with the data time sequential row-wise.

Data file	Comment
FIXE	File Header line 1
ROW	File Header line 2
MANOT HK4 3FORMULA	Block Header line1
1990,1,1,0,1,3285,8,1,0,1,8	Block Header line2
3.675 4.3354 0.3098 -3.505 2.3966	Block Header line3
.3884 .3884 .3884 .3884 .3884 .3884 .3884 .3884	row 1
.3884 .3884 .3884 .3884 .3884 .3884 .3884 .3884	row 2
.3884 .3884 .3884 .3884 .3884 .3884 .3884 .3884	row 3
.3884 .3884 .3884 .3884 .3884 .3884 .3884 .3884	row 4
etc.	

The series code, start date, block layout, conversion factor, reference level, start position of first data field and length of the data field are then entered from the screen.

5.3 NON-EQUIDISTANT TIME SERIES

The data files of non-equidistant time series comprise only one data block, which may contain a number of series, structured column-wise. For entry to the HYMOS data base a non-equidistant time series data file should have the following layout:

Line 1 to 10

pos. 1 - 10: station code of first series
11 - 12: data type of first series followed by similar declarations for the other data series on lines 2 to 10.

In case it is required to skip certain columns or the file contains less than 10 data columns, leave the corresponding lines open. A maximum of 10 columns of data can be loaded from the same file.

Next lines: per line (free format):
- year,
- month,
- day,
- hour,

- minute,
- value series 1,
- value series 2,
  etc.
- /

NOTE

It is not allowed to enter a column which contains empty spaces. In that case, the empty spaces have to be filled with for example the selected value for missing data!

Example 5.7 at page E-5 illustrates the format for data entry for Non-Equidistant time series.

5.4 STAGE-DISCHARGE DATA

The stage-discharge data file should have following layout:

First line: Station code (format A10)

Next line:
- year, month, day of the measurement
- number of the measurement
- gauge zero (m + M.S.L.)
- water level (m)
- discharge (m^3/s)
- gradient (m/day) or fall (m)
- width (m)
- wetted perimeter (m)
- cross-sectional area (m^2)

Etc. for the next lines.

NOTE

1. All data should be separated by comma's or blanks. To break off a record (if e.g. the last items are not available) use "/"; then the omitted values will be set to the default = 0.
2. Data should be in SI units.

Example 5.8 at page E-6 illustrates the format for the entry of stage-discharge data.

6.0 - DATA VALIDATION

6.1 SCREENING

6.1.1 General

As a first step in data validation screening of data is performed to obtain proper listings of series for easy reference and first checks on the range of data. HYMOS provides following options for first validation of series:

1. listing of series
2. screening of series,
3. comparison of series, and
4. tabulation of series.

The first option applies to equidistant and non-equidistant series; all other options can only be executed for equidistant time series.

The options are elaborated in the following sections.

6.1.2 Listing of series

Series can quickly be presented in dedicated tables and data blocks.

Dedicated tables:

For equidistant time series with the following time intervals tables with a dedicated layout can be obtained:

- 15 minutes,
- hour,
- day,
- decade
- month, and
- annual

Data blocks:

For equidistant and non-equidistant time series the data can be presented in data blocks by prescribing the number of rows and columns on one page.

Further options include:

- specification of number of decimals in the tables,
- coding of data:
  - ' ' = original data
  - '*' = series' element is completed
  - '+' = series'element is corrected

Example 6.1 and 6.2 on page E-7 and E-8 respectively presents listings in dedicated table and data block format respectively for daily rainfall data at Khudiyaghat station for the year 1982.

6.1.3 Screening of series

Screening of series comprises listing of equidistant time series, combined with:

1. computation of statistics, and
2. marking of outliers.

To what extent the options apply depends on the choice of the table.

In case of dedicated tables this includes:

- statistics:
  - effective number of data
  - number of data missing
  - sum and mean
  - standard deviation
  - coefficient of variation
  - minimum
  - maximum
  - number of data below lower boundary
  - number of data above upper boundary

- marking of outliers: data exceeding boundaries will be marked with '+'. The boundaries are determined in one of the following ways:
  - based on given boundaries: X^+, X^-
  - relative boundaries: $X^+ = m_x + \alpha . s_x$

    $X^- = m_x - \beta . s_x$

  where α and β are input and m_x and s_x refer to mean and standard deviation of series X; e.g. for monthly series these quantities refer to monthly mean and standard deviation.

In case of data blocks no statistics will be computed: only outliers exceeding the given boundaries X^+ and X^- will be marked.

An illustration of the screening option for daily rainfall data for Bajag station is presented in Example 6.3 on page E-9.

6.1.4 Comparison of series

The comparison option includes the selection of pairs of series with the same time interval. It provides the possibility to obtain a quick summary of differences between the two series. A table is provided showing the data for the time-steps the series differed. This option is particularly useful when differences between updated/corrected series and their original have to be detected.

Example 6.4 on page E-10 shows the use of this option in comparing the original and updated daily rainfall series at Khudiyaghat station. It may be seen that an extraordinary high rainfall as reported in the original data has been corrected to an acceptable value.

6.1.5 Tabulation of series

A listing is presented of up to 6 time series side by side. This technique is particularly useful to trace shifts between series , e.g. for rainfall data. These shifts may e.g. be caused by errors in dating of the data. Well known is the day shift for daily precipitation.

Example 6.5 on page E-10 illustrates the use of Tabulation option in trying to see if there is any shift in the values of six daily rainfall series.

6.2 TIME SERIES GRAPHS

6.2.1 General

The <time series graphs> option include graphs of:

- time series,
- residual series,
- residual mass curves,
- moving averages,
- water balances,
- barcharts of series availability.

These main options are typically meant for data validation purposes. Graphics for reports can better be made via the <graphics> option under <reporting>. Nevertheless, <time series graphs> provides a number of user options to improve the layout of graph. The main options are dealt with in the sections 6.2.2 to 6.2.7.

6.2.2 Time series

Up to 5 series can be plotted in one graph. Some examples of time series graphs, showing the flexibility of the option are shown in Fig. 6.1 and 6.2 given on page F-6 & F-7 respectively. From Fig. 6.1 a view of the monthly rainfall of 11 years for 5 stations may be taken at once. Discrepancy, if any, in this, may be looked into for finer details. Similarly, in Fig. 6.2, daily rainfall of four stations is plotted for the month of June. 1982. An unsual value at KHUDIYAGHAT station may at once be noticed.

6.2.3 Residual series

A residual series is a series plotted relative to the mean value of the series. The residual series gives a quick insight in wet and dry periods. This shows best if the series is plotted as bars. Although not strictly necessary, best is to plot only one series per graph. An example of residual series for monthly rainfall at five stations is shown in Fig. 6.3 on page F-8.

6.2.4 Residual mass curve

A residual mass curve represents accumulative departures from the mean. It is an efficient tool e.g. to detect climatic variabilities or other inhomogeneities. The residual mass curve Y_i is derived as follows:

$$Y_{x,i} = Y_{x,i-1} + (X_i - m_x) = \sum_{j=1}^{i} (X_j - \frac{1}{N} \sum_{k=1}^{N} X_k) \quad \ldots \qquad (1)$$

where: N ⇒ number of elements in the series

The curve can be interpreted as follows:

- an upward curve indicates an above average sequence
- a horizontal curve indicates an about average sequence, and
- a downward curve indicates a below average period

The original series X_i can be plotted together with the residual mass curve if so required, by selection of <plot series>.

An example is shown in Fig. 6.4 on page F-9 in which residual mass curve for DINDORI station is plotted. It may be inferred from this plot that from 1981 it started to be drier period which gradually ultimately became wetter in the year 1990. This inference would be stronger if the length of the data is more.

6.2.5 Moving Average

To investigate the long term variability or trends in series moving average curves are useful. A moving average series Y_i of series X_i is derived as follows:

$$Y_{x,i} = \frac{1}{2M + 1} \sum_{j=i-M}^{i+M} X_j \qquad (2)$$

where averaging takes place over 2M+1 elements. An element of the moving average series gets a missing value if one of the X_j is missing.

Fig.6.5 on page F-10 shows the moving average of monthly rainfall at GITHORI station.

6.2.6 Balance

To check the consistency of series the mass conservation condition is often a useful investigative tool. This applies in particular to discharge series. Basically, water balances are made of discharge series of successive stations along a river or of stations around a junction, where there should be a surplus, a balance or a deficit, depending on water is added or lost. To give full flexibility in using this option signs and multipliers to series values are input. At maximum 4 series can be selected. The balance equation $Y_i = F(X_{\cdot,i})$ reads:

$$Y_i = \pm\, a.X_{1,i} \pm b.X_{2,i} \pm c.X_{3,i} \pm d.X_{4,i} \qquad (3)$$

where : a,b,c,d = multipliers entered by user (default = 1)

$\pm$ = sign entered by user (default = +)

In the balance plot two function axes, one for the X_j's and one for Y_i can be specified.

6.2.7 Series availability

The availability of equidistant and non-equidistant time series can be presented in a bar chart. The availability of data of up to 20 series can be shown in one chart. In case of equidistant time series all series should have the same time interval. The series can be selected randomly, from the displayed scrolling menu, or sequentially. In the latter case the sequence corresponds with the sequence in the scrolling menu; the first and last series code have to be indicated.

In the legend of the barchart symbols for missing data and empty vectors (space where no data are loaded yet) are given.

In case of non-equidistant time series the number of data per calendar unit are presented.

An example of a barchart of series availability is presented in Fig. 2.2 on page F-4.

6.3 RELATION CURVES

6.3.1 General

A relation curve gives a functional relationship between two series of the following form $Y_t = F(X_{t+t1})$. The curves can be used for :

1. detection of random errors,
2. detection of systematic errors,
3. filling in of missing data, and
4. forecasting purposes,

If there is a strong one to one relationship between two series random errors will be shown in a relation curve plot as outliers. To arrive at a one to one relationship (i.e:elimination of loopings) the introduction of a time shift (t1) between the two series may be necessary.

By comparing two relation curves or data of one period with the curve of another period, shifts in relationships, e.g. in water level series due to changes in the gauge zero, can be detected.

The relation curve fitted to the data of two series can be used to fill-in missing data in the dependent variable of the relation (Y) (also see section 7.1 on Interpolation).

If the series in the relation are mutually shifted in time, with sufficient lead-time for the independent variable X(t1 negative), the relation curve may be used to forecast the dependent variable in the relation Y from observations on X.

The parameters of the established relationships for a period of time can be stored in the data base for e.g. later comparison, filling-in missing data.

The main options under <relation curves>includes:

- optimization of time shift t1,
- plotting of time series data Y_t versus X_{t+t1},
- fitting a polynomial to Y_t, X_{t+t1},
- validation of relation curve,
- display and comparison of relation curves.

Fig.6.6 on page F-11 gives the plot of relation curve, alongwith the data, of monthly rainfall series values of two very nearby stations MANDL1 & MANDL2.

The equation of the relation curve is given by :

Y = 0.8 + 1.0765 X - 0.1081*10**(-3) X**2

The standard error for the above is 28.06.

6.4 DOUBLE MASS ANALYSIS

6.4.1 General

Double mass analysis is a technique to detect possible inhomogeneities in series, like jumps, trends, etc. by investigating the ratio of accumulated values of two series, viz:

- the series to be tested, and
- the base series.

The base series is generally an artificial series, i.e. the average of reliable series of nearby stations, which is assumed to be homogeneous.

The result of the analysis is presented in a table and in a plot: the double mass curve. This curve will show a straight line if the test-series is homogeneous. A jump in the test-series will create a break in the double mass curve, whereas a trend will create a curved line.

In the tabular results 9 columns are presented:

1. time.
2. value of series X
3. accumulated value of series X
4. accumulated value as a percentage of the total of X
5. value of series Y
6. accumulated values of series Y
7. accumulated value as a percentage of the total of Y
8. ratio (item 3)/(item 6), equation 4
9. ratio (item 4)/(item 7), equation 5

Example 6.6 and Fig.6.7 on page E-11 and F-12 gives the results of the double mass analysis in Tabular and graphical form respectively. In this illustration rainfall at Barbaspur station is checked with the help of four base stations, namely, Dindori, Sakka, Vikrampur, Githori.

If the curve shows a distinct break with curve slopes α before and β after the break, adjustment may take place in two ways:

- either the data before the break are adjusted to the present conditions by multiplication by the ratio : β/α, or
- the data after the break are adjusted to the pre-break conditions : in that case the recent data are multiplied by a factor α/β.

The correction can be materialised by the transformation option of HYMOS under <data compilation >.

6.5 SERIES HOMOGENEITY TESTS

6.5.1 General

Dependent on the type of analysis series must fulfill one or more of the following requirements :

- stationarity: i.e. the properties or characteristics of the series do not vary with time,
- homogeneity: i.e. all elements of a series belong to the same

- population ;
- randomness: i.e. series elements are independent.

HYMOS includes following statistical tests to investigate series' stationarity, homogeneity or randomness :

1. Median run test: a test for randomness by calculating the number of runs above and below the median ;
2. Turning point test : a test for randomness by calculating the number of turning points;
3. Difference sign test :a test for randomness by calculating the number of positive and negative differences;
4. Spearman rank correlation test :the Spearman rank correlation coefficient is computed to test,
   - the existence of correlation between two series,
   - the significance of serial rank correlation, and
   - the significance of a trend;
5. Arithmetic serial correlation coefficient: a test for serial correlation;
6. Wilcoxon-Mann-Whitney U-test: a test to investigate whether two series are from the same population;
7. Student t-test : a test on difference in the mean between two series ;
8. Wilcoxon W-test : a test on difference in the mean between two series ;
9. Linear trend test :a test on significance of linear trend by statistical inference on slope of trend line ;
10. Range test :a test for series homogeneity by the rescaled adjusted range.

Notes:

1. The Spearman rank correlation test may be used as a single or two series test; in the single series mode it tests the significance of correlation with time.
2. Tests nrs. 6,7 and 8 (Wilcoxon-Mann-Whitney U-test, Student t-test and Wilcoxon W-test) are basically two series tests; however, the test can also be used for a single series by means of the split-sample approach, where a series is divided into two parts, which are mutually compared.

Example 6.7 and 6.8 on page E-11 and E-14 gives the results of one and two series test for daily rainfall series for Bajag and Dindori & Githori rainfall series respectively.

6.6 SPATIAL HOMOGENEITY TESTS

6.6.1 General

The test described here is applicable to quality and quantity parameters with a spatial character, like rainfall, temperature, evaporation, etc., but sampled at a number of stations (point measurements).

To investigate the reliability of point observations at a station, called the base station, the observations are compared with weighted averages of the rainfall at neighbor stations. The weights are inversely proportional to some power of the distance between the base station and the neighboring stations. The test considers the difference between the observed and estimated values at the base station. If the absolute difference between observation and estimate exceeds specific limits (absolute and relative), the observation will be flagged out (not deleted) to stress the need for further investigation.

6.6.2 Test procedure

To be specific and to avoid general phrasing the test is explained here for rainfall series, where rainfall may be replaced by any other spatial parameter.

In this section the following topics are discussed:

- selection of neighbor stations
- estimation of point rainfall
- test criterion
- corrections for heterogeneity
- limitations

Selection of neighbour stations:

Following criteria are used to select the neighbors of the base station:

1. series with the same data type and interval as the one under investigation should be available
2. the distance between the basic station and a neighbour should be less than a specified maximum correlation distance R_{max} (km);
3. maximum amount of neighbors is 8;
4. per quadrant at maximum 4 stations out of 4 fulfilling criterion 2 can be selected, see Fig. 6.8, but criterion 3

remains valid, default are the two stations nearest to the base station.

The selection on quadrants is applied to obtain a proper spatial distribution of stations around the base station. However, due to prevailing wind conditions or orographical effects spatial heterogeneity may be present. In those cases normalized rather than actual values should be investigated.

Estimation of point rainfall:

The point estimate for the base station based on the observations at N neighbour stations for the same time interval reads :

$$P_{est}(t) = \frac{\sum_{i=1}^{N} P_i(t)/D_i^b}{\sum_{i=1}^{N} 1/D_i^b} \qquad (4)$$

where:

$P_{est}(t)$	= estimated rainfall at the base station at time t
$P_i(t)$	= measured rainfall at neighbour station i at time t
D_i	= distance between the base station and neighbour station i
N	= number of neighbour stations taken into account
b	= power of distance D, (usually b = 2).

Test criterion:

The difference between the observed value, $P_{meas}(t)$, and the estimated value, $P_{est}(t)$, is considered to be insignificant if the following conditions are met :

$$|P_{meas}(t) - P_{est}(t)| \leq X_{abs} \text{, and} \qquad (5)$$

$$|P_{meas}(t) - P_{est}(t)| \leq X_{rel} * S_{P_{est}(t)} \qquad (6)$$

with :

X_{abs} =admissible absolute difference

$S_{pest(t)}$ = standard deviation of neighbouring values, see equation (7)

X_{rel} = multiplier of standard deviation

$$S^2_{P_{est}}(t) = \frac{1}{N} \sum_{i=1}^{N} (P_i(t) - \bar{P}_i(t))^2 \qquad (7)$$

If the difference is unacceptably high, the recorded value is flagged "+" or "-", depending on whether the observed total is greater or less than the estimated. In case no estimate is available the value will be flagged with "*". Only the flagged , i.e. the suspicious, data will be printed.

Corrections for hetrogeneity

To correct for sources of heterogeneity, e.g. orographical effects, normalised rather then actual values may be used. This implies that in the equations (4) through (7) the observations at the neighbour stations are multiplied by the ratio of the base station normal and the neighbour station normal :

$$P_{ci} = (N_{base}/N_i).P_i \qquad (8)$$

where :

P_{ci} =for heterogeneity corrected value at neighbour station i

N_{base} =normal of base station

N_i =normal of neighbour station i

The station normals are read from a station-normal file or are given as a function of the altitude of a station.

The data for the former option can be entered via <station normals> of <input data files> from the <data entry & editing> menu.

The station normal as a function of the station altitude are of the following form :

$$N_i = a_1 + b_1 . H_s \qquad \text{for } H_s < H_1 \qquad (9)$$

$$N_i = a_2 + b_2 . H_s \qquad \text{for } H_s > H_1 \qquad (10)$$

Limitations:

Following limitations to the use of the spatial validation option apply:

1. Only series of the same type are considered
2. Only series with the same time interval are considered
3. Generally, all series available in the data base of the selected data type and time interval will be considered.

Example 6.9 on page E-16 gives the results for the spatial homogeneity test for the daily rainfall at Vikrampur station.

7.0 - SERIES COMPLETION AND REGRESSION

7.1 INTERPOLATION

7.1.1 General

To fill - in missing data HYMOS offers following interpolation methods :

- linear interpolation
- use of relation equations
- spatial interpolation

The methods are presented in the sections 7.1.2 to 7.1.4

7.1.2 Linear interpolation

In a number of cases gaps in series can well be filled in by linear interpolation between the last value before the gap and the first one after, provided that the distance over which the interpolation takes place is not too large.

The use of this option requires following input :

- selection of series interval,
- selection of series (from a scrolling menu),
- the period to be considered for filling -in , and
- the maximum interpolation distance (expressed as a number of time intervals). This means that gaps larger than this maximum will not be filled -in.

7.1.3 Relation equation

Relation/regression equations can be used to fill-in missing data, provided that the standard error in the fit is small. Since relations between stations may change seasonally, HYMOS offers the option to apply a relation only to a period in the year, to get the best estimate possible for the data gap.

The following types of equations may be used to fill-in missing data :

-Polynominal
-Simple linear
-Expotential
-Power

-Logarithimic
-Hyperbolic
-Multiple linear

7.1.4 Spatial interpolation

The spatial interpolation technique is applicable to quality and quantity parameters with a spatial character, like rainfall, temperature, evaporation, etc., but sampled at a number of stations (point measurements). Missing data at a base station are estimated by weighted averages on observations at neighbour stations. The weights are inversely proportional with some power of the distance between the base station and the neighbour stations.

The procedure of selection of neighbour stations and correction for hetrogeneity has been discussed in section 6.6.2.

Estimation of point rainfall:

The point estimate for the base station based on the observations at N neighbour stations for the same time interval is given by equation 6.

This option is utilized for filling the missing values of all the daily rainfall series in the data base.

7.2 REGRESSION ANALYSIS

7.2.1 General

The regression analysis option in HYMOS includes:
-computation of correlation matrix, and
-fitting of following type of functions
- -polynomial
- -simple linear
- -exponential
- -power
- -logarithmic
- -hyperbolic, and
- -multiple linear.

The multiple linear functions can be fitted by means of multiple or stepwise regression techniques.

The main steps in running the regression option include:

-input: to enter the data set,
-function: to select one of the available functions,
-select: to select the series in regression, and
-store: to store parameters in the data base.

7.2.2 Regression equations

The following types of regression equations are available, with Y the dependent variable and X_i's the independent variables:

1. polynomial

$$Y_i = \sum_{j=0}^{n} C_j X_i^n \qquad (11)$$

with : n = degree of polynomial : $n \leq 9$,

C_j = coefficient

2. simple linear

$$Y_i = A + B.X_i \qquad (12)$$

with : A,B = coefficients

3. exponential

$$Y_i = A \exp (B.X_i) \qquad (13)$$

with: A,B - coefficients

4. exponential

$$Y_i = A \exp (B/X_i) \qquad (14)$$

with : A,B - coefficients

5. power

$$Y_i = A.X_i^B \qquad (15)$$

with: A,B = coefficients

6. logarithmic

$$Y_i = A + B.\ln(X_i) \qquad (16)$$

with: A, B = coefficients

Example 7.1 and Fig. 7.1 on page E-17 & F-11 respectively illustrates the use of regression analysis for monthly rainfall at

BARBASPUR and the areal average of MANOT sub-basin.

8.0 - PROCESSING OF FLOW MEASUREMENTS

8.1 GENERAL

HYMOS can treat two types of flow measuring methods:

1. point velocity method
2. moving boat method

In both cases average velocities in a number of verticals in the cross-section are computed. From these velocities the discharge is computed by:

1. mean-section method
2. mid-section method

8.2 FITTING OF RATING CURVE

8.2.1 General

HYMOS includes following options to fit stage-discharge data by a rating curve:

1. simple rating curve
2. rating curve with unsteady flow correction
3. rating curve with backwater correction.

The rating curve parameters are stored in the database. A rating curve is valid for a certain period of time. Each curve can be described by at maximum 3 sets of parameters valid for a specific water level-range. The curves may be of the parabolic or of the power type equation.

Full reports of the quality of fit and linear and double-logarithmic scale plots of the stage-discharge data and rating curve can be obtained.

In addition to the above options a procedure is included to qualify shift adjustments on water levels to account for river bottom variations in the stage-discharge conversion.

8.2.2 Before computation

A print-out of the stage-discharge data together with linear and double logarithmic plots are useful prior to the determination of the parameters of the rating curve:

- to check the availability of data within water-level ranges, and

- to investigate distinct breaks in the double logarithmic stage-discharge plot, which marks the range of applicability of sets of parameters in the rating curve.

It is advised to use approximately the same amount of data points per unit of depth in the determination of a set of parameters of a rating equation applicable to a certain water level range.

8.2.3 Simple rating curve

When unsteady flow and backwater effects are negligibly small the stage-discharge data can be fitted by a simple relationship, valid for a given period of time and water level range.

Following rating equations can be applied:

- parabolic type:

for $h_i < h \leq h_{i+1}$: $$Q = a_1 + b_1 h + c_1 h^2 \qquad (17)$$

- power type:

for $h_i < h \leq h_{i+1}$: $$Q = c_2 (h + a_2)^{b_2} \qquad (18)$$

where:

Q = discharge (m^3/s)

a_i, b_i, c_i = parameters

h_i, h_{i+1} = lower and upper water level for which the rating equation applies.

The coefficients a_1, b_1 and c_1 of the parabolic equation are determined by the least squares method. The shift parameter a_2 in the power equation is either input or determined by an adapted Johnson method. A computerized Johnson method (see for a description of the method e.g. WMO Operational Hydrology Report no.13, 1980) is used to get a first estimate of a_2 and subsequently the coefficients b_2 and c_2 are determined by the least squares method applied to the logarithms of Q and ($h + a_2$). Next the estimate for a_2 is varied within 2m around its first estimate to obtain a set of parameters for which the mean square error is minimum.

Each rating curve may consist of a maximum 3 equations (3 sets of parameters valid for specific water-level ranges).

Example 8.1 on page E-17 illustrates the fitting of simple rating curve for gauge-discharge data at Manot G-D site for the period between 1-6-90 and 31-12-90. Fig. 8.1 & Fig. 8.2 on pages F-14 & F-15 gives the rating curve on linear and double-logarithmic scale respectively .

8.2.4 Rating curve with unsteady flow correction

If the rate of change of the water level is high the stage-discharge relation will not be unique but it will show loopings for the rising and falling stages. Omitting the acceleration terms in dynamic flow equation the relation between the unsteady discharge Q_m and steady discharge Q_c,

$$Q_m = Q_c \sqrt{\left(1 + \frac{1}{SV_w}\frac{dh}{dt}\right)} \qquad (19)$$

The factor $1/SV_w$ varies with the water level. This factor is fitted by a parabolic function of h:

$$\frac{1}{SV_w} = a_3 + b_3\ h + c_3\ h^2 \qquad \text{for } h > h_{min} \qquad (20)$$

with: h_{min} = the lowest water level for which the Jones correction has to be applied.

In addition to h_{min} a maximum value for $1/SV_w$ has to be entered as well to avoid that unacceptably high values of $1/SV_w$ take part in the fit of equation 22.

8.2.5 Rating curve with backwater correction

Stage-fall-discharge or the twin gauge station fall discharge methods are used to include backwater effects on stage discharge ratings. HYMOS includes:

1. constant fall method
2. normal fall method

In these methods the fall F between the water level at the discharge measuring site and a downstream station is considered as an additional parameter, to account for the effect of water surface slope on discharge. Both methods are based on the following equation:

$$Q_m = Q_r \left(\frac{F_m}{F_r}\right)^p \tag{21}$$

where Q_m – backwater affected discharge
Q_r – reference discharge
F_m – measured fall
F_r – reference fall
p – power, with: $0.4 \leq p \leq 0.6$

Constant fall method:

In this method the reference fall F_r is taken as a constant. A special case of the constant fall method is the unit fall method, where $F_r = 1$ m is applied.

In the computational procedure a value for F_r is assumed. Then a rating curve is fitted to the values:

$$Q_m = Q_r \left(\frac{F_r}{F_m}\right)^p \tag{22}$$

according to the standard procedure outlined in Chapter 8.2.3. The value for p is optimized between the boundaries 0.4 and 0.6 based on the least squares principle.

In the plot the fit of Q_r to the rating curve is shown, whereas in the error analysis the measured discharge Q_m is compared with the computed discharge according to eq.(21).

Normal fall method:

In this method the reference fall F_r is modelled as a function of the water level: $F_r = f(h)$. This function is represented by a parabola:

$$F_r = a_4 + b_4 h + c_4 h^2 \qquad (23)$$

valid for $h > h_{min}$ where h_{min} is a lower threshold of h above which the backwater correction is applied.

The normal fall method goes in two steps:

1. computation of the backwater free rating curve to represent the reference discharge Q_r
2. fitting of normal fall equation (23) to the reference falls.

Backwater free rating curve:

To isolate the backwater free data from the rest of the measurements a data flag = 2 has to be added to the data. This is done by selection of option <Adjust> from the screen and replacement of flag = 1 by 2 where applicable. Then to all backwater free data a rating curve is fitted analogous to the simple rating curve procedure described in Chapter 8.2.3. Note that sufficient backwater free data have to be available for a proper fit, else data have to be added (temporarily) to shape the rating curve.

Reference fall:

Next all remaining data above h_{min} with backwater effect are used to fit a parabola (23) to the reference fall computed as :

$$F_r = F_m \left(\frac{Q_r}{Q_m}\right)^{1/p} \qquad (24)$$

where; Q_r is the reference discharge $Q_r = f(h)$ computed from the backwater free stage discharge data. The parameter p is optimized between 0.4 and 0.6.

8.3 VALIDATION OF RATING CURVE

8.3.1 General

In section 8.2 the following fitting procedures of stage discharge data is dealt with:

1. simple rating curve
2. rating curve with unsteady flow correction
3. rating curve with backwater corrections using:
- constant fall, and

- normal fall.

The option VALIDATION OF RATING CURVE covers the situation where a rating curve was developed previously and additional measurements become available. With HYMOS the validity of the existing rating curve for the new measurements can be evaluated.

8.3.2 Analysis

The analysis starts with the selection of the stage discharge measurements and the rating curve. In addition the number of data used for the fitting of the original rating curve and the standard error of the fit have to be entered for each water level interval, in which the rating curve has been split, to allow statistical tests.

Validation can be done in various ways:

1. examination of the goodness of fit from the stage discharge plot
2. examination of tabulated results:
   - difference between observed and computed discharge
   - time sequence of difference
   - relative difference
   - statistical test on fit.

HYMOS carries out a Student t-test on differences between the rating curve and the new measurements.

Let the number of data used to determine the rating curve be N and the number of new data N_1 and the percentage difference in both cases be denoted by respectively ΔQ and ΔQ_1 then the test statistics t becomes:

$$t = \frac{\overline{\Delta Q_1}}{a \cdot b} \qquad (25)$$

with

$$a^2 = \frac{\Sigma(\Delta Q)^2 + \Sigma(\Delta Q_1 - \overline{\Delta Q_1})^2}{N + N_1 - 2} \qquad (26)$$

$$b^2 = (N + N_1)/(N \cdot N_1) \qquad (27)$$

In Example 8.2 on page E-18 validation of rating for year 1989 at Manot gauging site is done against the data of year

1990. The corresponding plot is shown in Fig. 8.3 & Fig. 8.4 on page F-16 & F-17 gives the plot of the validation of the rating curve on linear and double-logarithmic scale respectively.

8.4 EXTRAPOLATION OF RATING CURVE

8.4.1 General

The following procedures may be considered to extrapolate the stage discharge relation (ISO, 1982):

1. double logarithmic straight line extrapolation.
   If the hydraulic characteristics of the control section do not change beyond the measured range, the power type stage discharge relation is assumed to remain valid in the lower and upper end.
2. extension of the stage area (h-A) and stage-velocity (h-v) curve beyond the measured range.
   This procedure is based on the observation that the h-v relation has little curvature under normal circumstances. The product of A and v can be used to obtain values of Q in the lower and upper end.
3. Extrapolation based on the Manning's or Chezy's equation for steady flow.

HYMOS includes graphical and numerical options to assist in the generation of synthetic stage discharge data in the extrapolation range by:

1. computation of cross sectional data
2. display of geometrical and hydraulic quantities in the measured range
3. computation of the same quantities in the extrapolated range from cross sectional data, slope and roughness.

8.5 STAGE-DISCHARGE TRANSFORMATION

8.5.1 General

Water level series can be transformed in discharge series by use of a stage discharge relation of one of the following forms:

1. simple rating curve
2. rating curve with unsteady flow correction

3. rating curve with constant fall backwater correction
4. rating curve with normal fall backwater correction
5. general structure database
6. user structure equation
7. measuring structure relations

For a particular station the combination of water level(s) and discharge series, cross-sections and structure parameters required to transform stages into discharges can be stored in the database to facilitate the transformation at subsequent occasions.

Fig. 8.5 on page F-18 illustrates the use of rating curve developed in Example 8.1 to transform the hourly values of water level at Manot G-D site for the period between 1-6-90 and 31-12-90.

9.0 - DATA COMPILATION

9.1 (DIS-) AGGREGATION

9.1.1 General

Aggregation of series implies the creation of a series with a larger time interval, by adding or averaging data of the series with the smaller interval: for example aggregation of series with an interval equal to one day to a series with an interval of one month, or from month to year, etc.. Disaggregation is the opposite process: by disaggregation, series with a smaller time interval are created. The various aggregation and dis-aggregation options are explained in the sections 9.1.2 and 9.1.3 respectively.

9.1.2 Aggregation

Basic and resulting series:

The original series. i.e. the series to be aggregated, is called basic series. The series with the aggregates is called the resulting series.

In aggregating series, two cases are distinguished:

1. for instantaneous observations the aggregated data are averages of the originals, e.g. discharges in m^3/s.
2. for accumulative observations the aggregated data are the sums of the originals, e.g. rainfall or discharges in mm.

All the available daily rainfall series have been aggregated to monthly series. The resulting monthly series have been aggregated to annual series.

9.1.3. Dis-aggregation

Basic and resulting series:

The original series i.e. the series to be dis-aggregated, is called basic series. The series with the dis-aggregates is called the resulting series.

In disaggregation of series following options exist:

1. for instanteneous observations
- basic and resulting series data are equal
- resulting series data are interpolated linearly between the mid point values of the basic series data;
2. for accumulative observations
- resulting series data for fractions of the basic series data, derived by division by the number of resulting series intervals in a basic series interval,
- as above, but additionally with a linear interpolation between the midpoints of the basic series intervals.

9.2 SERIES TRANSFORMATION

9.2.1 General

The series transformation option of HYMOS includes:
- algebraic transformation of series,
- transformation of non-equidistant series into equidistant series,
- creation of accumulative series, and
- error spreading.

These transformation options are dealt with in sections 9.2.2 to 9.2.5.

9.2.2 Algebraic transformations

The following algebraic transformations are possible to create a series Y by some function of series X_j, j = 1,2,...

1. linear equation

$$Y_i = C_1.X_{1,i} + C_2.X_{2,i} + C_3.X_{3,i} + C_4.X_{4,i} + C_5.X_{5,i} + C_6$$

2. multiplication $Y_i = X_{1,i} * X_{2,i}$

3. division $Y_i = X_{1,i} / X_{2,i}$

4. involution $Y_i = X_{1,i} \wedge X_{2,i}$

5. natural logarithm $Y_i = \ln(X_i)$

6. common logarithm $Y_i = {}^{10}\log(X_i)$

7. exponential $Y_i = \exp(X_i)$

8. power of 10 $Y_i = 10\hat{\ }X_i$

9. power $Y_i = X_i\hat{\ }C$

10. power of constant $Y_i = C\hat{\ }X_i$

where X_j = equidistant time series

C_j = coefficients

In the application of the above transformations different start dates can be applied for each of the series.

9.2.3 Non-equidistant to equidistant series

Non-equidistant time series can be transformed into equidistant time series. Generally, the non-equidistant series may not fill all equidistant time steps. One can select one of the following options to solve this problem:

- zero: the series values at intermediate time steps will be filled with zero's
- missing: the series values at intermediate time steps will be filled with missing values
- linear: the series values at intermediate time steps will be a linear interpolation between surrounding non-equidistant series observations
- equal to last: the series values at intermediate time steps will be equal to the last observation, (i.e. block type filling in)

9.2.4 Accumulative series

Under the accumulative series option a series Y is created which is a continuous summation of a basic series X as follows:

$$Y_i = \sum_{j=1}^{i} X_j$$

9.3 MINIMUM AND MAXIMUM SEARCH

This option of HYMOS comprises the computation of minimum, maximum and mean values for specific time periods.

Minimum, maximum and mean values for following time periods can be obtained:
- day
- month
- year
- period within the year

The results, i.e. minimum, mean and/or maximum series can be written to the data base or stored in a file.

9.4 AREAL RAINFALL

9.4.1 General

HYMOS offers a number of options to compute catchment rainfall from point rainfall data. The methods differ in the weights given to the point rainfall stations. Following weights are possible:

1. equal station weights,
2. user provided station weights,
3. weights according to Thiessen method, and
4. weights according to kriging method.

There are two ways to enter the codes and weights of the point rainfall stations:

1. the series are selected from the displayed series and the weights are entered manually (method 2) or are computed, or
2. the series codes and weights are read from a file, prepared at a previous occasion.

9.5 KRIGING

9.5.1 General

HYMOS includes point and block kriging methods.

The point kriging option is used to:

- compute areal rainfall
- plotting of isolines (isohyets, isopotentials, etc.),
- design of measuring networks, and
- computation of rainfall station weights.

For computation of catchment rainfall and plotting of isohyets use is made of the kriging technique. For this a rectangular grid is placed over the catchment (=area of interest). Estimates of the rainfall at the grid points is obtained as a weighted average of the rainfall at surrounding stations. The station weights are determined by kriging and depend on the distances between the grid points and the rainfall stations on the one hand and the adopted covariance model on the other. The estimates for the grid points are expressed in a statistical way: the kriged value, which is the best estimate (unbiased and minimum variance), and the uncertainty in this value indicated by the standard deviation of the estimate. The technique can also be applied to other quantities with a spatial character. Well known is the application to derive groundwater level contours.

The weights for all stations in and around the Manot sub-basin taking the daily rainfall values and based on this method is given in Example 9.1 on page E-20. In this example the generalised covariance function is assumed.

The block kriging method is used to compute the best linear estimate and variance of rainfall in an area. Example 9.2 on page E-21 gives the results of this option taking the monthly rainfall values. Fig. 9.1 and 9.2 on page F-19 and F-20 gives the plot of monthly isohytes and the isolines for its satndard deviation.

10.0 - STATISTICAL ANALYSIS

10.1 BASIC STATISTICS

10.1.1 General

The following statistics and distributions are included in this option:

- minimum value
- maximum value
- mean value
- median
- mode
- standard deviation
- skewness
- kurtosis
- empirical frequency distribution, and
- empirical cummulative frequency distribution

10.1.2 Selection of data

Data for statistical analysis can be entered in two ways:

- from HYMOS data base, or
- from file

If the data are read from the HYMOS data base following type of data can be considered:

- actual values
- annual minimum values, and
- annual maximum values.

Example 10.1 on page E-22 gives the basic statistics of non-zero areal average rainfall of the Manot sub-basin. Fig. 10.1 on page F-21 gives the plot of the histogram and cummulative frequency.

Example 10.2 on page E-23 gives the basic statistics of the annual maximum of the daily areal average rainfall of the Manot sub-basin.

10.2 FITTING DISTRIBUTION

10.2.1 General

HYMOS includes the fitting of the commonly used theoretical frequency distributions:

1. Normal distribution
2. Log-normal distribution
3. Box-Cox transformation to normality
4. Pearson Type III or Gamma distribution
5. Raleigh distribution
6. Exponential distribution
7. General Pearson distribution
8. Log-Pearson Type III distribution
9. Extreme Type I or Gumbel distribution
10. Extreme Type II or Frechet distribution
11. Extreme Type III distribution
12. Goodrich/Weibull distribution
13. Pareto distribution, and
14. Peaks over Threshold (POT)-method for extremes (Pareto distribution)

For each distribution one can obtain:

- estimation of parameters,
- summary of observed and theoretical probabilities,
- goodness of fit-tests - binomial,
  - Kolmogorov-Smirnov,
  - Chi-squares,
- computation of extreme values for specific return periods, either related to probability of non-exceedance or exceedance, and
- plot of distribution function with 95% confidence limits (optional).

Example 10.3 on page E-25 illustrates the fitting of GVI type of distribution to the annual maximums in the daily areal average seires of the Manot sub-basin rainfall. Fig.10.2 on page F-22 gives the corresponding plot of the distribution function.

Example 10.4 on page E-26 illustrates the fitting of the Normal distribution to the annual areal average rainfall of the Manot sub-basin. Fig. 10.3 on page F-23 gives the corresponding plot of the distribution function.

Example 10.5 on page E-28 illustrates the fitting of the Normal distribution annual maximum of the monthly areal average rainfall of the Manot sub-basin. Fig. 10.4 on page F-24 gives the corresponding plot of the distribution function.

10.3 STATISTICAL TABLES

10.3.1 General

Variates, probabilities of non-exceedance and return periods can be computed for the following frequency distributions:

1. Normal distribution
2. Log-normal distribution
3. Box-cox transformation to normality
4. Pearson Type III or Gamma distribution
5. Raleigh distribution
6. Exponential distribution
7. General Pearson distribution
8. Log-Pearson Type III distribution
9. Extreme Type I or Gumbel distribution
10. Extreme Type II or Frechet distribution
11. Extreme Type III distribution
12. Goodrich/Weibull distribution
13. Pareto distribution
14. Peaks over Threshold (POT)-method for extremes (Pareto distribution)
15. Student-t distribution and
16. Fisher F-distribution

Example 10.6 on page E-29 illustrates the use of the statistical table for the Normal distribution for a mean value of 15.0 with the standard deviation as 2.5.

10.4 GENERATION OF RANDOM VARIABLES

Normal and gamma distributed variables can be generated. The maximum length of the generated series is 1000.

The user has to provide the required number of data to be generated and the model parameters:

1. for the normal distribution the parameters:
   - mean of X,
   - standard deviation of X
2. for the gamma distribution the parameters:
   X_0 = location parameter, ($X_0 \leq X$)
   β = scale parameter

Example 10.7 on page E-29 illustrates the generation of 100 random numbers having Normal distribution with mean value to be 15.0 and standard deviation equal to 2.5.

10.5 FREQUENCY AND DURATION CURVES

10.5.1 General

The frequency and duration curve option of HYMOS includes the computation and plotting of:

- frequency curves,
- duration curves, and
- average duration curves.

A convenient way to show the variation of hydrological quantities through the year, by means of frequency curves, where each frequency curve indicates the magnitude of the quantity for a specific probability of non-exceedance. The duration curves are a ranked representation of these frequency curves. The average duration curve gives the average number of occasions a given value was not exceeded in the years considered.

Example 10.8 on page E-30 gives the results of the analysis for frequency and duration curves for the monthly areal average series for the sub-basin. Fig. 10.5 and Fig. 10.6 on page F-25 and F-26 gives the corresponding figures of frequency and duration curves.

11.0 - TIME SERIES ANALYSIS

11.1 INTRODUCTION

Time series analysis includes the execution of following types of analysis:

1. Correlation analysis
2. Spectral analysis
3. Range analysis
4. Run analysis

The analysis for the above is described in the next sections.

11.2 CORRELATION ANALYSIS

11.2.1 General

Correlation analysis covers the computation of:

1. auto-covariance function
2. auto-correlation function
3. cross-covariance function
4. cross-correlation function

HYMOS produces tabular and graphical presentations of these functions.

11.2.2 Auto-covariance and auto-correlation functions

For the series x_i, $i=1,N$ the auto-covariance function $c_{xx}(k)$, $k = 0, L_{max}$ is computed as follows:

$$c_{xx}(k) = \frac{1}{N} \sum_{i=1}^{N-k} (x_i - m_x)(x_{i+k} - m_x) \qquad (28)$$

where:

m_x = average of x_i, $i=1,N$.

k = time-lag in time units equal to the time interval

L_{max} = maximum lag

The auto-correlation function $r_{xx}(k)$ is determined from:

$$r_{xx}(k) = c_{xx}(k)/c_{xx}(0) \qquad (29)$$

The 95% tolerance or confidence limits for zero correlation are computed from:

$$CL_p(k) = \frac{-1}{N-k+1} + 1.96 \frac{(N-k-1)}{(N-k+1)} \sqrt{\frac{1}{N-k}} \qquad (30)$$

$$CL_n(k) = \frac{-1}{N-k+1} - 1.96 \frac{(N-k-1)}{(N-k+1)} \sqrt{\frac{1}{N-k}} \qquad (31)$$

where:

$CL_p(k)$ = upper confidence limit for zero correlation at lag k

$CL_n(k)$ = lower confidence limit for zero correlation at lag k

Example 11.1 on page E-32 illustrates the calculations for an auto-correlogram of monthly areal average rainfall of the Manot sub-basin. Fig. 11.1 on page F-27 gives the plot of the correlogram.

11.2.3 Cross-covariance and cross-correlation functions

The cross-covariance functions $c_{xy}(k)$, and $c_{yx}(k)$, $k = 0$ to L_{max} are computed as follows:

$$c_{xy}(k) = \frac{1}{N} \sum_{i=1}^{N-k} (x_i - m_x)(y_{i+k} - m_y) \qquad (32)$$

$$c_{yx}(k) = \frac{1}{N} \sum_{i=1}^{N-k} (x_{i+k} - m_x)(y_i - m_y) \qquad (33)$$

where:

m_x = average of x_i, $i=1, N$

m_y = average of y_i, $i=1, N$.

The cross-correlation functions $r_{xy}(k)$ and $r_{yx}(k)$ are estimated from :

$$r_{xy}(k) = c_{xy}(k)/(s_x . s_y) \qquad (34)$$

$$r_{yx}(k) = c_{yx}(k)/(s_x . s_y) \qquad (35)$$

where:

s_x = standard deviation of x_i, $i=1,N$

s_y = standard deviation of y_i, $i=1,N$

Tabular output of the calculation for the cross-covariance and cross-correlation analysis for the two series, areal monthly rainfall of the sub-basin and monthly rainfall at Dindori staion, is given in Example 11.2 on page E-32.

11.3 Spectral analysis

The smoothed auto-spectral estimate $C_{xx}(f)$, for $f=0,..,1/2$ is calculated from:

$$C_{xx}(f) = 2\ \{C_{xx}(0)+2\sum_{k=1}^{M-1} C_{xx}(k)w(k)\ \cos(2\pi fk)\} \qquad (36)$$

where: f = frequency in cycles per time interval, computed at spacings $1/(2N_f)$, where N_f is 2 to 3 times M

N_f = number of frequency points

$C_{xx}(k)$ = autocovariance function at lag k

M = truncation point or maximum lag of the autocovariance function used to estimate the autospectrum; clearly M is conditioned by: $M \leq L_{max}$

$w(k)$ = window function

Following window $w(k)$ for $k=1, M-1$ according to Tukey is used to smoothen the spectral estimate:

$$w(k) = \frac{1}{2}\ (1+\cos(\frac{\pi k}{M})) \qquad (37)$$

The band B and number of degrees of freedom are given by:

$$B = 4/(3M) \qquad (38)$$

$$N_f = 8N(3M) \qquad (39)$$

The logarithm of the auto-spectrum is computed by:

$$C_{log}(f) = \log^{10} C_{xx}(\,) \qquad (40)$$

In the results $C_{log}(f)$ will be set to -100 if $C_{xx}(f) \leq 0$.

The spectral density function follows from:

$$R_{xx}(f) = \frac{C_{xx}(f)}{C_{xx}(o)} = 2\{1+2 \sum_{K=1}^{M-1} r_{xx}(K)\ W(K) \text{Cos}\ (2\pi fK)\} \qquad (41)$$

Example 11.3 on page E-33 presents the spectral density function of monthly areal average rainfall of Manot sub-basin. The plot is given in Fig. 11.2 on page F-28.

11.4 Range analysis

In Fig. 11.3 on page F-29 a definition sketch of the following range related quantities is given :

- adjusted surplus ${}_aS_N^+$
- adjusted deficit ${}_aS_N^-$
- adjusted range ${}_aR_N$, and
- rescaled adjusted range ${}_aR_N^*$.

The quantities are computed from the accumulative departures from the mean S_i for i = 0, N and with S_o = 0;

$$S_i = \sum_{j=0}^{i} (x_j - m_x) c_f \qquad (42)$$

where: m_x = average of x(i), i = 1, N

c_f = conversion factor (time units per time interval) to transfer intensities into volumes

It follows for:

- Surplus ${}_aS_N^+$:

$$ {}_aS_N^+ = \max\ (S_0,\ S_1 \ldots\ldots, S_N) \qquad (43)$$

- Deficit ${}_aS_N^-$:

$$ {}_aS_N^- = \min\ (S_0,\ S_1, \ldots\ldots S_N) \qquad (44)$$

- Adjusted range ${}_{\alpha}R_N$:

$$ {}_{\alpha}R_N = {}_{\alpha}S_N^+ - {}_{\alpha}S_N^- \qquad (45) $$

- Rescaled adjusted range ${}_{\alpha}R_N^*$:

$$ {}_{\alpha}R_N^* = {}_{\alpha}R_N/(S_x.c_f) \qquad (46) $$

where : S_x = standard deviation of x_i, $i = 1, N$

Example 11.4 on page E-34 illustrates the calculation for the range analysis for the monthly areal rainfall of the Manot sub-basin.

11.5 Run analysis

A definition sketch for run analysis is presented in Fig. 11.4 on page F-30.

Up and down crossing and runs:
Let x_c be a crossing level then an up crossing is defined by:

$$ x_{i+1} \geq x_c \text{ and } x_i < x_c \qquad (47) $$

and a down crossing by:

$$ x_{i+1} < x_c \text{ and } x_i \geq x_c \qquad (48) $$

A run is an excursion above or below the level x_c, i.e. bounded by an up crossing and a down crossing or a down crossing and an upcrossing. Note: HYMOS also interprets as runs the first and last excursion above or below level x_c, which are only bounded by an upcrossing or a downcrossing; these runs are incomplete.

Run length

With respect to run length, the following distinction has to be made:
- positive run length RL^+,

- negative run length RL^-, and
- total run length, i.e. successive pair of $RL^+ + RL^-$

RL^+ is the time space between an upcrossing and downcrossing and RL^- is the time span between a down crossing and an up crossing given as a number of time intervals.

Run sum

The positive and negative runsums RS^+, and RS^-, respectively, are computed from :

$$RS^+ = \sum_{i=j}^{k} (x_i - x_c)C_f \qquad (49)$$

where,

j = location of an up crossing
k = location of the next down crossing
c_f = conversion factor (= time units per time interval) to transfer intensities into volumes

$$RS^- = \sum_{i=k}^{m} (x_c - x_i)\ C_f \qquad (50)$$

where k = location of the down crossing
m = location of the next up crossing

Example 11.5 on page E-34 gives the calculation for the Run analysis for the monthly areal rainfall of the Manot sub-basin.

12.0 - REPORTING AND RETRIEVAL

12.1 REPORTS

12.1.1 General

The option reports includes the ready for publication preparation of station reports:

- station characteristics
- series characteristics
- current metering data and rating parameters
- station reports

The various options are dealt with in the Chapters 12.1.2 to 12.1.4 respectively.

12.1.2 Print of station characteristics

Following output can be obtained:

- station characteristics, and
- station histories

Station characteristics:
For printing of station characteristics following steps have to be taken:

- Select <Station> from the main options.
- Select <Characteristics> from the next menu.,

If the selection switch is off the characteristics of all station of the 'current data base' will be printed.

If the selection switch is on selection by one of the following items can be made:

. Station Code	. Latitude
. Station name	. Longitude
. River	. Altitude
. District	. Catchment area, and
. Country	. Agency

For the selected item one or a range of names/values may be specified by selecting respectively Equals or Range and by entering subsequently the name(s)/value(s).

Station histories:
For printing of station histories following steps have to be

taken:

- Select <Station> from the main options
- Select <History> from the next menu

If the selection switch is off the histories of all stations of the 'current data base' will be printed.

If the selection switch is on a selection on station code can be made. One or a range of station codes may be specified by selecting respectively <Equals> or <Range> and by entering subsequently the station code(s).

12.1.3 Print of series characteristics and data

Following output can be obtained:

- series characteristics
- current-metering data
- stage-discharge parameters
- sediment-discharge parameters

Series characteristics:

Series characteristics cover: series code, time and basic time interval, time shift, observation type and start and end date of data availability. For printing of these characteristics following steps have to be taken.

- Select <Series> from the main HYMPRN options.
- Select <Characteristics> from the next menu

If the selection switch is off the characteristics of all series of the 'current data base' will be printed.

If the selection switch is on a selection on one of the following items can be made:

. Station code . Interval, and
. Type . Period

For the selected item one or a range of names/values may be specified by selecting respectively <Equals> or <Range> and by entering subsequently the name(s)/value(s).

12.1.4 Print of station reports

Following reports station wise can be obtained:

1. Station characteristics, and/or
2. Station histories, and
3. Time series data.

For printing of the reports following steps have to be taken:

- Select <Report> from the main options
- Select a station from the next menu
- Select time interval of time series to be printed in the report.
- Select the data types from the available series
- Specify requirement of:
  - Station characteristics
  - Station history

- Enter the start data.
- Enter the number of months/years to be printed

Example 12.1 from page E-36 to E-46 illustrates the use of the above option in which the complete report of the daily rainfall series at Githori station is given for the period 1981 to 1991.

12.2 GRAPHICS

12.2.1 General

The graphics options cover the drawing of functions and of isolines with many facilities for reporting.
To produce figures, following input files are required:

1. a picture file, including information about the lay-out of figure and about function to be plotted. The use of preprocessor creates these files with the extension .PCT.
2. data files, contain information (function values) to be drawn. The user creates these files with extension .MAT. More than one data file can be used.

Furthermore, information has to be added on the plot configuration, plot device, etc.

The set up of the graphics option is modularly. The various parts will be described separately. Through these parts so-called "tasks" are created. The .PCT files is a collection of tasks which describe a drawing and also define the functions to be plotted.

Following main options are available:
1. Data: to create data (.MAT) -files
2. Pre-processor: to create picture (.PCT) -files, and
3. Draw: to make a plot

4. Edit: to edit data (.MAT) - files

Example are shown in Fig. 8.5, 9.1 and 9.2 on page F-18, F-19 and F-20 respectively giving an idea about the facility in the grphics option.

12.3 RETRIEVAL AND TRANSFER

12.3.1 General

HYMOS includes following options for data retrieval and transfer:

1. retrieval of data for external usage,
2. transfer to internal HYMOS data base, and
3. transfer to external HYMOS data base.

The options are discussed in the sections 11.4.2 and 11.4.3.

12.3.2 Transfer to user files

The data stored in the data base can be retrieved for transfer to file. This covers following data:

1. equidistant time series,
2. non-equidistant data, including:
   - station and history data,
   - time series,
   - current metering data,
   - stage discharge parameters, and
   - series relation parameters.

Station/series code, start and end date of series, field length specification and user file name are generally required to execute the transfer.

12.3.3 Transfer to HYMOS data base

In the transfer to a HYMOS data base, two cases are distinguished:

1. transfer to an internal data base, and
2. transfer to an external data base.

Transfer to internal data base:

This refers to transfer of series to another HYMOS data base on the same system or in the user network, e.g. from a temporary data base to a final one storing only validated and corrected data. The required input includes:

- series code,
- data drive of the receiving data base,
- name and extension of the receiving data base, and
- start and end date

For this transfer it is necessary that the characteristics of the series to be transferred are available on both data bases.

Transfer to external data base:

This refers to transfer of series to another HYMOS data base on a different system. HYMOS creates a data file with the proper read instructions for easy load in the other data base. The input includes:

- series code,
- field length and number of decimals,
- start and end date of the period to be transferred, and
- name of file the data will be (temporarily) stored.

13.0 - CONCLUSION

It is obvious that as compared to the manual handling and processing of hydrological data a computer based processing would have many advantages. In general, HYMOS is an efficient hydrological database management and processing software. It is well tailored to suit the requirements of the hydrological data processing. Some of the specific capabilities and shortcomings of HYMOS are listed below for a better understanding of this software.

(a) As is required for a hydrological database, HYMOS is able to recognize as many number of data types and for each data type any time interval ranging from 1 minute to 1 year.

(b) There is no need of remembering the names of the datafiles as the data can be retrieved by choosing the name from the list which is displayed in the scrolling window on the screen as and when desired. This avoids the confusion and the need to recollect the filenames which becomes extremely difficult as the size of the database increases.

(c) Data may be edited with the help of specially designed editor which displays the time lable at each data location. In absence of such lables the user is many times lost in counting the time lables. The data may be corrected whenever required and the origin of the data viz., original or corrected is stored alongwith data so as to later interpret it suitably.

(d) Data may very conveniently and fastly be validated by graphical and other statistical options.

(e) HYMOS has adequate facility for completion and regression techniques.

(f) Full facility is available in HYMOS for handling the flow data. Development of rating curves and thier subsequent validation is very conveniently and swiftly done.

(g) Various options are available for (Dis-) aggregation of series, series transformation and computation of areal rainfall by different procedures.

(h) A very strong statistical analysis and time series support is rendered by the software which may be utilised in the processing of the hydrological data very conveniently.

(i) Reporting and retrieval of data is very easily and efficiently accomplished by the help of this software. There is a very sophisticated graphics support available and may be utilised in bringing out figures in a very impressive manner.

(j) All the operations are done with the help of menu driven selection procedure and thus avoids the difficult problem of file management and data entry and retrieval actions.

(k) The most important thing to emphasis here is that even after making an attempt the real impression of the capabilities of such a software may be very difficult to be brought out in the form of report like this. Instead, it is very easy and convincing if the exercise of working with such software is undertaken.

REFERENCE

1. Delft Hydraulics (1992). "HYMOS manual", Delft Hydraulics, The Netherlands, March 1992.

2. Hemant Chowdhary (1992). Training report on "Hydrological data processing", National Institute of Hydrology, 1992.

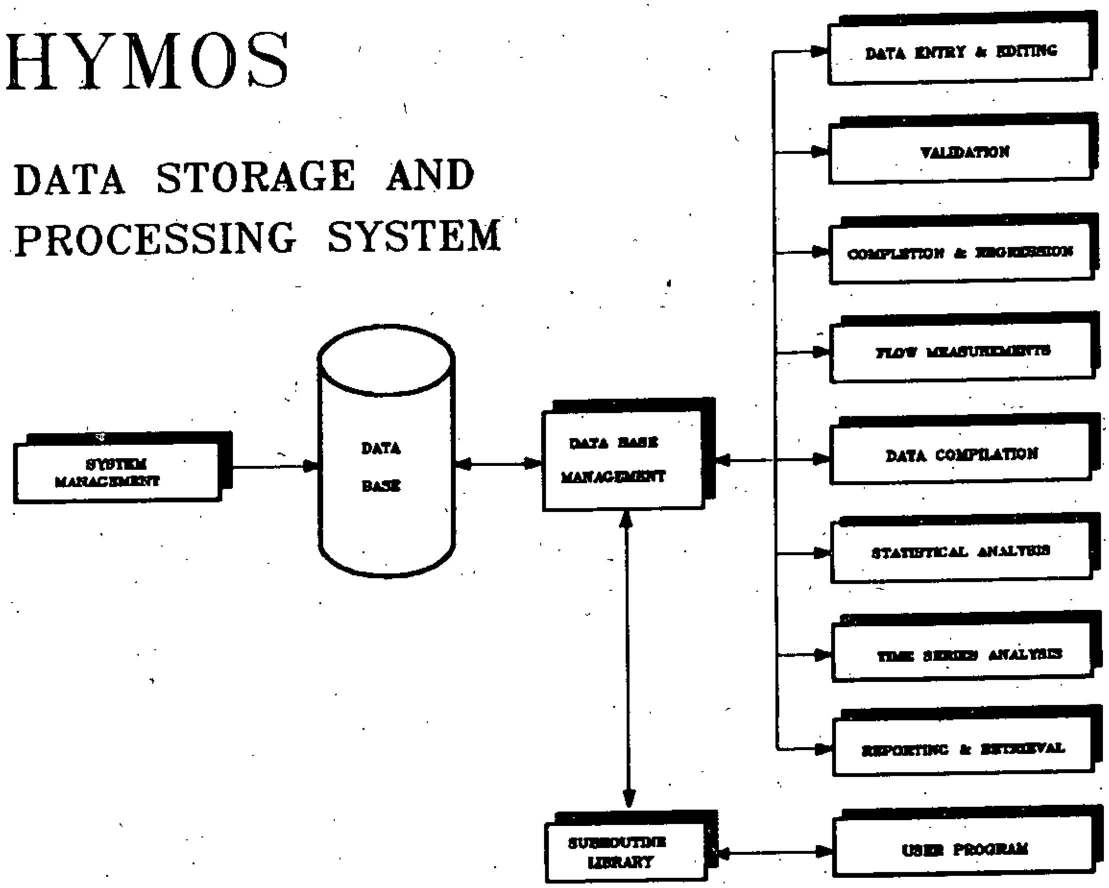


Fig. 1-1 Structure of HYMOS.

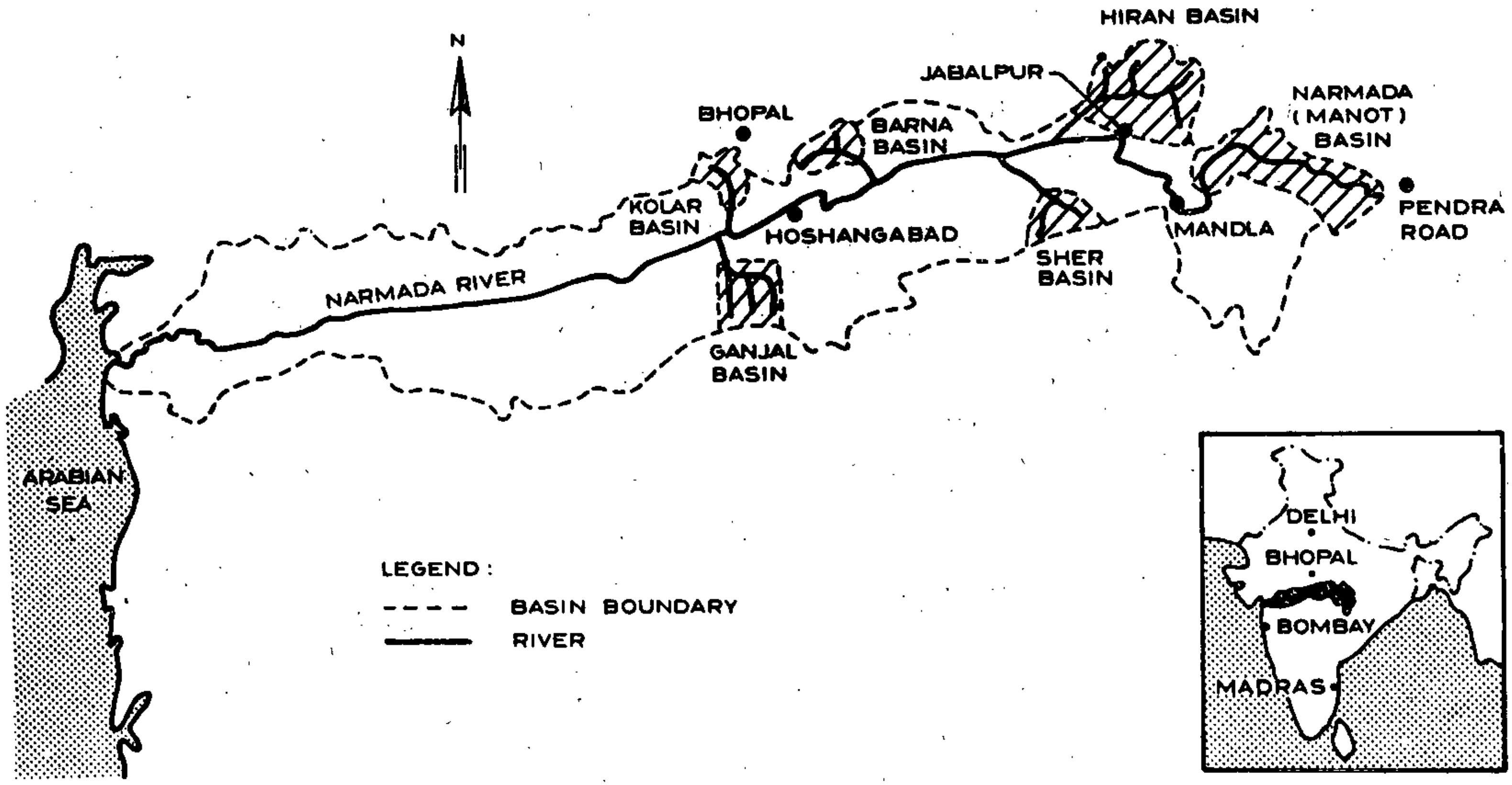


FIG 2·1 - INDEX MAP OF THE NARMADA RIVER BASIN

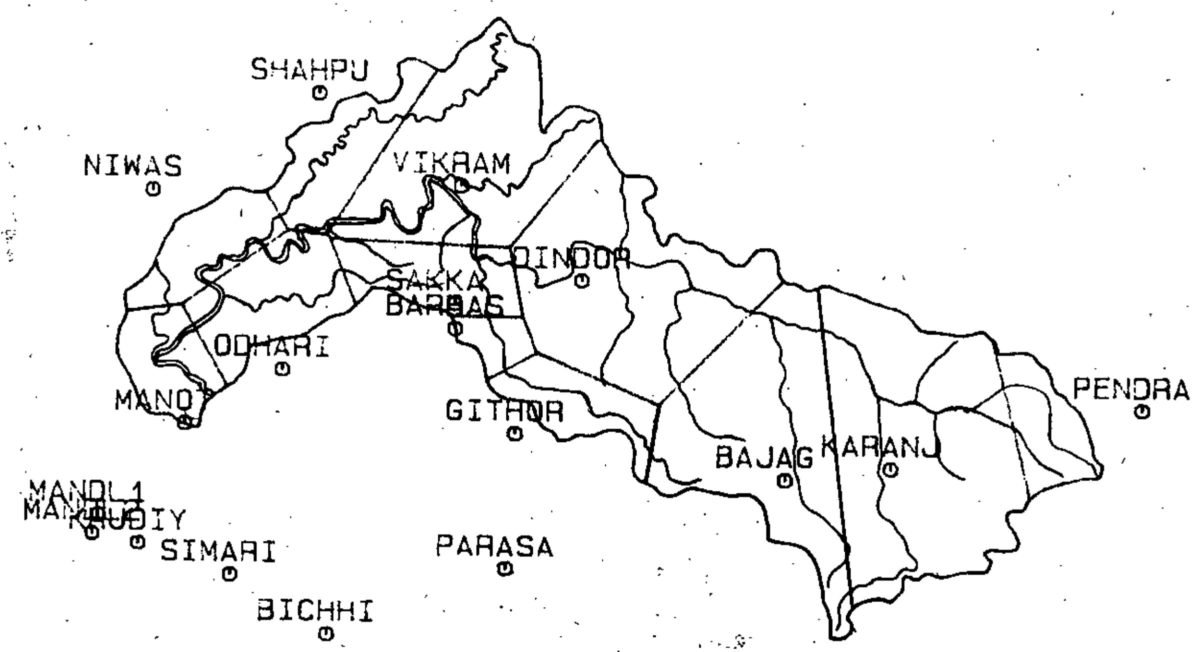


FIG. 2·2 CATCHMENT BOUNDRY AND LOCATION OF RAINGAUGE STATIONS

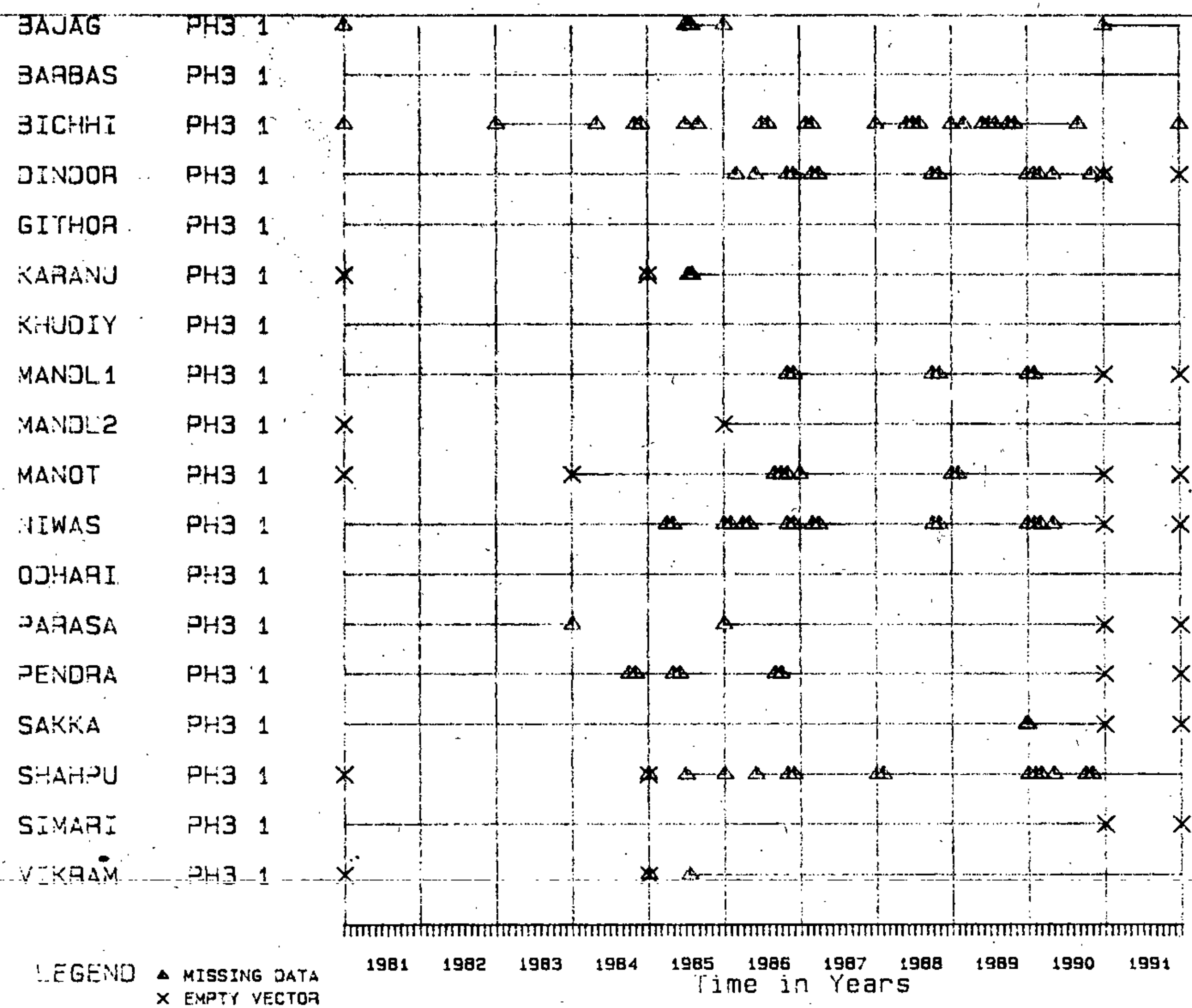
NATIONAL INSTITUTE OF HYDROLOGY

MANOT SUB-BASIN

DAILY RAINFALL DATA AVAILABILITY CHART

SWA&M DIVISION

FIG. 2.3



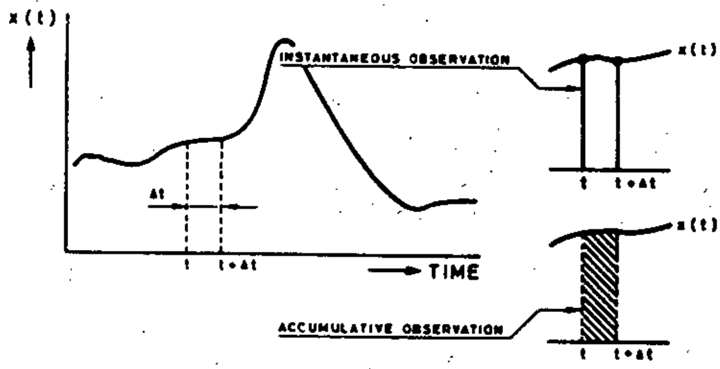


FIG. 3-1 INSTANTANEOUS AND ACCUMULATIVE OBSERVATIONS

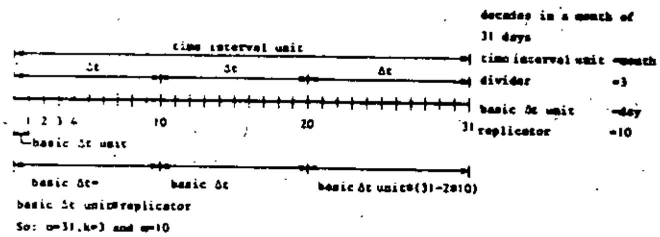


FIG 3-2 EXPLANATION OF BASIC TIME INTERVAL

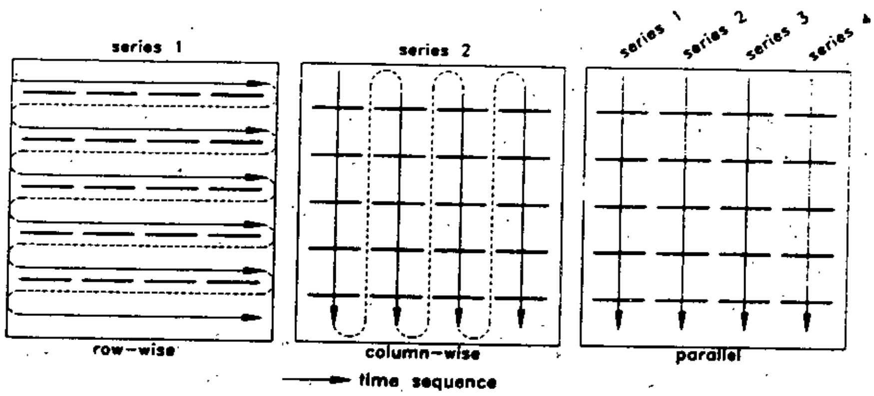
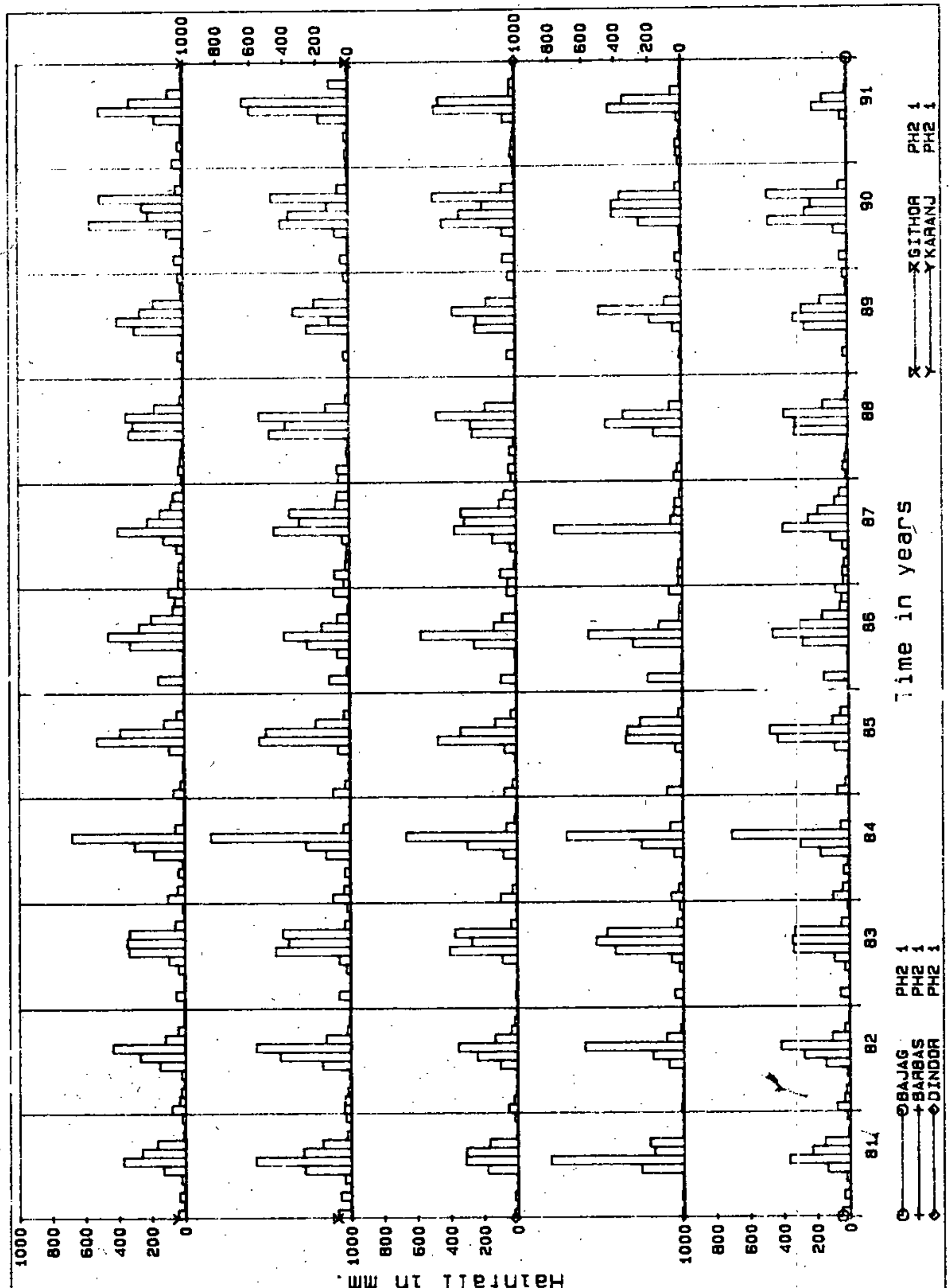
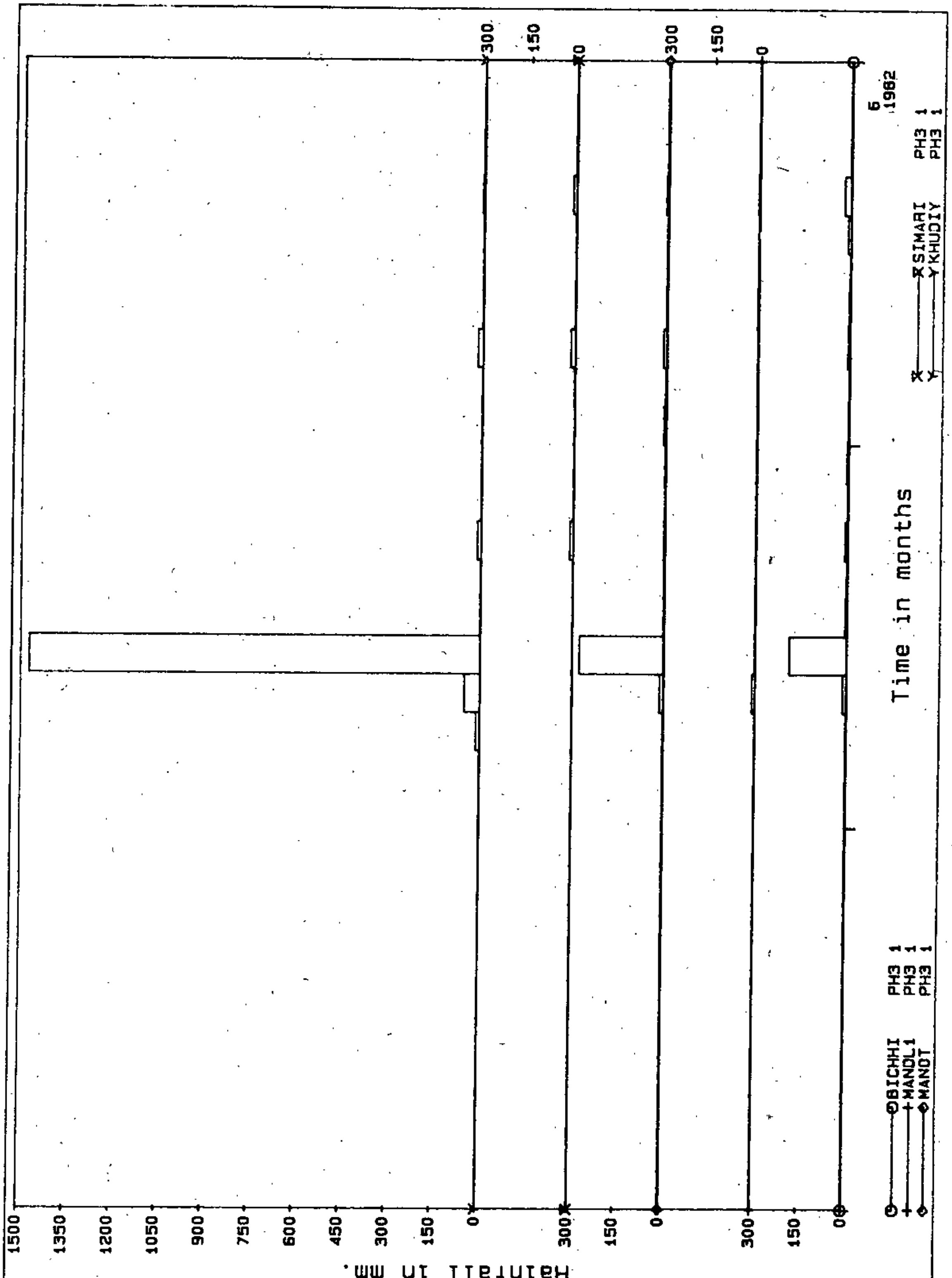


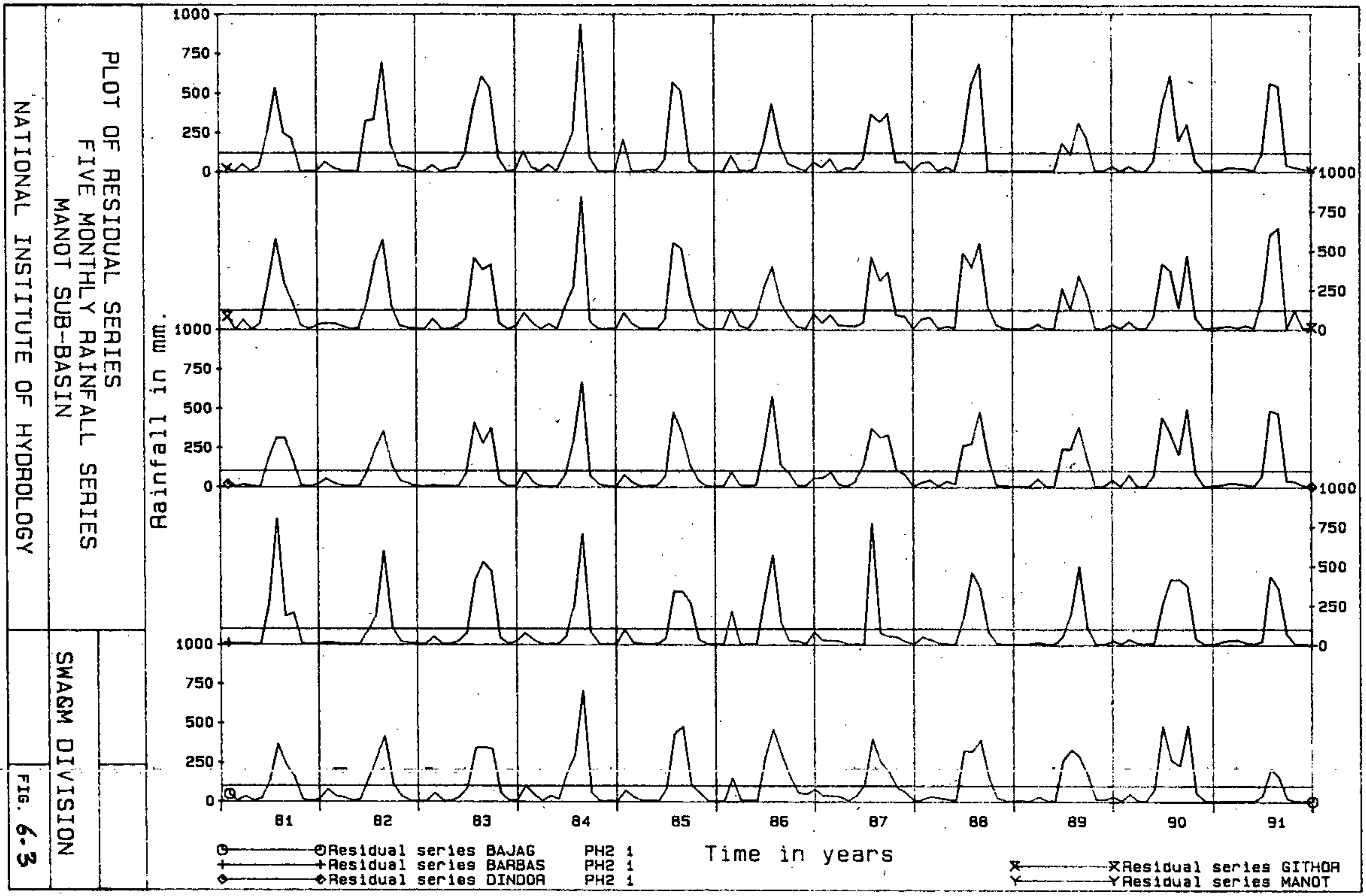
FIG. 5-1 ROW-WISE, COLUMN-WISE AND PARALLEL ORGANISATION OF DATA-FILES

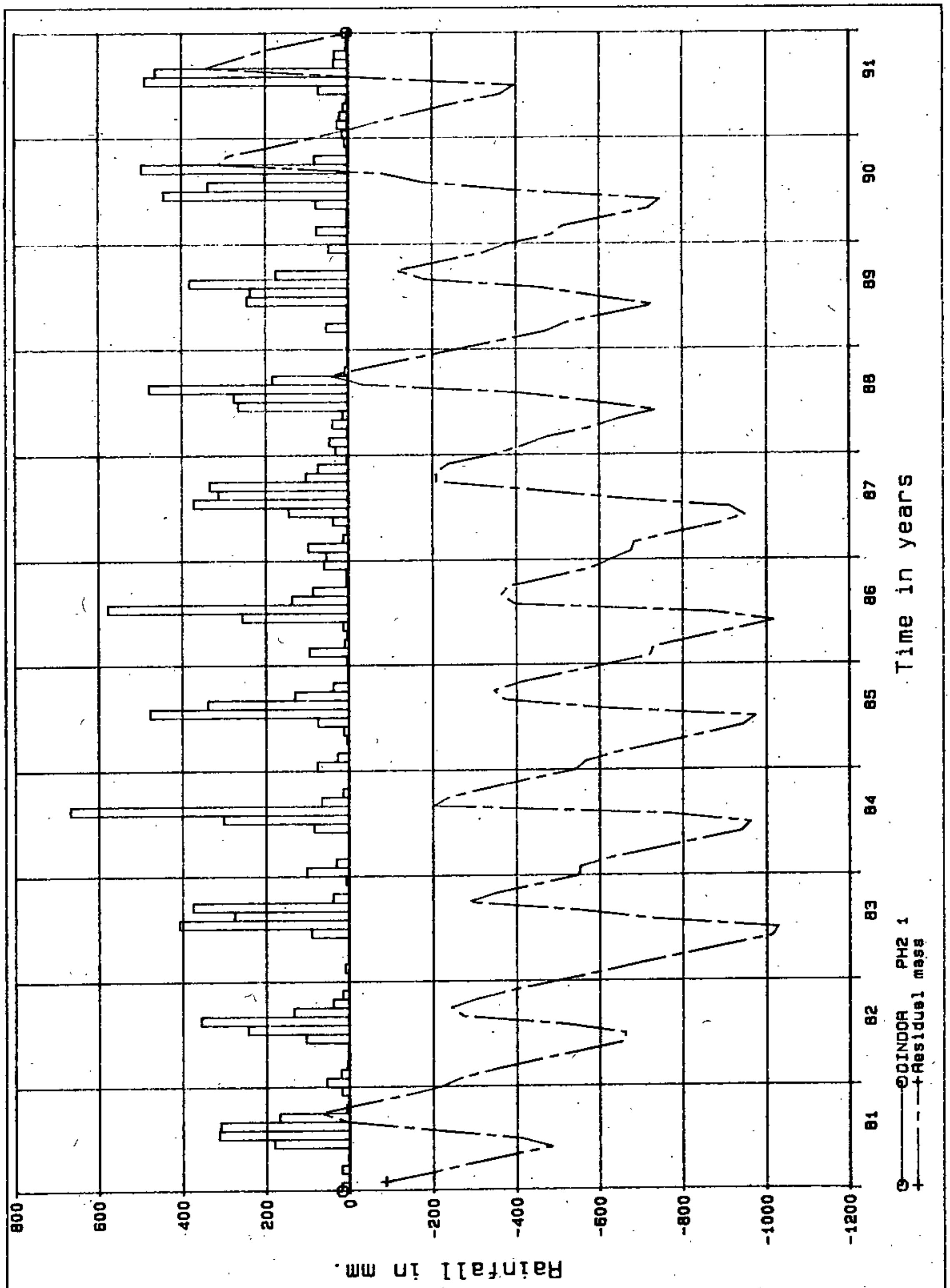


VALIDATION BY TIME SERIES GRAPHS MONTHLY RAINFALL OF FIVE STATIONS	SWA&M DIVISION
MANOT SUB-BASIN	FIG. 6.1

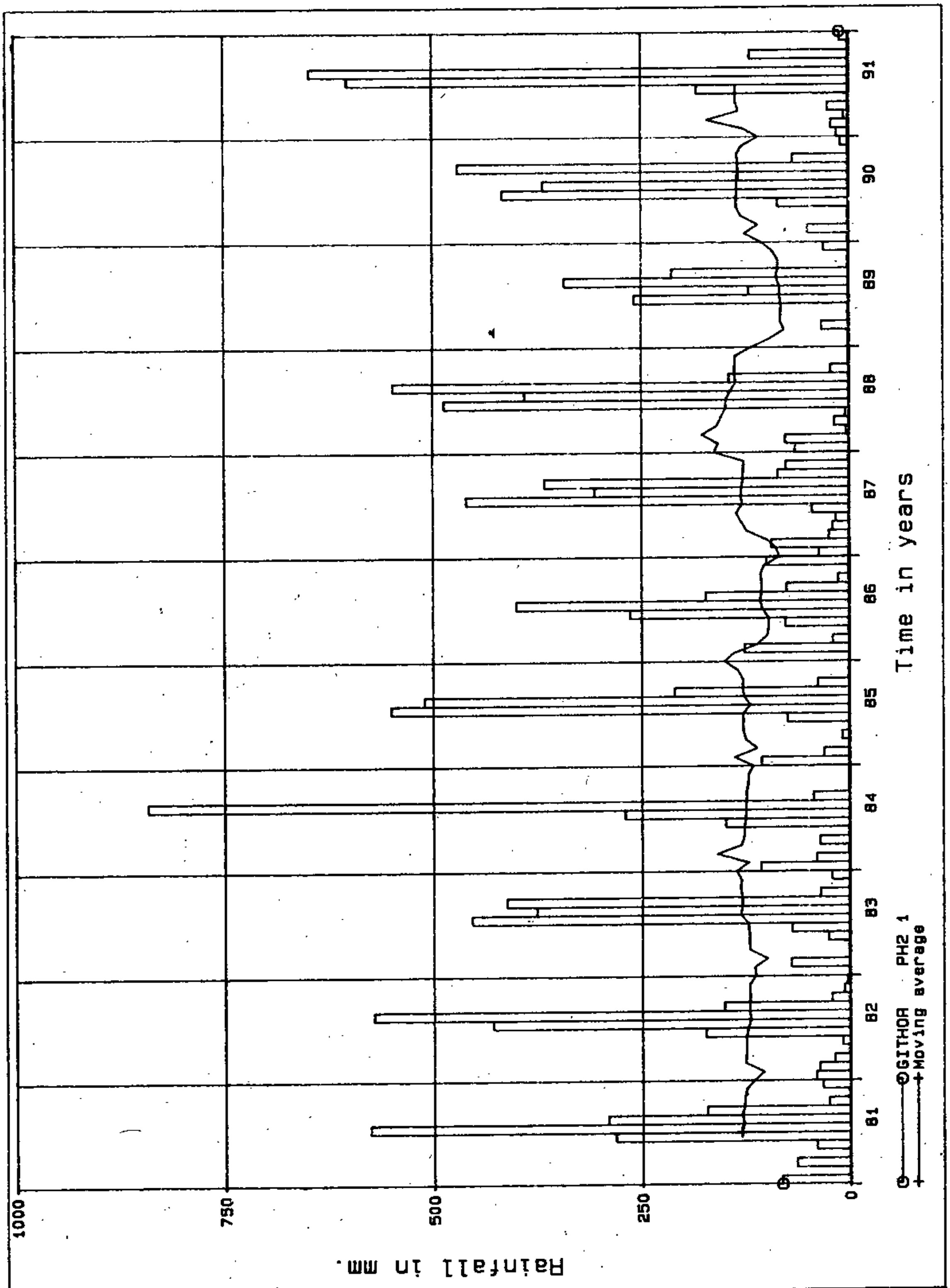


VALIDATION BY TIME SERIES GRAPHS VERY HIGH RAIN OBSERVED ON 15.6.82 AT KHUDIYAGHAT STATION	SWA&M DIVISION
MANOT SUB-BASIN	FIG. 6.2

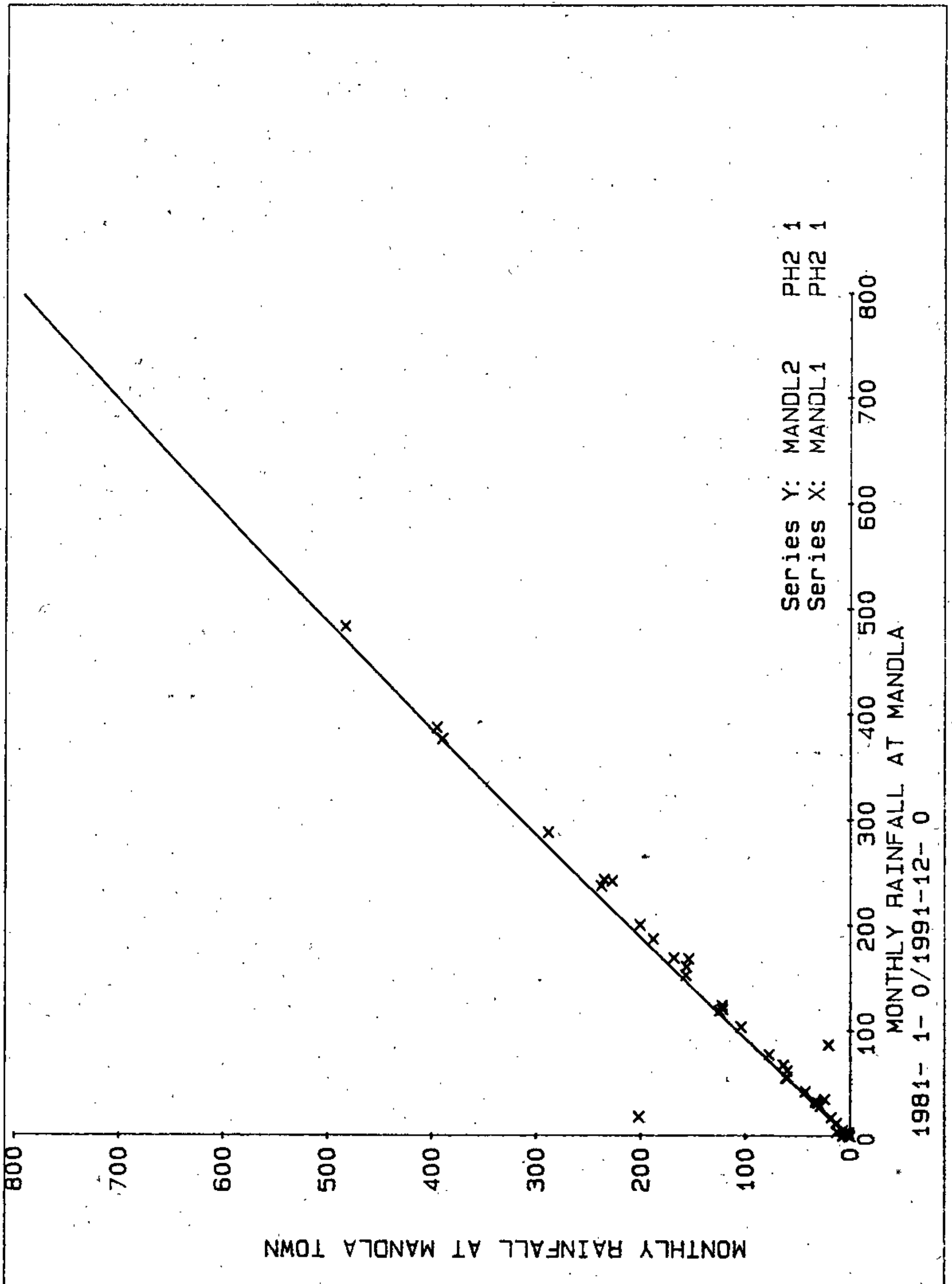

PLOT OF RESIDUAL SERIES
FIVE MONTHLY RAINFALL SERIES
MANOT SUB-BASIN
NATIONAL INSTITUTE OF HYDROLOGY
SW&M DIVISION
FIG. 6.3
Rainfall in mm.
1000
750
500
250
0
81
82
83
84
85
86
87
88
89
90
91
Time in years
Residual series BAJAG PH2 1
Residual series BARBAS PH2 1
Residual series DINDOR PH2 1
Residual series GITHOR
Residual series MANOT



PLOT OF RESIDUAL MASS CURVE OF MONTHLY RAINFALL AT DINDORI STATION MANOT SUB-BASIN	SWA&M DIVISION
NATIONAL INSTITUTE OF HYDROLOGY	FIG. 6.4



PLOT OF MOVING AVERAGE CURVE OF MONTHLY RAINFALL AT GITHORI STATION MANOT SUB-BASIN	SWA&M DIVISION
NATIONAL INSTITUTE OF HYDROGRAPH	FIG. 6-5

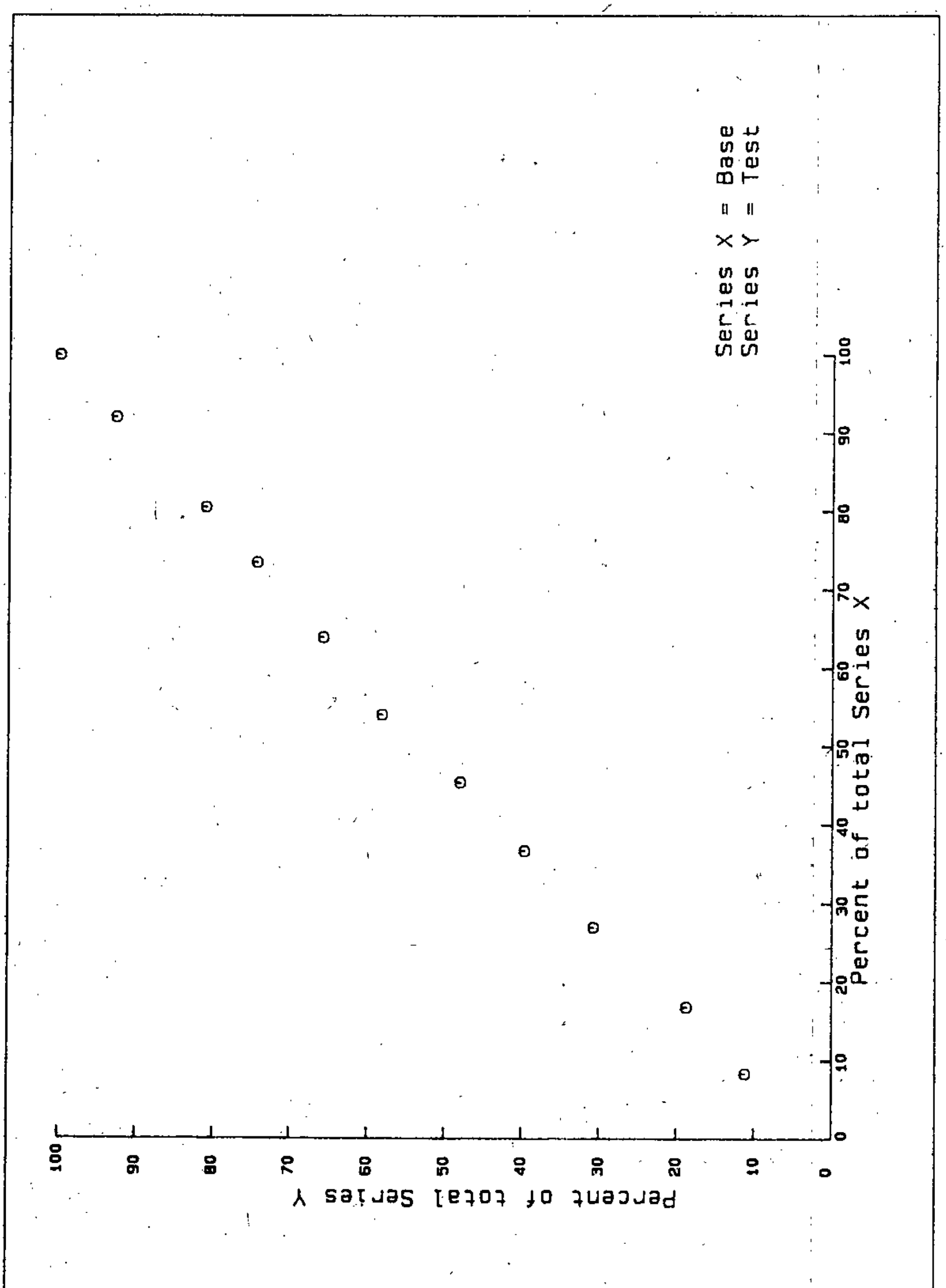


RELATIN CURVE BETWEEN MONTHLY RAINFALL SERIES OF TWO VERY NEARBY STATIONS MANDLA & MANDLA TOWN (MANDL1 & MANDL2)

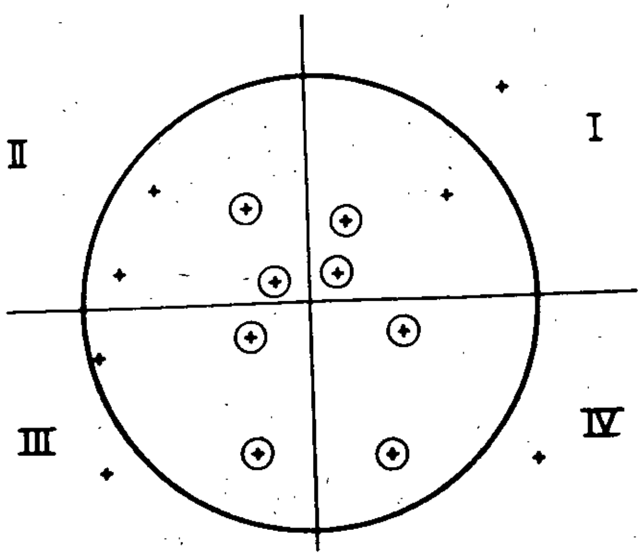
SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

FIG. 6.6



DOUBLE MASS ANALYSIS FOR ANNUAL RAINFALL AT BARBASPUR STATION	SWA&M DIVISION	
NATIONAL INSTITUTE OF HYDROLOGY		FIG. 6.7



Legend:
+ = neighbour station
(+) = selected neighbour station
I, etc. = quadrant

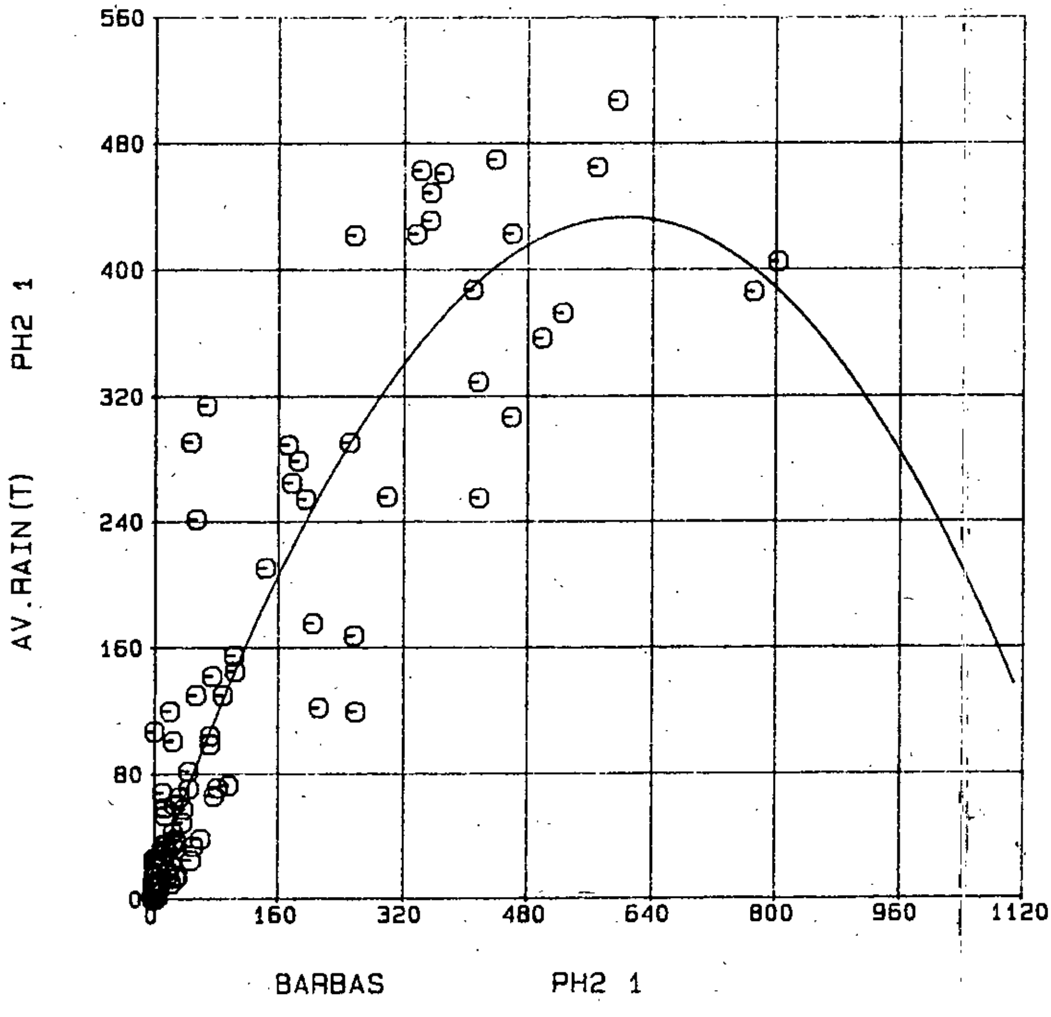
FIG. 6-8 DEFINITION SKETCH

——— DATA FIT f(x) = c0+c1*x+c2*x^2+...

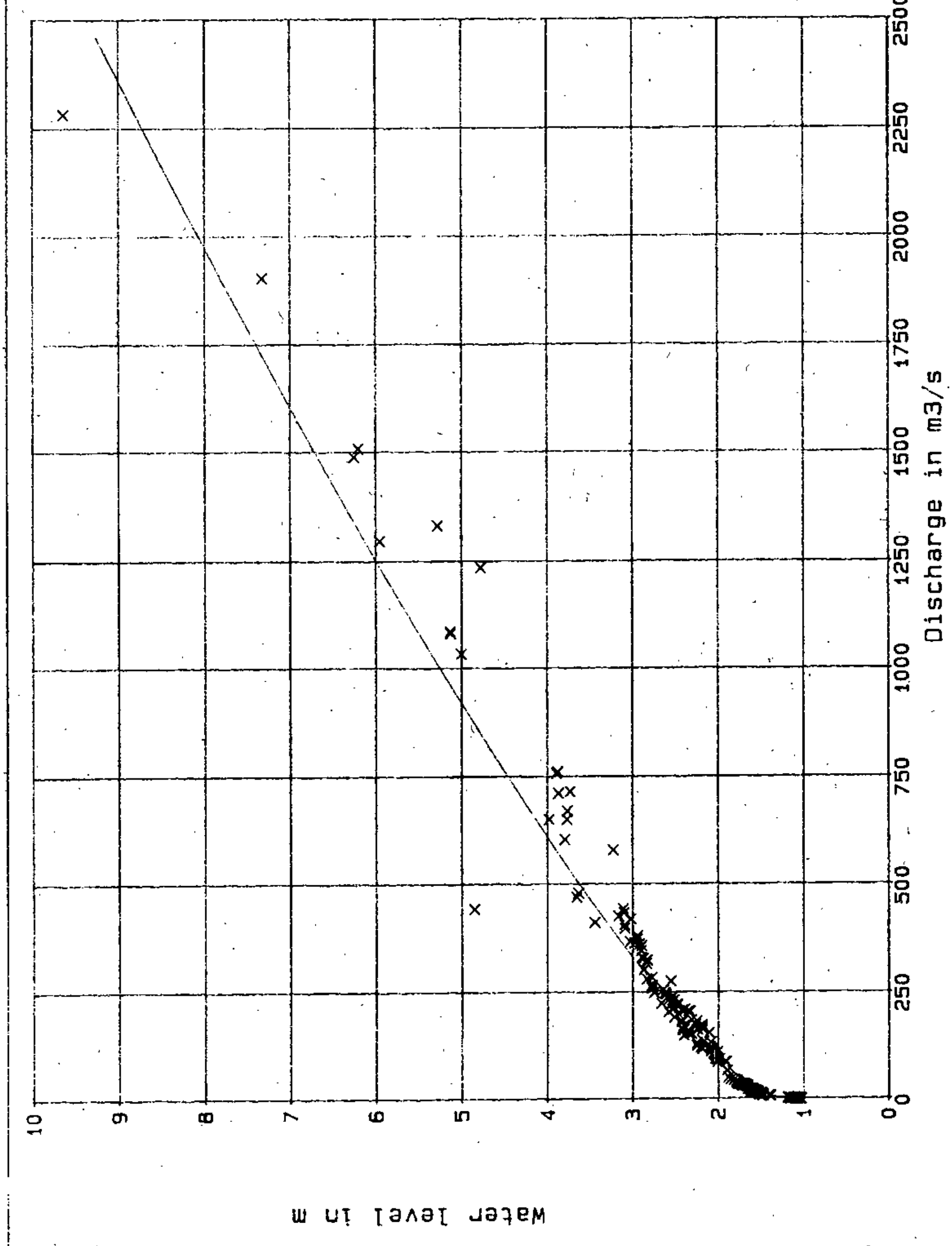
Degree of polynomial is : 2

C(0) = .11407E+02
C(1) = .13983E+01
C(2) = -.11594E-02

See = .53020E+02



POLYNOMIAL REGRESSION CURVE FITTING BETWEEN MONTHLY RAINFALL AT BARBASPUR AND AREAL ESTIMATE FOR MANOT SUB-BASIN	SWA&M DIVISION	
NATIONAL INSTITUTE OF HYDROLOGY		FIG. 7-1

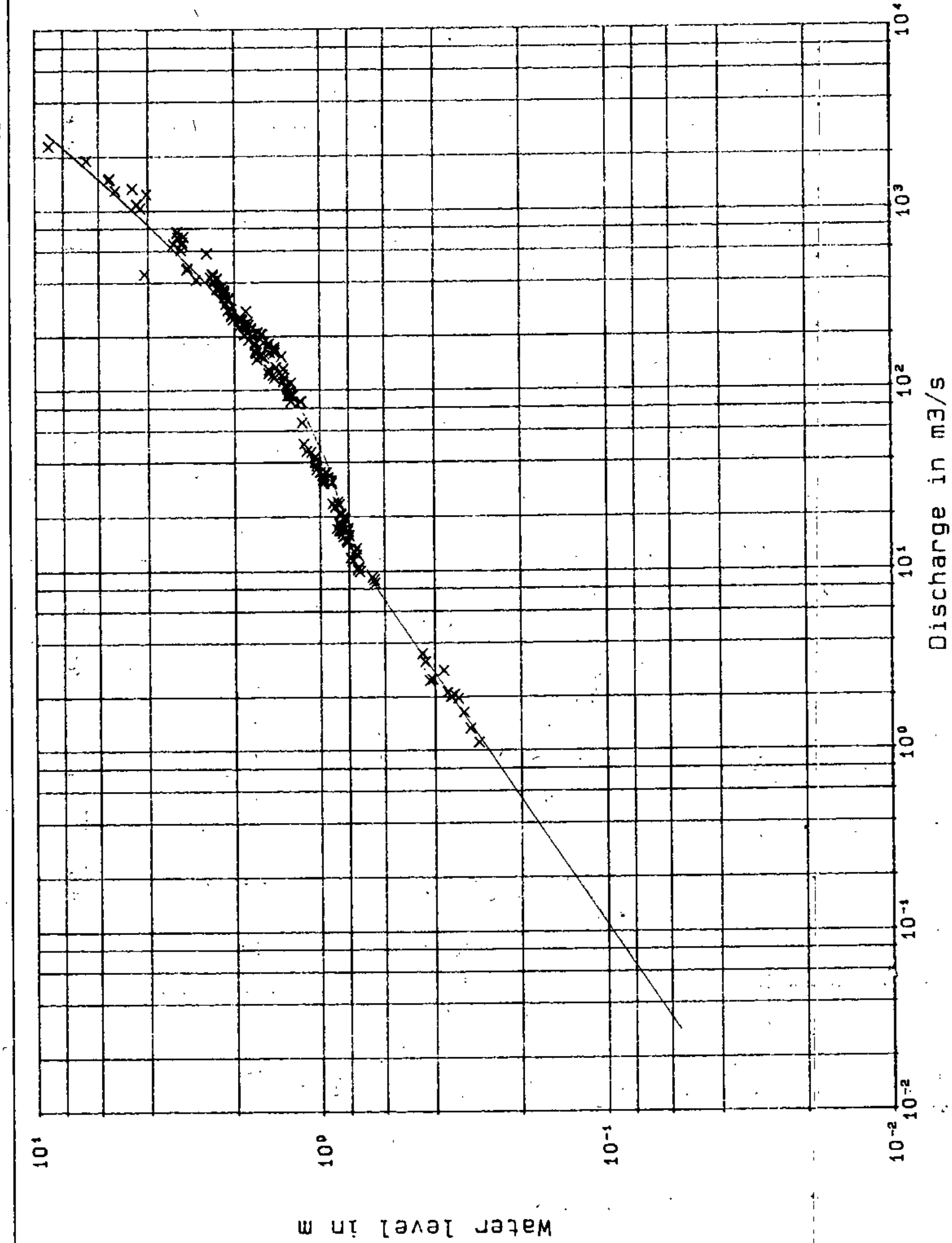


FITTING OF STAGE-DISCHARGE DATA BY A SIMPLE RATING CURVE FOR MANOT GD SITE FOR THE PERIOD FROM 1-6-90 TO 31-12-90

SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

FIG. 8·1

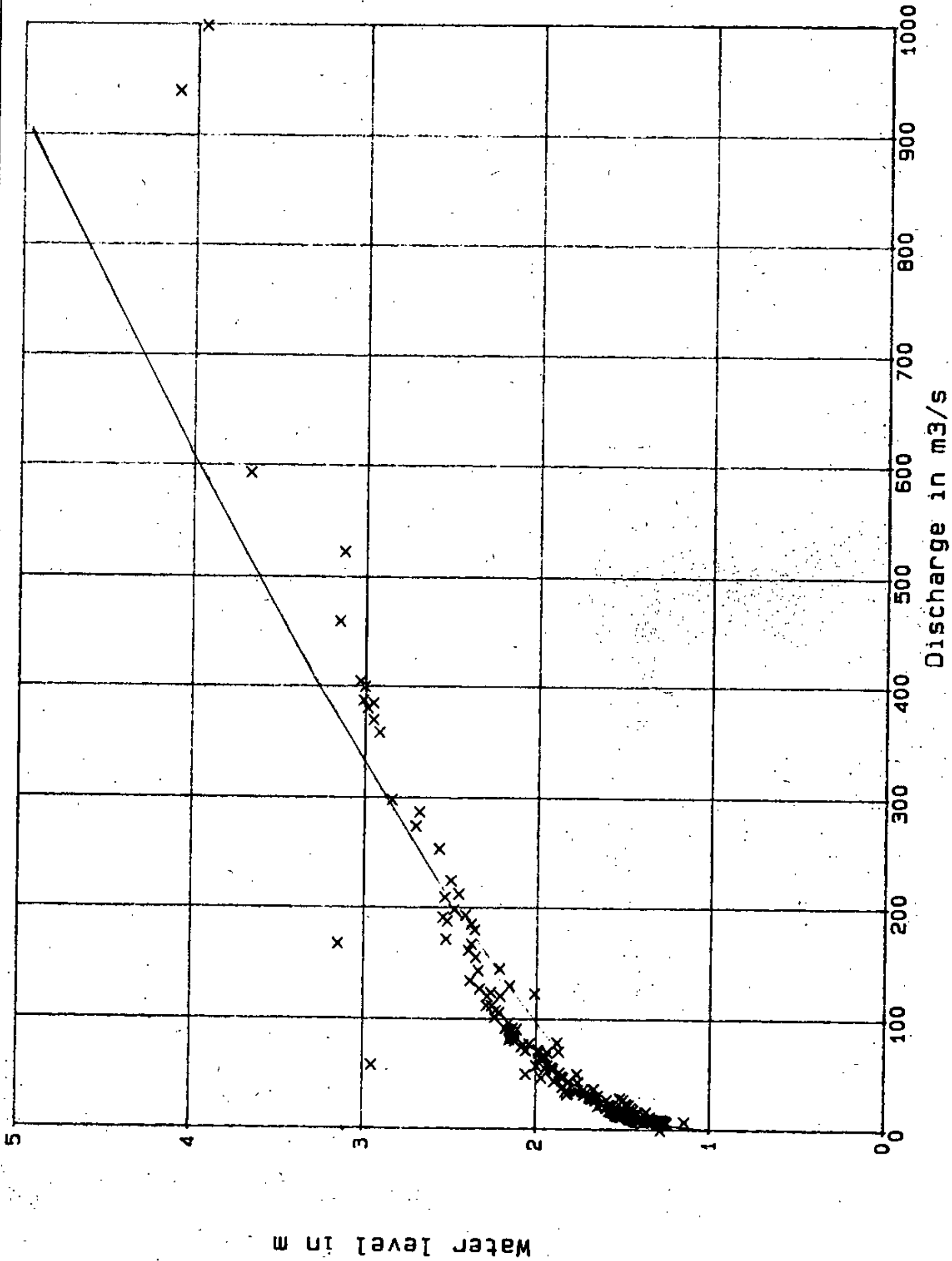


FITTING OF STAGE-DISCHARGE DATA BY A SIMPLE RATING CURVE FOR MANOT GD SITE FOR THE PERIOD FROM 1-6-90 TO 31-12-90

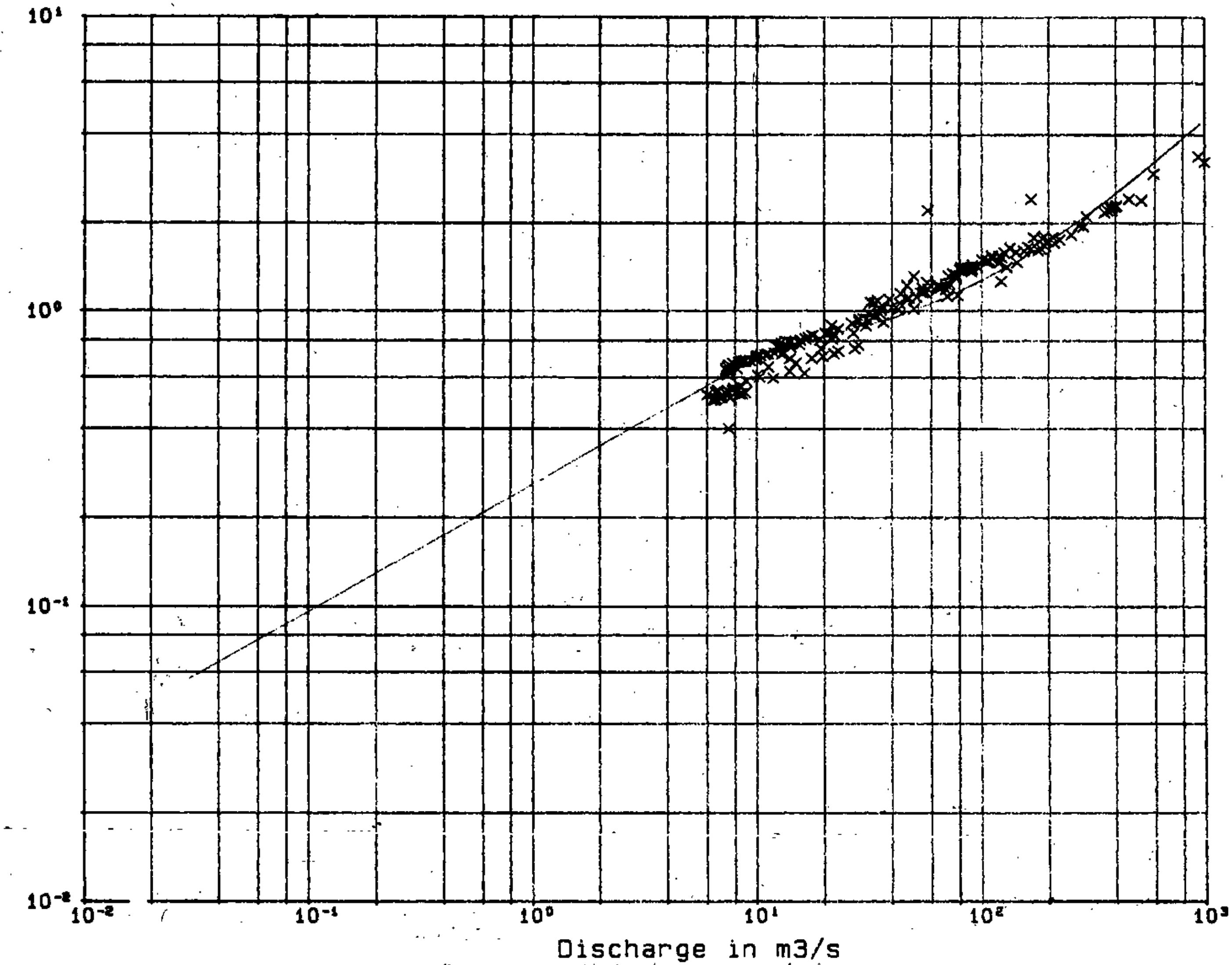
SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

FIG. 8.2



VALIDATION OF RATING CURVE AT MANOT GD SITE FOR THE PERIOD 1-6-90 TO 31-12-90 AGAINST THE DATA OF 1-6-89 TO 31-12-89	SWA&M DIVISION
NATIONAL INSTITUTE OF HYDROLOGY	FIG. 8.3



VALIDATION OF RATING CURVE AT MANOT GD SITE FOR THE PERIOD 1-6-90 TO 31-12-90 AGAINST THE DATA OF 1-6-89 TO 31-12-89

NATIONAL INSTITUTE OF HYDROLOGY

SWAGM DIVISION

FIG. 5.4

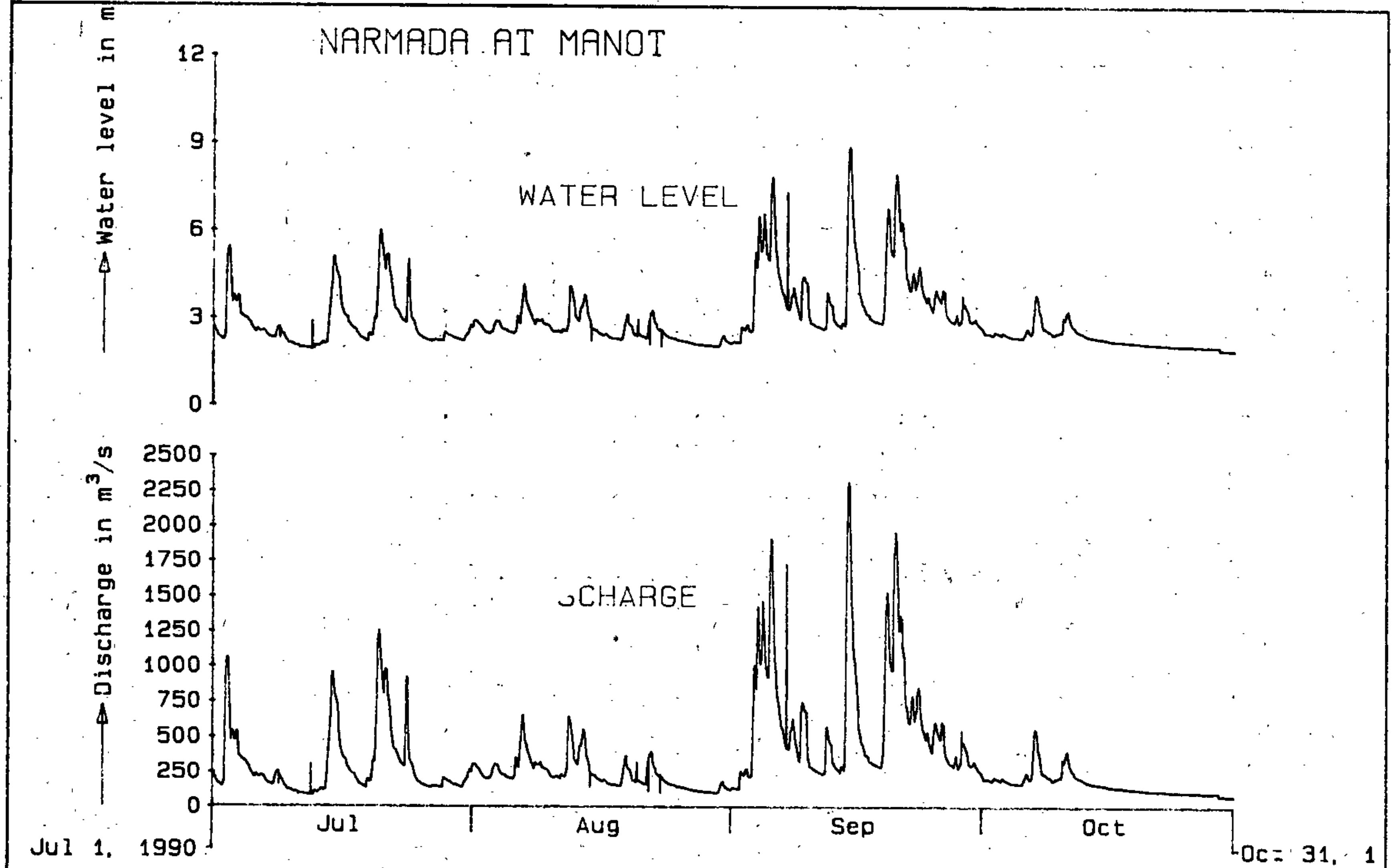


FIG. 8·5 PLOT OF HOURLY WATER LEVEL AND TRANSFORMED DISCHARGE

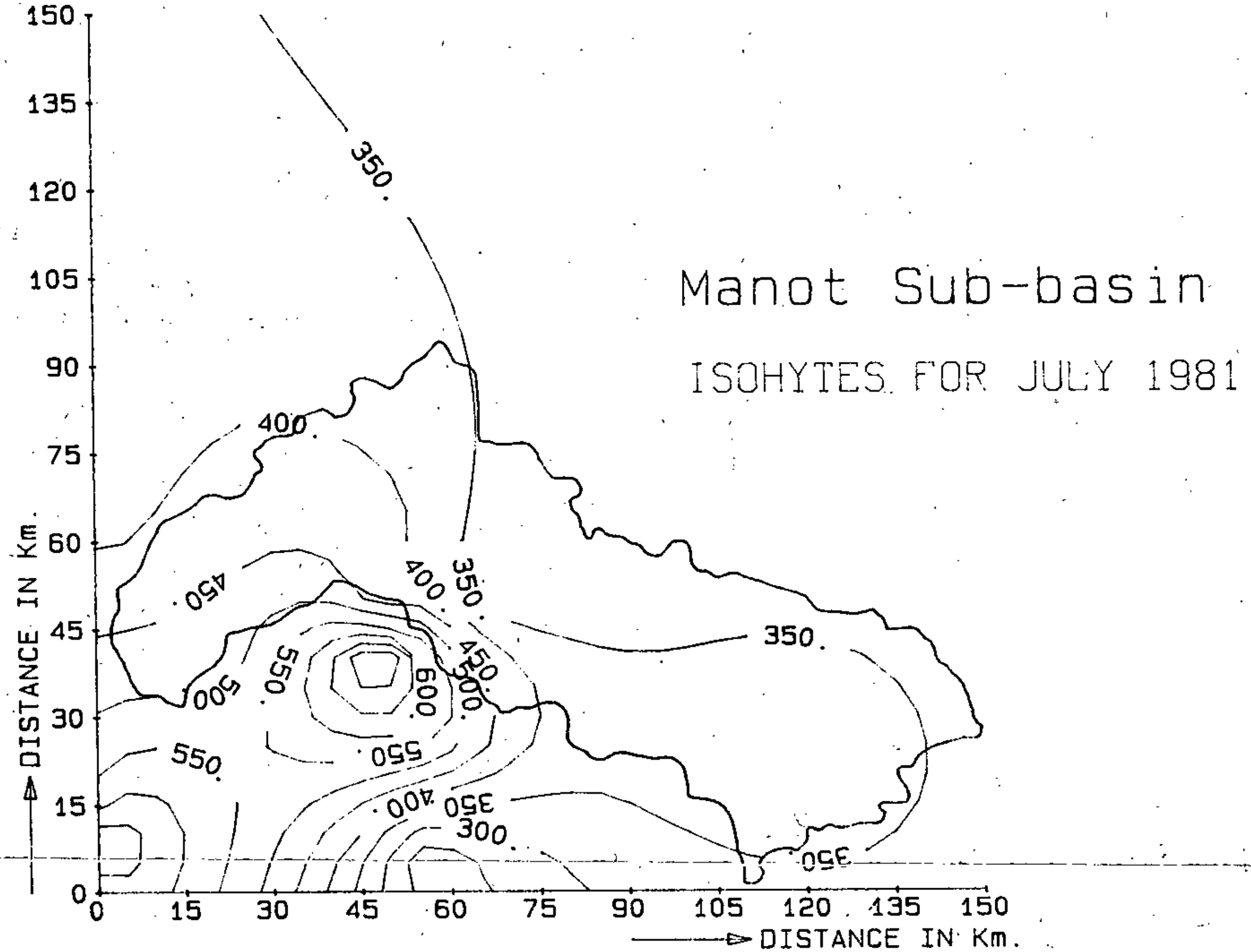


FIG. 9·1 ISOHYTES FOR THE SUB BASIN FOR JULY 1981

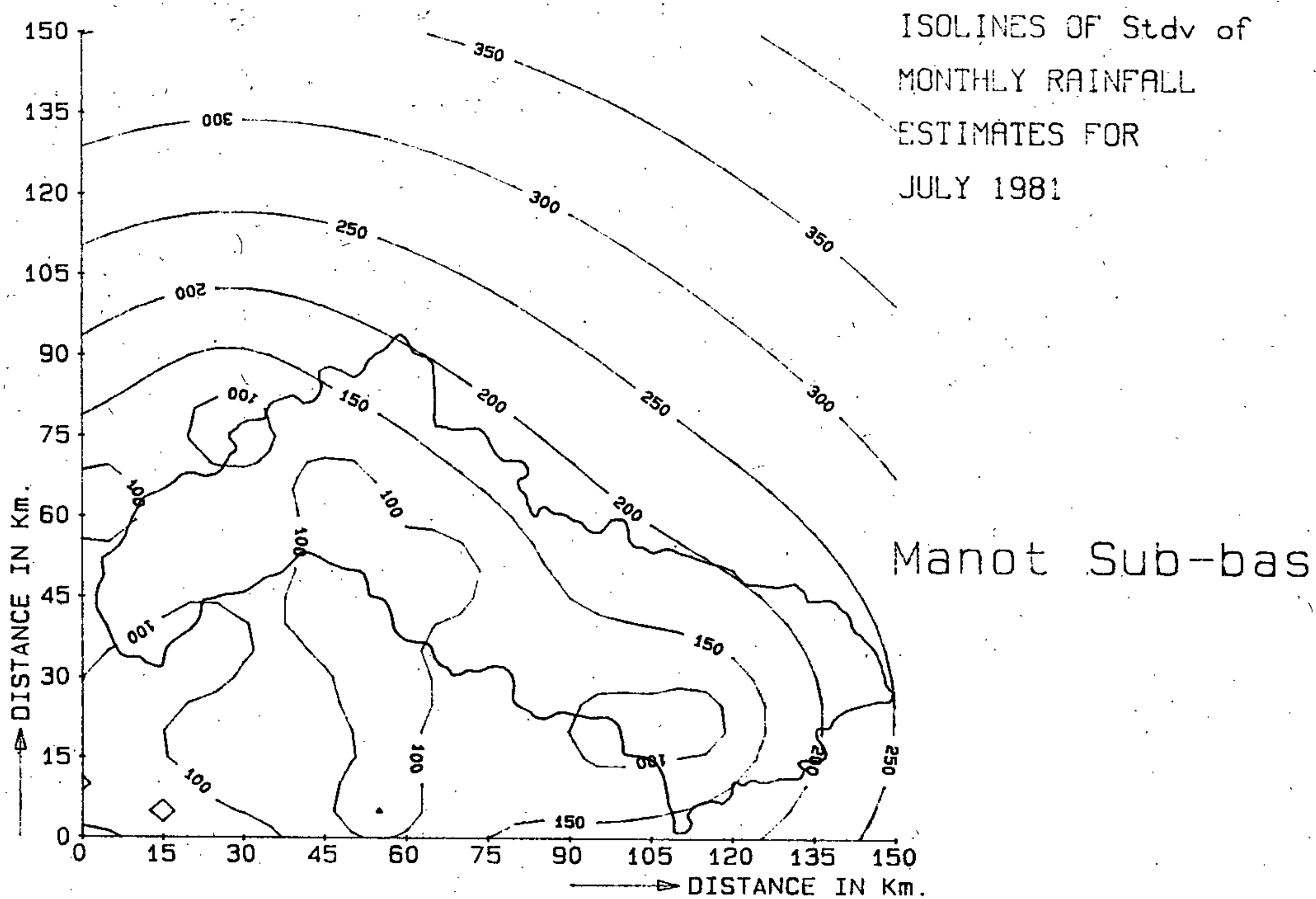


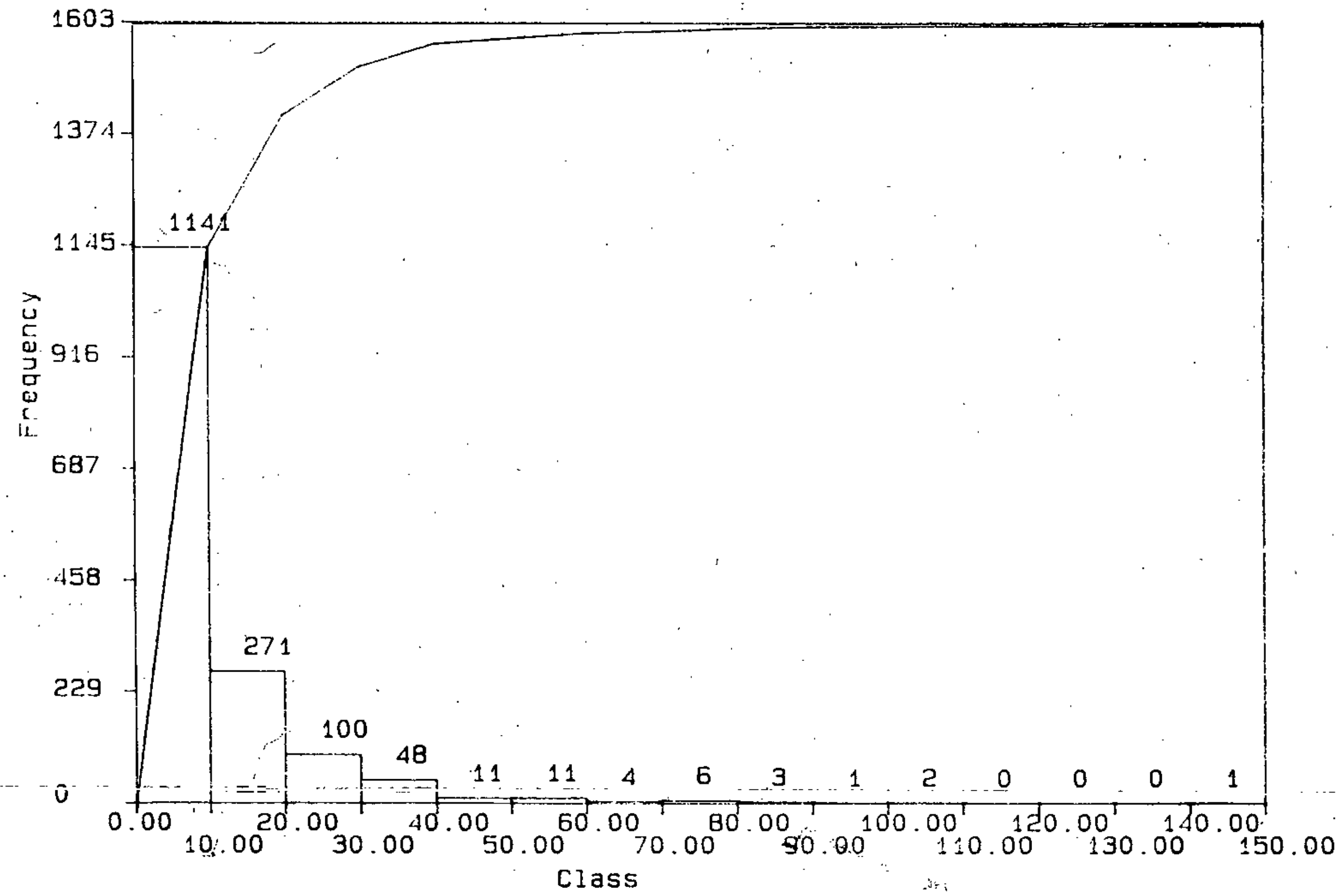
FIG. 9.2 ISOLINES OF STANDARD DIVIATION FOR JULY 1981

PLOT OF HISTOGRAM OF AVERAGE DAILY RAINFALL (THIESSEN WEIGHTS) OF MANOT SUB-BASIN. (THRESHOLD - 0.1 mm).

NATIONAL INSTITUTE OF HYDROLOGY

SWAGM DIVISION

FIG. 10.1



PLOT OF DISTRIBUTION FUNCTION GV1 FOR ANNUAL
MAX-DAILY AREAL AVERAGE RAINFALL OF MANOT
SUB-BASIN

NATIONAL INSTITUTE OF HYDROLOGY

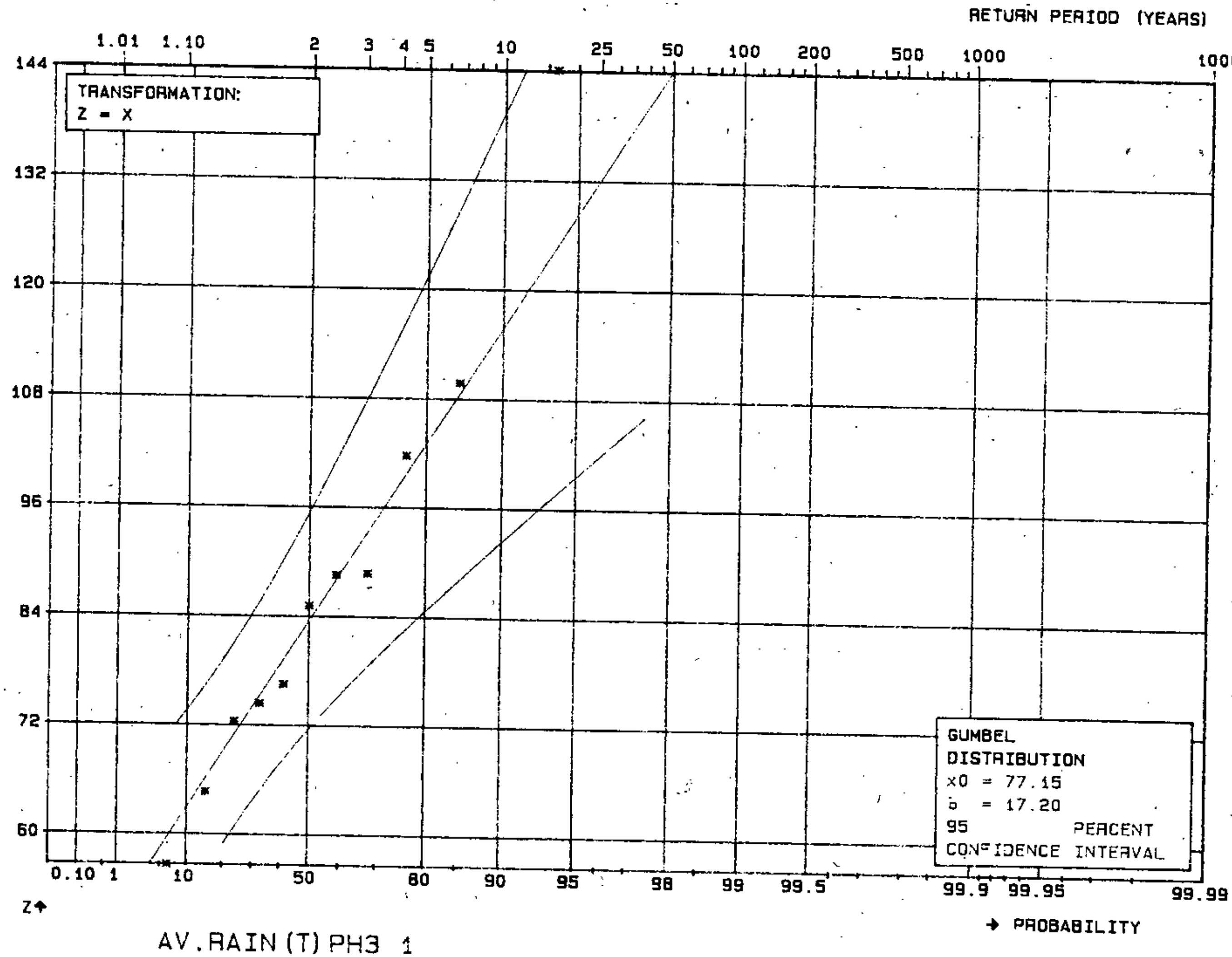
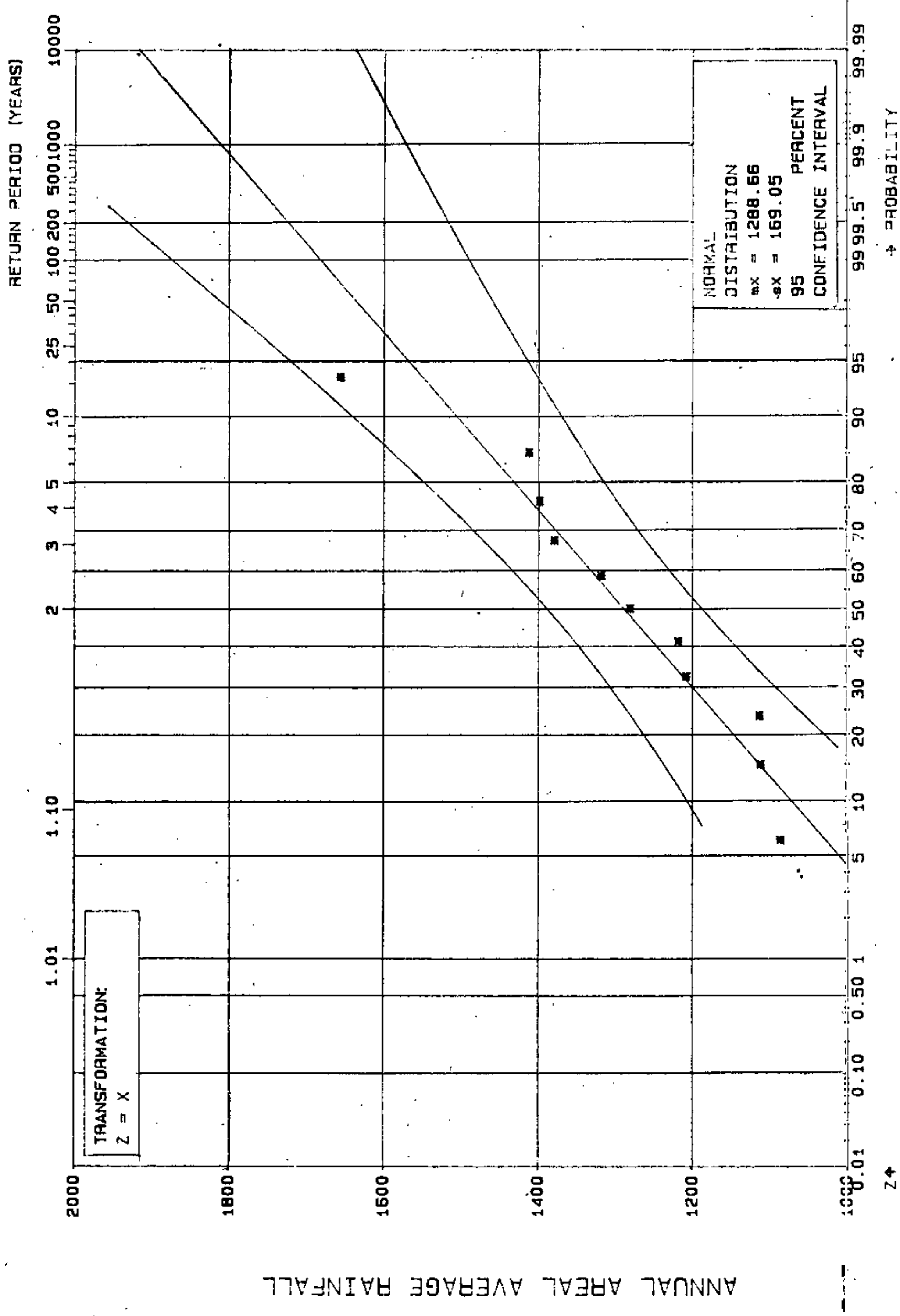


FIG.102

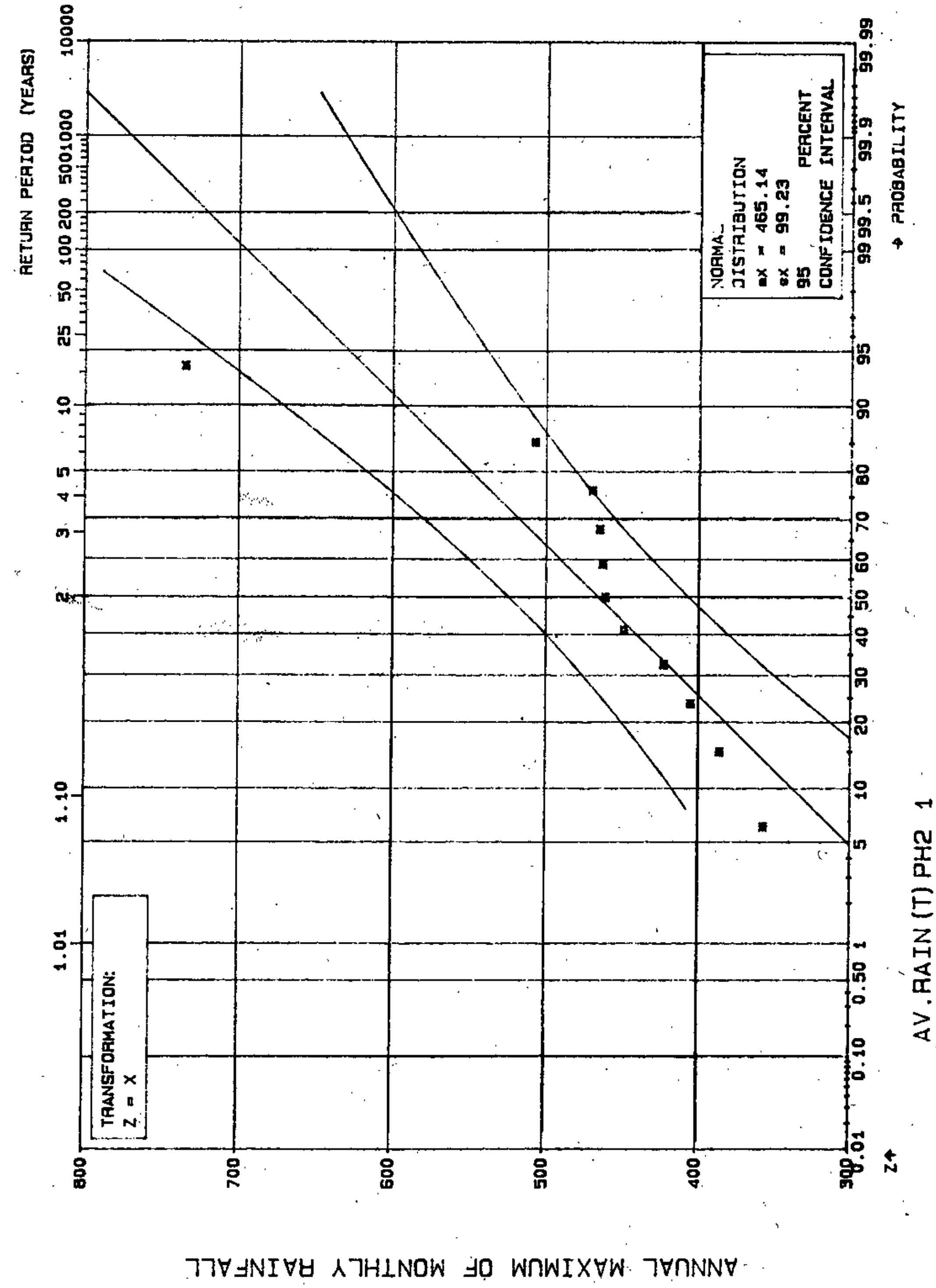


PLOT OF DISTRIBUTION FUNCTION - NORMAL FOR ANNUAL AREAL AVERAGE RAINFALL OF MANOT SUB-BASIN.

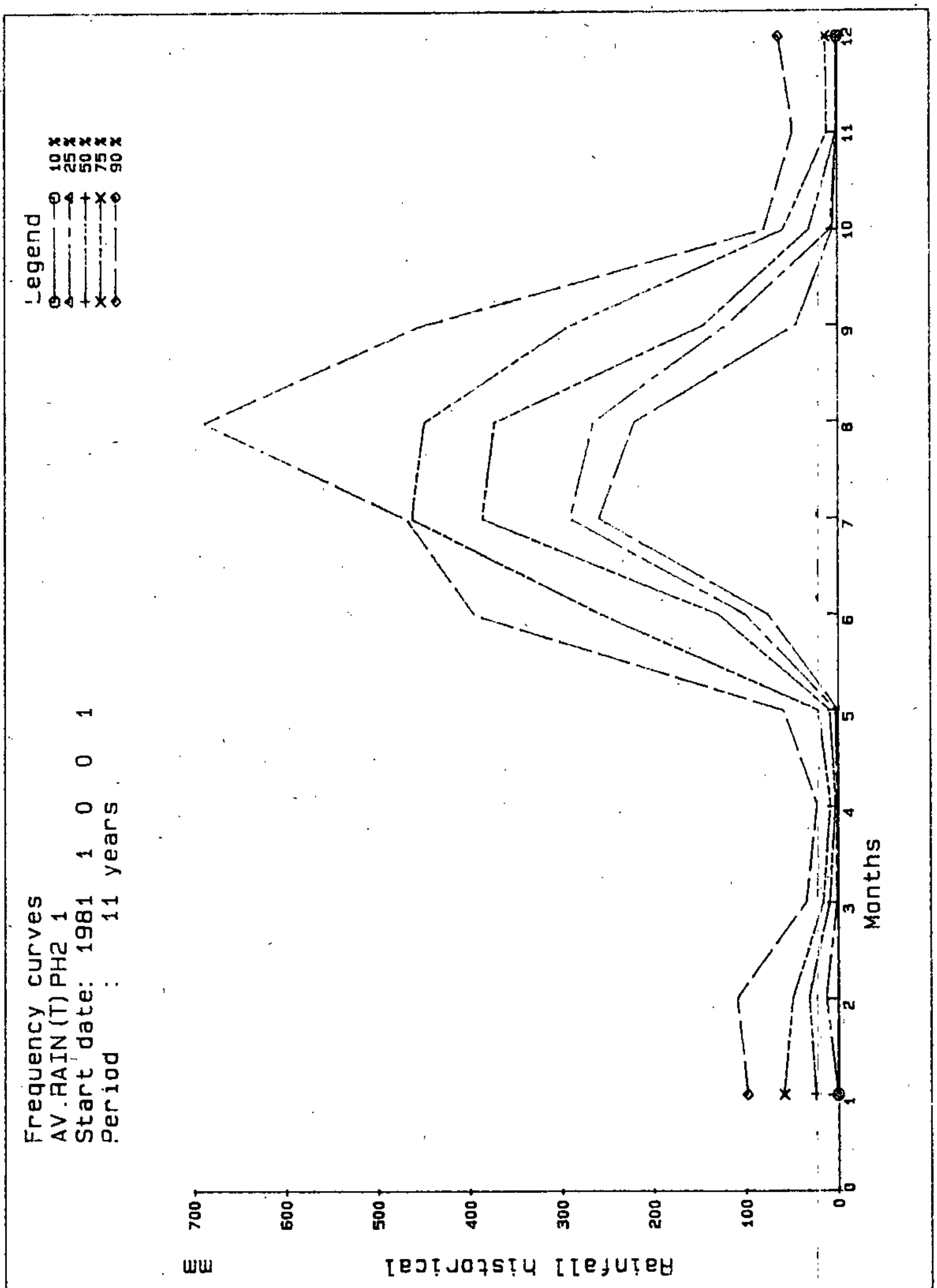
SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

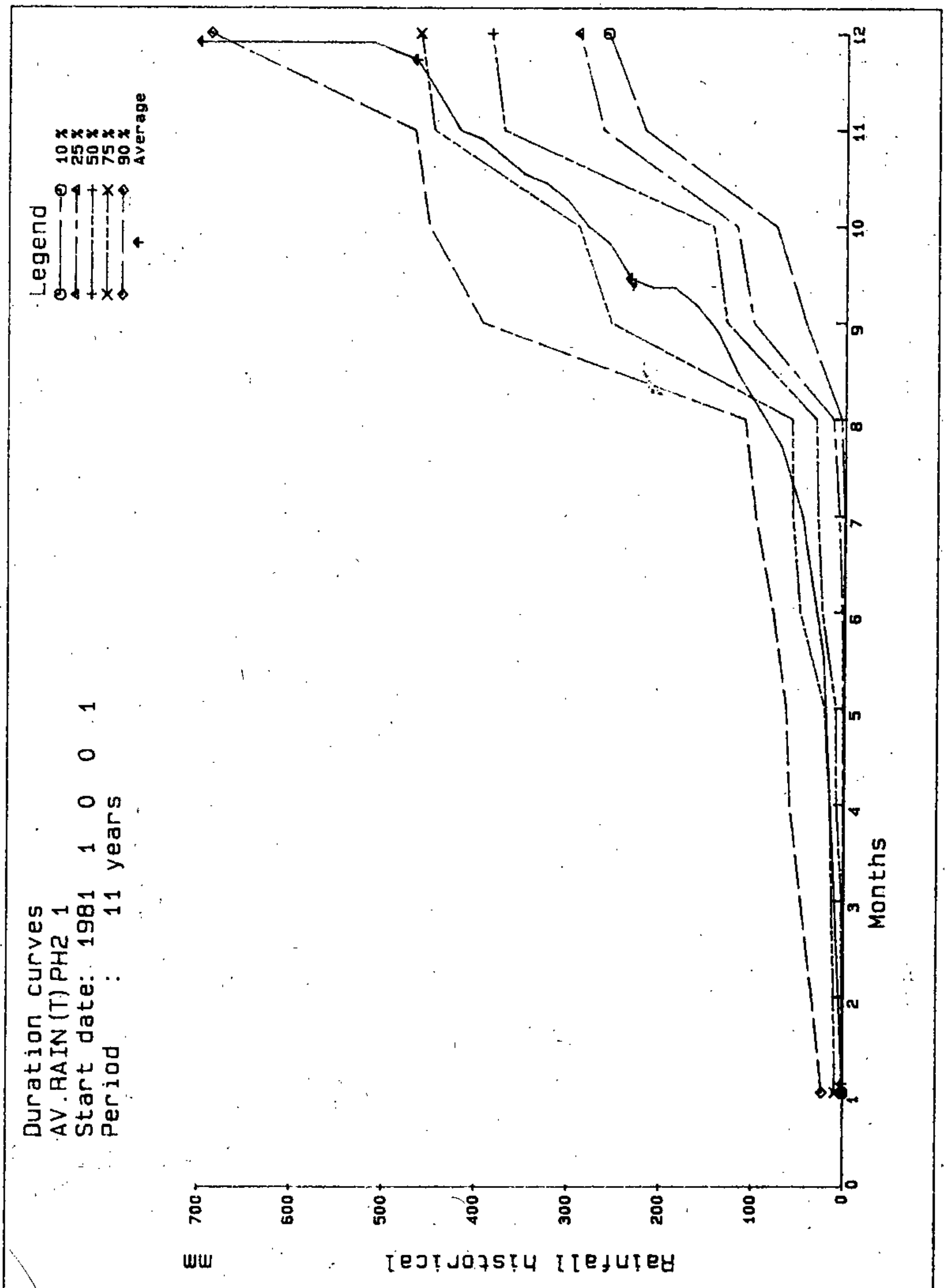
FIG. 15.3



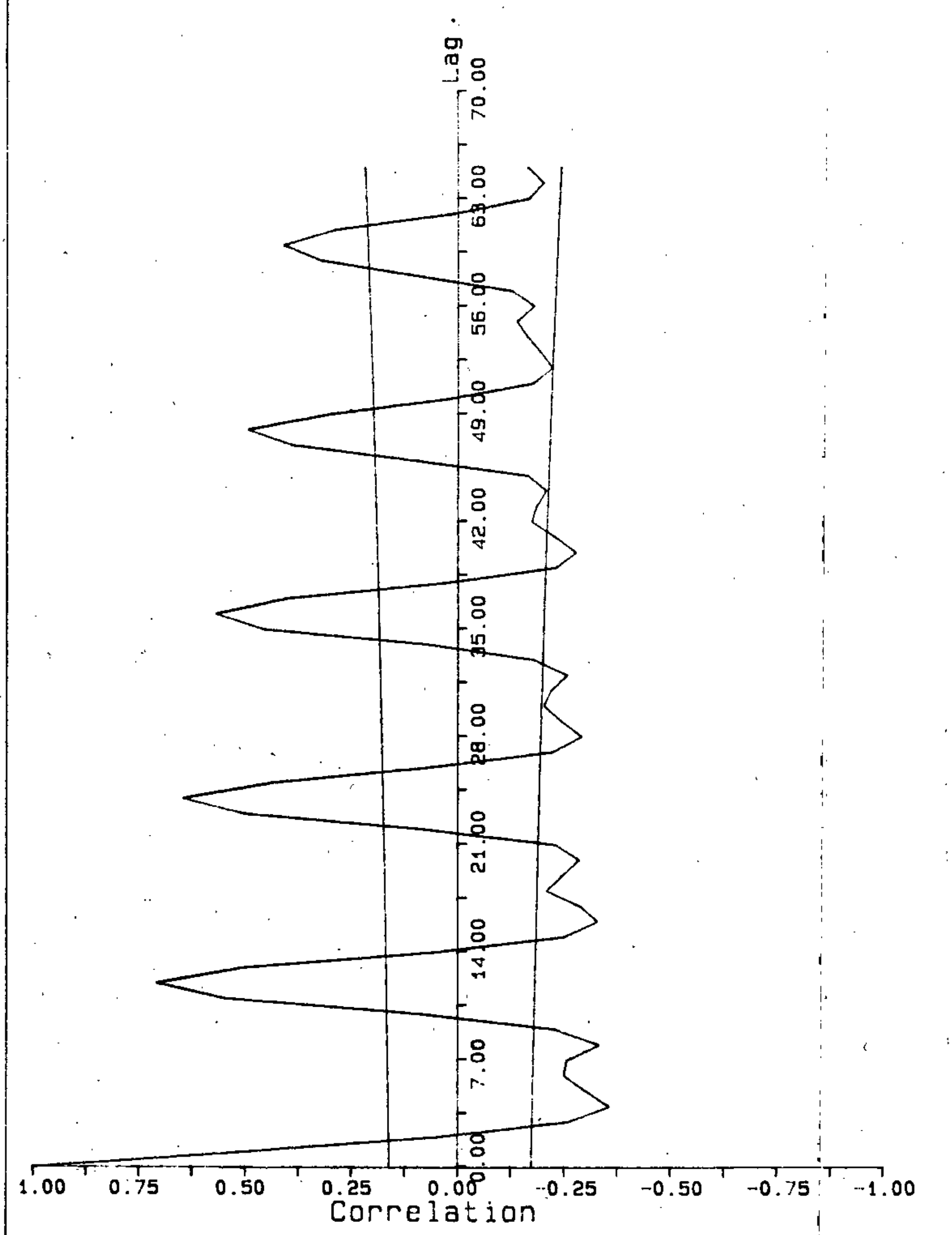
PLOT OF DISTRIBUTION FUNCTION FOR ANNUAL MAX. OF MONTHLY AREAL AVERAGE RAINFALL OF MANOT SUB-BASIN	SWA&M DIVISION
NATIONAL INSTITUTE OF HYDROLOGY	FIG. 10·4



FREQUENCY CURVES FOR MONTHLY AREAL RAINFALL OF MANOT SUB-BASIN	SWAM DIVISION	
NATIONAL INSTITUTE OF HYDROLOGY		FIG. 10.5



DURATION CURVES FOR MONTHLY AREAL RAINFALL OF MANOT SUB-BASIN	SWAM DIVISION
NATIONAL INSTITUTE OF HYDROLOGY	FIG. 10.6

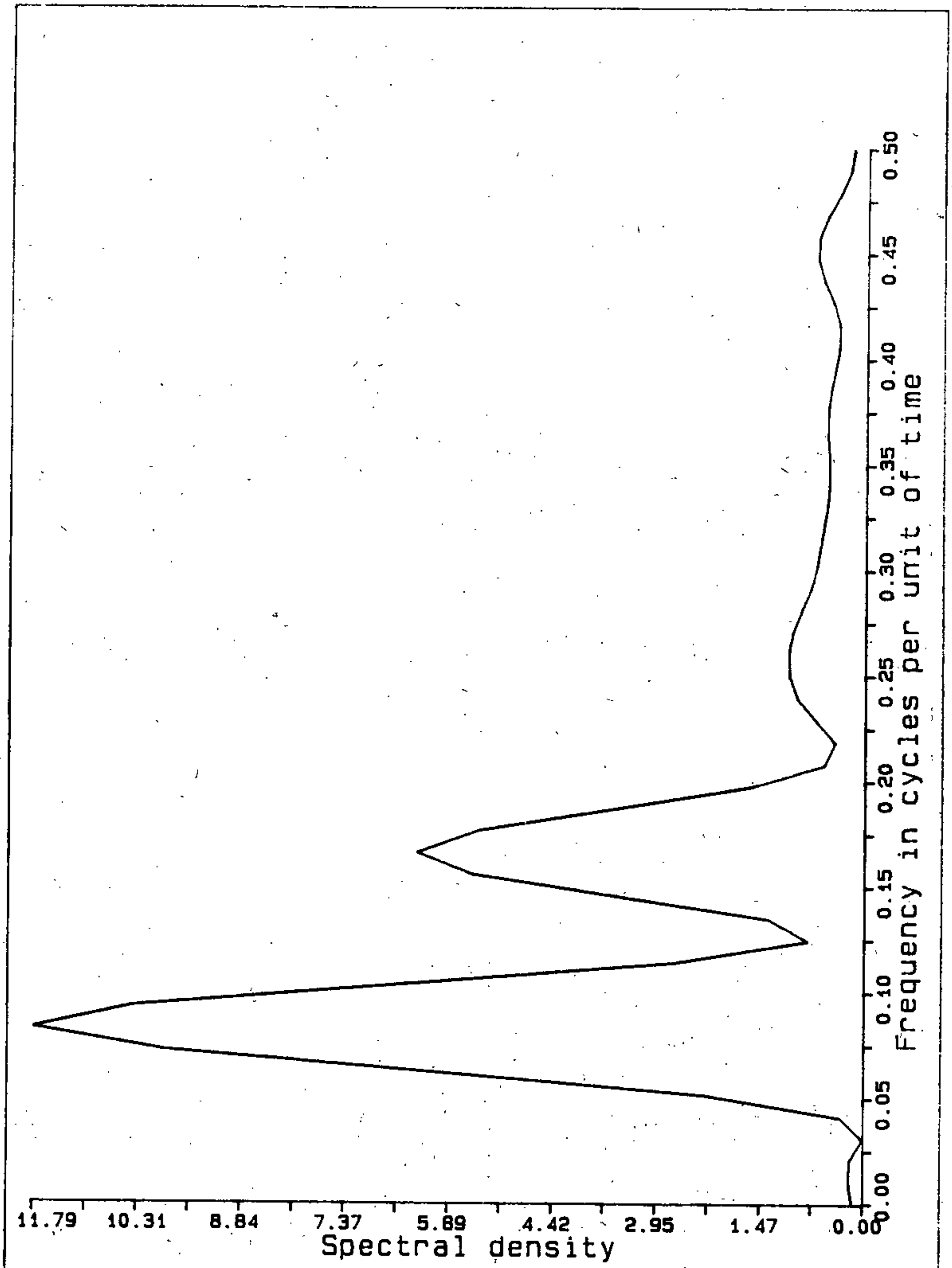


Autocorrelogram for monthly areal average rainfall for manot sub-basin.

SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

FIG. 11.1



Spectral density function
Series code AV.RAIN(T)PH2 1

SWA&M DIVISION

NATIONAL INSTITUTE OF HYDROLOGY

FIG. 11.2

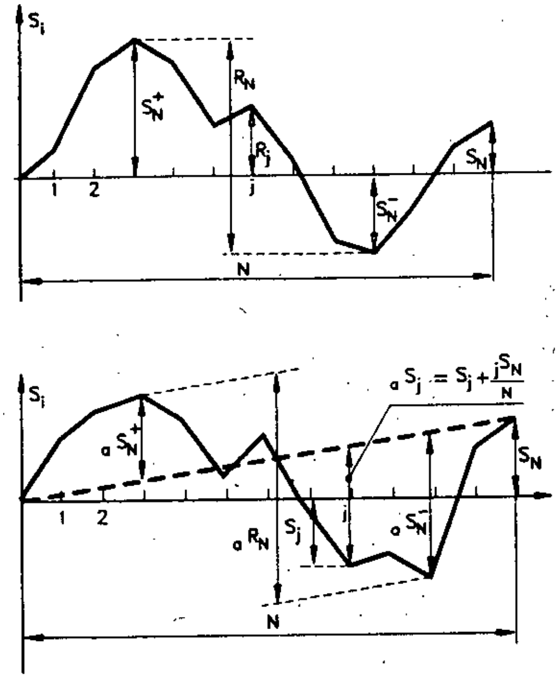


FIG. 11·3-DEFINITION SKETCH OF RANGE QUANTITIES

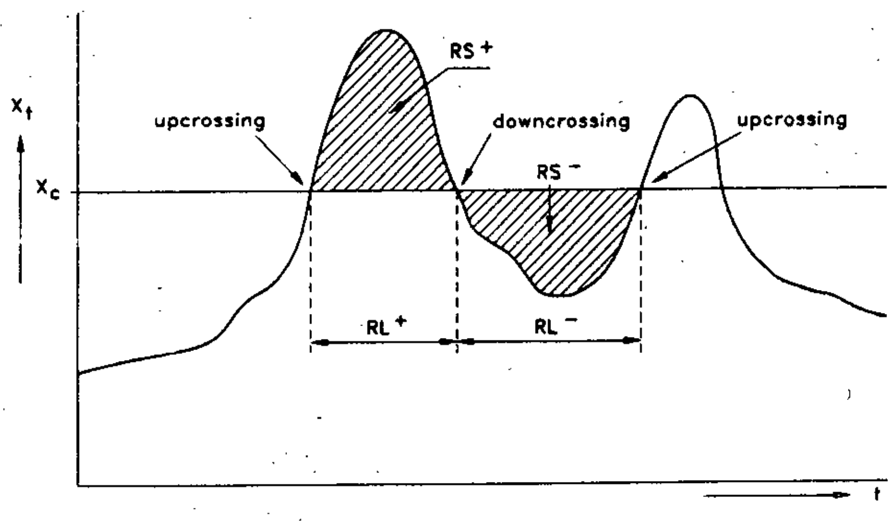


FIG. 11·4- DEFINITION SKETCH FOR RUN ANALYSIS

Example : 5.1 : Format for FREE+ROW

Datafile format :

```
---------------------------------------------------------------------------
FREE
ROW
BAJAG      PH3 1
1991, 7, 1, 0, 1, 8, 8, 1., 0
   6.4      .0      .0      .0      .0      .0      .0     6.6
   3.2     2.6      .0     4.8      .0     9.4    13.4     5.2
  11.0    14.8    19.4    13.8    17.0     9.2     7.4    23.6
   7.4     4.4      .0      .0     9.0    16.6     8.2      .0
   3.2     2.8     4.4    11.2    17.0      .0      .0      .0
    .0      .0      .0      .0      .0      .0    30.8    17.0
   8.8     5.4     3.8      .0     4.2     7.4      .0      .0
   8.2     8.8    20.4      .0      .0      .0 /
---------------------------------------------------------------------------
```

Example : 5.2 : Format for FIXE+ROW

Datafile format :

```
---------------------------------------------------------------------------
FIXE
ROW
BAJAG      PH3 1
1991, 7, 1, 0, 1, 8, 8, 1., 0, 1, 8
   6.4      .0      .0      .0      .0      .0      .0     6.6
   3.2     2.6      .0     4.8      .0     9.4    13.4     5.2
  11.0    14.8    19.4    13.8    17.0     9.2     7.4    23.6
   7.4     4.4      .0      .0     9.0    16.6     8.2      .0
   3.2     2.8     4.4    11.2    17.0      .0      .0      .0
    .0      .0      .0      .0      .0      .0    30.8    17.0
   8.8     5.4     3.8      .0     4.2     7.4      .0      .0
   8.2     8.8    20.4      .0      .0      .0
---------------------------------------------------------------------------
```

Example : 5.3 : Format for FREE+COL

Datafile format :

```
--------------------------------------------------------------------------------------------------------------
FREE
COL
BAJAG   PH3 1
1985 1 1 0 1 31 12 1 0
    31      28      31      30      31      30      31      31      30      31      30      31
  26.8    22.9      .0      .1      .0      .6      .0     1.3      .0      .0      .0      .0
   2.7     2.1      .0      .5      .0      .7      .0    98.6      .0     4.6      .0      .0
   1.1      .0      .0      .0      .0     2.1      .0     7.2     3.4     2.5      .0      .0
    .0      .0      .0      .0      .0     2.1      .0     1.3      .0      .0      .0      .0
    .0      .0      .0      .2      .0      .0      .0     2.0      .0      .0      .0      .0
    .0      .0      .0     4.9      .0      .0      .0    37.0      .0      .0      .0      .0
    .0      .0      .0      .0      .0     1.1      .0    65.4      .0     2.5      .0      .0
   1.6      .0      .0      .9      .0      .2     1.1     4.6      .0     7.6      .0      .0
   1.1      .0      .0      .0      .0     6.9     1.2     1.2      .0    23.4      .0      .0
   1.6      .0      .0      .0      .0     1.5     1.4     1.0    10.4      .0      .0      .0
  10.9      .0      .0      .0      .0      .2    85.4    30.0    18.6     8.6      .0      .0
   1.6      .0      .0      .0      .0      .0    21.4     1.2     2.2     4.5      .0      .0
    .5      .0      .0      .0      .0     2.0     5.8     9.6    10.4      .0      .0      .0
    .0      .3      .0      .0      .0      .0    24.5    25.0     6.8      .0      .0      .0
   1.1      .5      .0      .0      .0      .0    55.1     5.0    26.5      .0      .0      .0
   3.3      .0      .0      .0      .0      .0    22.2    39.2     2.4      .0      .0      .0
    .0      .0      .0      .0      .0      .0    27.6      .0      .0      .0      .0      .0
    .0      .0      .0      .0      .0      .0     1.3    69.2      .0      .0      .0      .0
    .0      .0      .0      .0      .0    29.2      .8     7.6      .0      .0      .0      .0
    .0      .0      .0      .0      .0     2.1    11.7    15.2     2.5      .0      .0      .0
   3.8      .0      .0      .0      .0      .0    12.3    19.6    13.4      .0      .0      .0
    .0      .0      .0      .0      .0      .0     7.2     6.4     2.7      .0      .0      .0
   6.0      .0      .0      .0      .0      .0    17.9     3.4      .0      .0      .0      .0
    .0      .0      .0      .0      .0      .2    50.0      .0      .0      .0      .0      .0
    .0      .0      .0      .0      .0     2.8    11.0      .0      .0      .0      .0      .0
    .0      .0      .0      .0      .0     4.2    30.0      .0      .0      .0      .0      .0
    .0      .0      .0      .0      .0    12.7      .0      .0     3.6      .0      .0      .0
    .0      .0      .0      .0      .0    21.3      .4     4.6      .0      .0      .0      .0
    .0       0      .0      .0      .0      .0    17.6    14.5      .0      .0      .0      .0
    .0       0      .3      .0      .0      .0    25.4    10.8      .0      .0      .0      .0
  10.9       0      .3       0      .0       0     2.8      .0       0      .0       0      .0
--------------------------------------------------------------------------------------------------------------
```

Example :5.4: Format for FIXE+COL

Datafile format

```
FIXE
COL
BAJAG     PH3 1
1985 1 1 0 1 31 12 1 0 6 10
          31      28      31      30      31      30      31      31      30      31      30      31
   1    26.8    22.9      .0      .1      .0      .6      .0     1.3      .0      .0      .0      .0
   2     2.7     2.1      .0      .5      .0      .7      .0    98.6      .0     4.6      .0      .0
   3     1.1      .0      .0      .0      .0     2.1      .0     7.2     3.4     2.5      .0      .0
   4      .0      .0      .0      .0      .0     2.1      .0     1.3      .0      .0      .0      .0
   5      .0      .0      .0      .2      .0      .0      .0     2.0      .0      .0      .0      .0
   6      .0      .0      .0     4.9      .0      .0      .0    37.0      .0      .0      .0      .0
   7      .0      .0      .0      .0      .0     1.1      .0    65.4      .0     2.5      .0      .0
   8     1.6      .0      .0      .9      .0      .2     1.1     4.6      .0     7.6      .0      .0
   9     1.1      .0      .0      .0      .0     6.9     1.2     1.2      .0    23.4      .0      .0
  10     1.6      .0      .0      .0      .0     1.5     1.4     1.0    10.4      .0      .0      .0
  11    10.9      .0      .0      .0      .0      .2    85.4    30.0    18.6     8.6      .0      .0
  12     1.6      .0      .0      .0      .0      .0    21.4     1.2     2.2     4.5      .0      .0
  13      .5      .0      .0      .0      .0     2.0     5.8     9.6    10.4      .0      .0      .0
  14      .0      .3      .0      .0      .0      .0    24.5    25.0     6.8      .0      .0      .0
  15     1.1      .5      .0      .0      .0      .0    55.1     5.0    26.5      .0      .0      .0
  16     3.3      .0      .0      .0      .0      .0    22.2    39.2     2.4      .0      .0      .0
  17      .0      .0      .0      .0      .0      .0    27.6      .0      .0      .0      .0      .0
  18      .0      .0      .0      .0      .0      .0     1.3    69.2      .0      .0      .0      .0
  19      .0      .0      .0      .0      .0    29.2      .8     7.6      .0      .0      .0      .0
  20      .0      .0      .0      .0      .0     2.1    11.7    15.2     2.5      .0      .0      .0
  21     3.8      .0      .0      .0      .0      .0    12.3    19.6    13.4      .0      .0      .0
  22      .0      .0      .0      .0      .0      .0     7.2     6.4     2.7      .0      .0      .0
  23     6.0      .0      .0      .0      .0      .0    17.9     3.4      .0      .0      .0      .0
  24      .0      .0      .0      .0      .0      .2    50.0      .0      .0      .0      .0      .0
  25      .0      .0      .0      .0      .0     2.8    11.0      .0      .0      .0      .0      .0
  26      .0      .0      .0      .0      .0     4.2    30.0      .0      .0      .0      .0      .0
  27      .0      .0      .0      .0      .0    12.7      .0      .0     3.6      .0      .0      .0
  28      .0      .0      .0      .0      .0    21.3      .4     4.6      .0      .0      .0      .0
  29      .0       0      .0      .0      .0      .0    17.6    14.5      .0      .0      .0      .0
  30      .0       0      .3      .0      .0      .0    25.4    10.8      .0      .0      .0      .0
  31    10.9       0      .3       0      .0       0     2.8      .0       0      .0       0      .0
```

Example : 5.5 : Format for FREE+PAR.

Datafile format

```
FREE
PAR
4
BAJAG     PH3 1
BARBAS    PH3 1
GITHOR    PH3 1
KARANJ    PH3 1
1991, 7, 1, 0, 1, 61, 4, 1., 0
        6.400000    0.000000E+00    0.000000E+00       19.000000
    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
    0.000000E+00       16.500000    0.000000E+00    0.000000E+00
    0.000000E+00        5.500000    0.000000E+00    0.000000E+00
    0.000000E+00    0.000000E+00    0.000000E+00       63.400000
    ...
    ...
    ...
        8.800000    0.000000E+00    0.000000E+00    0.000000E+00
       20.400000       25.000000    4.000000E-01       42.000000
    0.000000E+00        6.500000       17.200000       25.400000
    0.000000E+00    0.000000E+00      150.400000       15.000000
    0.000000E+00        2.500000        5.400000    0.000000E+00
```

Example : 5.6 : Format for FIXE+PAR.

Datafile format

```
FIXE
PAR
4
BAJAG     PH3 115 8
BARBAS    PH3 123 8
GITHOR    PH3 131 8
KARANJ    PH3 139 8
1991, 7, 1, 0, 1, 61, 4, 1., 0
910701 000000      6.4     .0      .0    19.0
910702 000000       .0     .0      .0      .0
910703 000000       .0   16.5      .0      .0
910704 000000       .0    5.5      .0      .0
910705 000000       .0     .0      .0    63.4
...
...
...
910827 000000      8.8     .0      .0      .0
910828 000000     20.4   25.0      .4    42.0
910829 000000       .0    6.5    17.2    25.4
910830 000000       .0     .0   150.4    15.0
910831 000000       .0    2.5     5.4      .0
```

Example : 5.7 : Format for Non-Equidistant time series.

Given is the water quality parameter datafile of MANOT station with following layout.

```
DATE        DIS    PH    TDS   FE     CL
80-01-01    2.5   7.93   122   0.04   136
80-02-01    2.4   7.80     0   0.02   150
80-07-01  449.5   7.99   109   3.4    115
80-08-01  735.0   7.07    82   4.1    172
80-09-01  552.0   7.48   159   0.83   151
80-10-01   86.1   7.51   187   0.08   146
80-11-01   23.6   7.40   132   -99.   141
81-02-03    5.7   8.00   135   -99.   138
...
...
...
```

The series codes are respectively for:

```
DIS   =   MANOT    QH
PH    =   MANOT    PH
TDS   =   MANOT    TD
FE    =   MANOT    FE
CL    =   MANOT    CL
```

To transfer these series to HYMOS database the file should have following format.

Datafile format

```
-------------------------------------------------
MANOT      QH
MANOT      PH
MANOT      TD
MANOT      FE
MANOT      CL



1980 01 01 00 00     2.5   7.93   122   0.04    136 /
1980 02 01 00 00     2.4   7.80     0   0.02    150 /
1980 07 01 00 00   449.5   7.99   109   3.4     115 /
1980 08 01 00 00   735.0   7.07    82   4.1     172 /
1980 09 01 00 00   552.0   7.48   159   0.83    151 /
1980 10 01 00 00    86.1   7.51   187   0.08    146 /
1980 11 01 00 00    23.6   7.40   132   -99.    141 /
1981 02 03 00 00     5.7   8.00   135   -99.    138 /
...
...
...
-------------------------------------------------
```

Example : 5.8 : Format for stage-discharge data.

Given the stage-discharge data for Manot gauge-discharge site from June 1990 onwards the format for the datafile would be as given below.

Here :
Column 1 : Year
Column 1 : Month
Column 1 : Day
Column 1 : Serial no.
Column 1 : Zero of the gauge
Column 1 : Gauge reading
Column 1 : Discharge

Datafile format

```
-------------------------------------------
MANOT      N
1990   6   1    152 442.0     1.055      1.635/
1990   6   2    153 442.0     1.040      1.327/
1990   6   4    155 442.0     1.020      1.110/
1990   6   5    156 442.0     1.100      2.114/
1990   6   6    157 442.0     1.090      2.000/
1990   6   7    158 442.0     1.390      8.984/
1990   6   8    159 442.0     1.385      8.586/
1990   6   9    160 442.0     1.400      9.251/
1990   6  11    162 442.0     1.180      3.469/
1990   6  12    163 442.0     1.170      3.129/
1990   6  13    164 442.0     1.110      2.790/
1990   6  14    165 442.0     1.080      2.050/
1990   6  15    166 442.0     1.070      1.949/
...
...
...
-------------------------------------------
```

Example : 6.1 : Listing by dedicated table option.

Daily data of series KHUDIY PH3 1 Year = 1982

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	.0	6.8	5.4	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	12.3	.0	.0	.0	.0
3	.0	6.2	.0	.0	.0	.0	.0	7.2	3.6	.0	.0	.0
4	.0	9.4	.0	.0	.0	.0	.0	10.7	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	9.4	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	11.2	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	6.1	8.4	2.6	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	34.8	78.4	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	63.5	54.2	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	55.3	11.5	12.6	.0	6.0	.0
11	3.8	.0	.0	.0	.0	.0	.0	12.2	9.2	.0	1.2	.0
12	.0	.0	.0	.0	.0	.0	.0	2.8	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	13.5	63.9	3.1	.0	.0	.0	.0
14	.0	.0	.0	.0	.0	52.8	15.4	42.8	.0	.0	.0	.0
15	4.6	.0	.0	.0	.0	45.4*	.0	23.4	.0	.0	.0	.0
16	.0	.0	.0	.0	.0	.0	.0	57.7	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	23.4	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	12.7	7.1	.0	.0	12.4	.0	.0
19	.0	.0	.0	.0	.0	.0	26.7	18.2	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	8.4	21.8	.0	5.2	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	23.2	.0	6.4	.0	.0
22	.0	.0	.0	.0	.0	.0	24.9	26.6	.0	5.2	.0	.0
23	.0	.0	.0	.0	.0	16.6	13.6	28.8	.0	.6	.0	.0
24	.0	.0	.0	.0	.0	.0	19.7	12.6	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	.0	12.4	15.2	.0	.0	.0	.0
26	6.8	.0	.0	.0	.0	.0	8.7	8.2	.0	.0	4.8	.0
27	.0	.0	.0	.0	.0	4.5	3.8	18.1	.0	.0	.1	.0
28	.0	5.2	.0	.0	.0	.0	16.2	4.6	.0	.0	.0	.0
29	.0	*********	.0	.0	.0	.0	27.8	.0	.0	.0	.0	.0
30	.0	*********	.0	.0	.0	.0	12.7	.0	.0	.0	.0	.0
31	7.4	*********	.0	*********	.0	*********	16.2	8.2	*********	.0	*********	.0
Data	31	28	31	30	31	30	31	31	30	31	30	31
Eff.	31	28	31	30	31	30	31	31	30	31	30	31
Miss	0	0	0	0	0	0	0	0	0	0	0	0
Sum	22.6	20.8	.0	.0	.0	146.5	402.4	517.4	111.8	29.8	12.1	.0
Mean	.7	.7	.0	.0	.0	4.9	13.0	16.7	3.7	1.0	.4	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Max.	7.4	9.4	.0	.0	.0	52.8	63.9	57.7	78.4	12.4	6.0	.0

Completed data marked with *
Corrected data marked with +

Example : 6.2 : Listing by data block option.

Data of series KHUDIY PH3 1 Date from 1982 1 1 0 1 (period 1)

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3.8	.0	.0	.0	4.6	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	6.8	.0	.0	.0	.0
7.4	.0	.0	6.2	9.4	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	5.2	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	13.5	52.8	46.4*	.0	.0	12.7	.0
.0	.0	.0	16.6	.0	.0	.0	4.5	.0	.0
.0	.0	.0	.0	.0	.0	.0	6.1	.0	63.5
55.3	.0	.0	63.9	15.4	.0	.0	.0	7.1	26.7
8.4	.0	24.9	13.6	19.7	12.4	8.7	3.8	16.2	27.8
12.7	16.2	6.8	12.3	7.2	10.7	9.4	11.2	8.4	34.8
54.2	11.5	12.2	2.8	3.1	42.8	23.4	57.7	23.4	.0
18.2	21.8	23.2	26.6	28.8	12.6	15.2	8.2	18.1	4.6
.0	.0	8.2	5.4	.0	3.6	.0	.0	.0	2.6
78.4	.0	12.6	9.2	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12.4	.0	5.2	6.4	5.2	.6	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	6.0	1.2	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	4.8
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0					

Maximum = 78.400, minimum= .000, mean= 3.461

Completed data marked with *
Corrected data marked with +

Missing data signified by -99.

Example : 6.3 : Daily data and statistics

Series BAJAG PH3 1 Year = 1985

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	26.8	22.9	.0	.1	.0	.6	.0	1.3	.0	.0	.0	.0
2	2.7	2.1	.0	.5	.0	.7	.0	98.6	.0	4.6	.0	.0
3	1.1	.0	.0	.0	.0	2.1	.0	7.2	3.4	2.5	.0	.0
4	.0	.0	.0	.0	.0	2.1	.0	1.3	.0	.0	.0	.0
5	.0	.0	.0	.2	.0	.0	.0	2.0	.0	.0	.0	.0
6	.0	.0	.0	4.9	.0	.0	.0	37.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	1.1	.0	65.4	.0	2.5	.0	.0
8	1.6	.0	.0	.9	.0	.2	1.1	4.6	.0	7.6	.0	.0
9	1.1	.0	.0	.0	.0	6.9	1.2	1.2	.0	23.4	.0	.0
10	1.6	.0	.0	.0	.0	1.5	1.4	1.0	10.4	.0	.0	.0
11	10.9	.0	.0	.0	.0	.2	85.4	30.0	18.6	8.6	.0	.0
12	1.6	.0	.0	.0	.0	.0	21.4	1.2	2.2	4.5	.0	.0
13	.5	.0	.0	.0	.0	2.0	5.8	9.6	10.4	.0	.0	.0
14	.0	.3	.0	.0	.0	.0	24.5	25.0	6.8	.0	.0	.0
15	1.1	.5	.0	.0	.0	.0	55.1	5.0	26.5	.0	.0	.0
16	3.3	.0	.0	.0	.0	.0	22.2	39.2	2.4	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	27.6	.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	1.3	69.2	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	29.2	.8	7.6	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	2.1	11.7	15.2	2.5	.0	.0	.0
21	3.8	.0	.0	.0	.0	.0	12.3	19.6	13.4	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	7.2	6.4	2.7	.0	.0	.0
23	6.0	.0	.0	.0	.0	.0	17.9	3.4	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.2	50.0	.0	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	2.8	11.0	.0	.0	.0	.0	.0
26	.0	.0	.0	.0	.0	4.2	30.0	.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	12.7	.0	.0	3.6	.0	.0	.0
28	.0	.0	.0	.0	.0	21.3	.4	4.6	.0	.0	.0	.0
29	.0	*********	.0	.0	.0	.0	17.6	14.5	.0	.0	.0	.0
30	.0	*********	.3	.0	.0	.0	25.4	10.8	.0	.0	.0	.0
31	10.9	*********	.3	*********	.0	*********	2.8	.0	*********	.0	*********	.0
Data	31	28	31	30	31	30	31	31	30	31	30	31
Eff.	31	28	31	30	31	30	31	31	30	31	30	31
Miss	0	0	0	0	0	0	0	0	0	0	0	0
Sum	73.1	25.8	.5	6.6	.0	89.9	434.2	480.9	102.9	53.7	.0	.0
Mean	2.4	.9	.0	.2	.0	3.0	14.0	15.5	3.4	1.7	.0	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Max.	26.8	22.9	.3	4.9	.0	29.2	85.4	98.6	26.5	23.4	.0	.0
High	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
Numb	0	0	0	0	0	0	0	0	0	0	0	0
Low	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Numb	0	0	0	0	0	0	0	0	0	0	0	0

Annual values:

Data	365	* Sum	1267.6	* Minimum	.0	* Too low	0
Effective	365	* Mean	3.5	* Maximum	98.6	* Too high	0
Missing	0						

Exceedance of:
- Lower bound (.00) marked with *
- Upper bound (300.00) marked with *

Example : 6.4 : Comparison is shown between raw and processed daily rainfall series at KHUDIYAGHAT station.

Since there was difference at only one place and so the table for only that year is given here.

Comparison between series KHO PH3 1 and KHUDIY PH3 1Year 1982

==========Data==========

Year	month	day	hour	sub.i	KHUDIY(O) PH3 1	KHUDIY PH3 1
1982	6	15	0	1	1471.8	46.4

Example : 6.5 : Tabulation of series, Year 1984

==========Data==========

Year	mth	day	hr	si	BICHHI PH	GITHOR PH	KHUDIY PH	MANDL1 PH	SIMARI PH	MANOT PH
1984	8	1			11.3	4.0	17.2	83.0	12.6	10.6
1984	8	2			48.7	7.0	7.8	12.6	79.2	9.8
1984	8	3			22.5	23.0	52.4	43.8	13.0	57.4
1984	8	4			1.8	5.0	3.2	9.6	.0	5.6
1984	8	5			.9	.0	.0	.0	1.6	.0
1984	8	6			3.2	.0	.0	.0	5.6	3.4
1984	8	7			19.1	4.0	4.5	2.8	30.0	4.8
1984	8	8			106.1	40.0	3.2	8.0	166.2	8.6
1984	8	9			134.7	112.0	135.6	145.0	144.0	110.0
1984	8	10			22.6	51.0	56.4	55.4	.0	64.8
1984	8	11			1.1	2.0	3.2	2.8	.0	2.6
1984	8	12			2.0	1.0	.0	.0	3.0	1.4
1984	8	13			.0	.0	.0	.0	.0	.0
1984	8	14			35.7	9.0	3.6	3.4	57.0	40.8
1984	8	15			32.3	54.0	11.4	16.8	29.6	51.4
1984	8	16			82.7	11.0	28.4	5.2	130.0	12.2
1984	8	17			242.3	62.0	132.8	79.0	353.0	81.6
1984	8	18			99.0	208.0	156.2	152.2	35.0	270.0
1984	8	19			6.8	12.0	13.8	16.8	2.4	28.4
1984	8	20			27.1	4.0	1.2	2.6	45.0	2.2
1984	8	21			16.3	2.0	13.4	11.4	23.2	3.2
1984	8	22			59.6	2.0	8.2	22.4	100.0	25.6
1984	8	23			39.0	38.0	43.4	23.0	38.0	39.4
1984	8	24			31.1	89.0	42.4	51.0	3.0	71.6
1984	8	25			2.5	1.0	.0	.2	4.0	3.2
1984	8	26			.5	2.0	.0	.0	.0	.6
1984	8	27			3.6	3.0	.0	1.0	5.0	1.0
1984	8	28			.7	3.0	.0	.0	.0	.0
1984	8	29			5.2	7.0	.0	.0	6.0	2.2
1984	8	30			22.5	55.0	6.4	3.2	13.8	2.4
1984	8	31			12.6	31.0	8.4	4.4	6.2	26.8

Example : 6.6 : Result of double mass analysis.

Double mass analysis
Test series: BARBAS PH3 1

Base series:			Weight
	BAJAG	PH3 1	.20
	DINDOR	PH3 1	.20
	GITHOR	PH3 1	.20
	ODHARI	PH3 1	.20
	SAKKA	PH3 1	.20

1	2	3	4	5	6	7	8	9
Period	Base			Test			Ratios	
	Amount	Cum	Perc	Amount	Cum	Perc	(6)/(3)	(7)/(4)
	mm	mm		mm	mm		-	-
1981	1208.9	1209.	8.4	1475.0	1475.	11.1	1.22	1.33
1982	1233.7	2443.	16.9	1012.0	2487.	18.7	1.02	1.11
1983	1467.0	3910.	27.0	1600.0	4087.	30.7	1.05	1.14
1984	1404.2	5314.	36.7	1187.0	5274.	39.7	.99	1.08
1985	1256.6	6570.	45.4	1118.0	6392.	48.1	.97	1.06
1986	1260.7	7831.	54.1	1343.0	7735.	58.2	.99	1.08
1987	1425.5	9257.	64.0	1013.6	8749.	65.8	.95	1.03
1988	1378.2	10635.	73.5	1143.2	9892.	74.4	.93	1.01
1989	1014.6	11649.	80.5	887.4	10779.	81.1	.93	1.01
1990	1668.5	13318.	92.0	1547.5	12327.	92.7	.93	1.01
1991	1154.4	14472.	100.0	967.6	13294.	100.0	.92	1.00

Total number of periods analysis: 11

Example : 6.7 : Statistical Tests on Data Homogeneity and Randomness

One Series Test

Series code: BAJAG PH3 1

Date of first element in series= 1981 1 1 0 1
Number of data = 1826
Median run test, error in execution
Too many values equal to median

Turning Point Test

```
Number of turning points (=Nt)   =       430
Mean of Nt                       =  1216.000
Standard deviation of Nt         =    18.008
Test statistic [u]  (abs.value)  =    43.646
Prob(u.le.[u])                   =     1.000
Hypothesis: H0: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     H0 rejected
```

```
Difference Sign Test
--------------------
Number of difference signs (=Nds)=         402
Mean of Nds                      =     399.000
Standard deviation of Nds        =       8.165
Test statistic [u]  (abs.value)  =        .367
Prob(u.le.[u])                   =        .643
Hypothesis: HO: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     HO not rejected

Spearman Rank Serial Correlation Test
-------------------------------------
Rank serial corr. coeff. (=rs)   =        .716
Test statistic [t]  (abs.value)  =      43.827
Degrees of freedom               =        1823
Prob(t.le.[t])                   =       1.000
Hypothesis: HO: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     HO rejected

Spearman Rank Correlation Trend Test
------------------------------------
Rank correlation coeff.  (=rs)   =       -.037
Test statistic [t]               =       1.570
Degrees of freedom               =        1824
Prob(t.le.[t])                   =        .942
Hypothesis: HO: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     HO not rejected

Arithmetical Serial Correlation Test
------------------------------------
Lag-1 serial corr. coeff. (=r1)  =        .376
Test statistic [t]               =      17.308
Degrees of freedom               =        1823
Prob(t.le.[t])                   =       1.000
Hypothesis: HO: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     HO rejected
```

```
Wilcoxon-Mann-Whitney U-Test
------------------
Number of data in first set          =      1095
Number of data in second set         =       731
Sum of ranks of first set            =  1019528.
Sum of ranks of second set           =   648523.
U-value                              =380977.000
Mean of U                            =400222.500
Standard deviation of U              =  9489.737
Test statistic [u]  (abs.value)      =     2.028
Prob(u.le.[u])                       =      .979
Hypothesis: H0: Split samples are from the same population
            H1: Split samples are from different populations
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     H0 rejected

Student t-Test with Welch modification
-------------------------------------
Number of data in first set          =      1095
Number of data in second set         =       731
Test statistic [t]  (abs.value)      =     1.143
Degrees of freedom                   =      1131
Prob(t.le.[t])                       =      .873
Mean of first set       (mA)         =     3.134
St.dev. of first set    (sA)         =     7.546
Mean of second set      (mB)         =     3.694
St.dev. of second set   (sB)         =    11.733
Var. test stat.   (Qi=sA^2/sB^2)     =      .414
Prob(Q.le.Qi)                        =      .000
Hypothesis: H0: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     H0 not rejected

Wilcoxon-Test on Differences in the Mean
--------------------------------------
Number of data in first set          =      1095
Number of data in second set         =       731
W-value                              =761954.000
Mean of W                            =800445.000
Standard deviation of W              = 22078.750
Test statistic [u]  (abs.value)      =     1.743
Prob(u.le.[u])                       =      .959
Hypothesis: H0: No difference in the mean of the split samples
            H1: Split samples have different mean values
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     H0 not rejected
```

```
Test for Significance of Linear Trend
-------------------------------------
Intercept parameter        (=b1)     =     2.665
Slope parameter            (=b2)     = .7585E-03
St.dev. of b2              (=sb2)    = .4192E-03
St.dev. of residual        (=se)     = .9443E+01
Test statistic [t]    (abs.value)    =     1.809
Degrees of freedom                   =      1824
Prob(t.le.[t])                       =      .965
Hypothesis: H0: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     H0 not rejected

Test on Rescaled Adjusted Range
-------------------------------
Number of data                        =      1826
Min. value of partial sum, Smin       =  -772.292
Max. value of partial sum, Smax       =   337.356
Sample standard deviation, sA         =     9.446
Resc. adj. range RaN                  =   117.472
Test statistic R=RaN/sqrt(N)          =     2.749
Hypothesis: H0: Series is homogeneous
            H1: Series is non-homogeneous
            A one-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.750
Result: H0 rejected
```

Example : 6.8 : Statistical Tests on Data Homogeneity and Randomness

```
Two Series Test
---------------

Series code: DINDOR     PH3 1

Date of first element in series= 1981  1  1  0  1
Number of data                 = 1826
Series code: GITHOR     PH3 1

Date of first element in series= 1981  1  1  0  1
Number of data                 = 1826

Spearman Rank Correlation Trend Test
------------------------------------
Rank correlation coeff.  (=rs)    =      .692
Test statistic [t]                =    40.899
Degrees of freedom                =      1824
Prob(t.le.[t])                    =     1.000
Hypothesis: H0: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.963
Result:     H0 rejected
```

```
Wilcoxon-Mann-Whitney U-Test
-------------------
Number of data in first set        =       1826
Number of data in second set       =       1826
Sum of ranks of first set          =   3287607.
Sum of ranks of second set         =   3382771.
U-value                            =**********
Mean of U                          =**********
Standard deviation of U            = 23263.310
Test statistic [u]  (abs.value)    =      2.045
Prob(u.le.[u])                     =       .980
Hypothesis: HO: Series are from the same population
            H1: Series are from different populations
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     HO rejected

Student t-Test with Welch modification
--------------------------------------
Number of data in first set        =       1826
Number of data in second set       =       1826
Test statistic [t]  (abs.value)    =      2.616
Degrees of freedom                 =       3347
Prob(t.le.[t])                     =       .996
Mean of first set         (mA)     =      3.093
St.dev. of first set      (sA)     =      9.878
Mean of second set        (mB)     =      4.116
St.dev. of second set     (sB)     =     13.473
Var. test stat.   (Qi=sA^2/sB^2)   =       .538
Prob(Q.le.Qi)                      =       .000
Hypothesis: HO: Series is random
            H1: Series is not random
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.962
Result:     HO rejected

Wilcoxon-Test on Differences in the Mean
----------------------------------------
Number of data in first set        =       1826
Number of data in second set       =       1826
W-value                            =**********
Mean of W                          =**********
Standard deviation of W            = 63718.420
Test statistic [u]  (abs.value)    =      1.494
Prob(u.le.[u])                     =       .932
Hypothesis: HO: No difference in the mean of the series
            H1: Series have different mean values
            A two-tailed test is performed
            Level of significance is  5.00 percent
            Critical value for test statistic 1.960
Result:     HO not rejected
```

Example : 6.9 : Spatial homogeneity check

Test station VIKRAM

Start date: 1981 1 0 0 1
End date: 1991 12 0 0 1

Radius of circle of influence : 100.000 (km)

Station weights proportional to : 1/D^2.00

Admissible absolute error : 200.000
Multiplier to stdv of neighbours: 2.000

Selected neighbour stations:

Quadrant	Station	Distance (km)
2	SHAHPU	25.166
3	BARBAS	21.532
3	ODHARI	38.512
3	NIWAS	45.923
4	DINDOR	22.855
4	GITHOR	38.134

Year	mth	day	hr	si	P_obs	flag	P_est	Stdv	n
1981	11	0	0	1	.01	+	.00	.00	6
1984	3	0	0	1	.20	+	.00	.00	6
1984	10	0	0	1	17.26	+	4.10	4.71	6
1985	1	0	0	1	56.72	-	86.20	14.55	6
1986	11	0	0	1	10.20	+	2.54	2.11	6
1990	12	0	0	1	22.00	+	2.95	4.23	6
1991	11	0	0	1	9.00	+	3.31	2.34	6

Legend
n = number of neighbour stations
+ = P_obs - P_est > 0
- = P_obs - P_est < 0
* = P_est is missing

Example : 7.1 : Tabular output for regression between monthly rainfall at BARBASPUR and areal estimate for the MANOT sub-basin.

(For the period Jan. 1981 to Dec. 1991)

DATA FIT f(x) = c0+c1*x+c2*x^2+...

Dependent variable : AV.RAIN(T) PH2 1

Independent variable : BARBAS PH2 1

Degree of polynomial is : 2

C(0) = .11407E+02
C(1) = .13983E+01
C(2) = -.11594E-02

Standard error of estimate : .53020E+02

No.	Yobs	Yest	Diff.	Rel. Diff.
1	.27165E+02	.25274E+02	.18904E+01	.74796E-01
2	.25907E+00	.11407E+02	-.11148E+02	-.97729E+00
3	.31437E+02	.25274E+02	.61625E+01	.24382E+00
4	.22234E+01	.12804E+02	-.10581E+02	-.82636E+00
5	.20145E+02	.22520E+02	-.23746E+01	-.10544E+00
6	.16743E+03	.29419E+03	-.12676E+03	-.43088E+00
7	.40463E+03	.38711E+03	.17523E+02	.45266E-01
8	.26438E+03	.22160E+03	.42784E+02	.19307E+00
9	.17507E+03	.24841E+03	-.73342E+02	-.29524E+00
10	.65483E+01	.16982E+02	-.10434E+02	-.61440E+00
11	.19045E+00	.11407E+02	-.11217E+02	-.98330E+00
12	.13127E+02	.15592E+02	-.24644E+01	-.15806E+00
...				
...				
...				

Example : 8.1 : Analysis of stage-discharge data

Station name : MANOT

Data from 1990 6 1 to 1990 12 31

Gauge Zero on 1990 6 1 = 442.000 m

Number of data = 173
h minimum = 1.02 meas.nr = 155
h maximum = 9.64 meas.nr = 175
q minimum = 1.110 meas.nr = 155
q maximum = 2283.000 meas.nr = 175

Given boundaries for computation of rating curve(s)

interval	lower bound	upper bound	nr. of data
1	.500	1.500	21
2	1.400	10.000	159

Power type of equation q=c*(h+a)**b is used

Boundaries / coefficients

lower bound	upper bound	a	b	c
.50	1.50	-.740	2.318	.2292E+02
1.50	10.00	-1.390	1.262	.1822E+03

Number	W level M	Q meas M3/S	Q comp M3/S	Diff M3/S	Rel.diff 0/0	Semr 0/0
152	1.055	1.635	1.574	.061	3.87	7.00
153	1.040	1.327	1.406	-.079	-5.60	7.48
155	1.020	1.110	1.198	-.088	-7.34	8.19
156	1.100	2.114	2.145	-.031	-1.46	5.82
157	1.090	2.000	2.010	-.010	-.48	6.05
158	1.390	8.984	8.441	.543	6.43	5.93
...						
...						
...						
361	1.485	12.310	11.580	.730	6.30	7.16
362	1.480	10.370	11.401	-1.031	-9.04	7.10
363	1.480	10.160	11.401	-1.241	-10.89	7.10
365	1.470	9.892	11.047	-1.155	-10.46	6.96

Overall standard error = 17.402

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	.500	1.500	21	9.96
2	1.500	10.000	153	18.20

Example : 8.2 : Validation stage-discharge data

Station name : MANOT

Data from 1989 6 1 to 1989 12 31

Gauge Zero on 1989 6 1 = 442.000 m

Number of data = 214
h minimum = .67 meas.nr = 162
h maximum = 4.10 meas.nr = 235
q minimum = .000 meas.nr = 334
q maximum = 999.400 meas.nr = 226

Number of data = 202
h minimum = 1.14 meas.nr = 164
h maximum = 4.10 meas.nr = 235
q minimum = .000 meas.nr = 334
q maximum = 999.400 meas.nr = 226

Station : MANOT Period: 1990 6 1 / 1990 12 31

Procedure : Standard

Equation type: Power

Interval	Boundaries		Parameters:		
1	.500	1.500	-.740	2.318	22.918
2	1.500	10.000	-1.390	1.262	182.164

Data used to estimate parameters:

Interval	St. error of est.	Number of data
1	9.960	21
2	18.200	153

Number	W level M	Q meas M3/S	Q comp M3/S	Diff M3/S	Rel.diff 0/0	Semr 0/0
164	1.140	7.500	2.739	4.761	173.83	38.55
165	1.360	16.400	7.565	8.835	116.78	12.48
166	1.570	22.200	20.899	1.301	6.23	7.85
167	1.575	22.300	21.634	.666	3.08	7.72
168	1.490	19.400	11.761	7.639	64.95	21.16
169	1.410	15.000	9.055	5.945	65.65	14.53
...						
...						
...						
358	1.250	7.600	4.810	2.790	57.99	20.09
359	1.270	8.000	5.259	2.741	52.12	17.63
360	1.335	11.900	6.877	5.023	73.05	12.72
361	1.370	14.100	7.851	6.249	79.59	12.64
362	1.515	15.600	13.185	2.415	18.31	9.66
363	1.500	14.200	11.219	2.981	26.57	22.08
364	1.460	13.000	10.699	2.301	21.50	18.46
365	1.420	8.900	9.372	-.472	-5.03	15.22

Overall standard error = 38.294

Statistics per interval

Interval	Lower bound	Upper bound	Nr.of data	Standard error
1	.500	1.500	69	51.80
2	1.500	10.000	135	28.15

Results of student T-test on absence of bias

Interval	Degrees of freedom	95% T-value	Actual T-value	Result
1	88	1.987	3.967	Reject
2	286	1.968	-4.755	Reject

Example : 9.1 : Result of Kriging

Point kriging for weights.

Type of series: PH3 1, date: 1981 7 1

Catchment: MANOT

Selected St.	X-x0	Y-y0	Obs
MANOT	12.72	32.41	48.01
BAJAG	102.16	25.01	47.21
MANDL1	.00	18.52	14.80
PARASA	60.69	11.11	20.30
NIWAS	7.66	67.61	20.00
BARBAS	52.87	47.23	50.00
BICHHI	34.21	.93	36.08
GITHOR	61.89	31.49	101.60
SHAHPU	32.33	82.43	33.50
KHUDIY	5.98	14.36	24.20
DINDOR	71.59	54.64	30.20
VIKRAM	53.53	68.75	58.95
ODHARI	27.30	40.75	89.80
SAKKA	52.86	50.94	71.10
SIMARI	19.66	9.72	25.00
KARANJ	117.83	26.86	44.26

Point kriging option
form of generalized covariance function used :

K(h) = A1 * ¦h¦

Generalized covariance function :
K(h)= .00000 + -30.922 * ¦h¦

Station	weights
MANOT	.0054
BAJAG	-.0017
MANDL1	.0824
PARASA	.0088
NIWAS	.0073
BARBAS	-.0186
BICHHI	.2795
GITHOR	-.0083
SHAHPU	-.0477
KHUDIY	-.0172
DINDOR	.1660
VIKRAM	-.0026
ODHARI	-.0019
SAKKA	.2038
SIMARI	.0349
KARANJ	.3099

Example : 9.2 : Result of Kriging.

Point/block kriging for isolines

Type of series: PH 21, date: 1981 7 0

Catchment: MANOT

Selected stations:

Station	X-x0	Y-y0	Obs
MANDL1	.00	18.52	512.90
BAJAG	102.16	25.01	367.77
NIWAS	7.66	67.61	387.50
BARBAS	52.87	47.23	802.00
SHAHPU	32.33	82.43	405.70
GITHOR	61.89	31.49	576.60
BICHHI	34.21	.93	478.87
KHUDIY	5.98	14.36	702.40
MANOT	12.72	32.41	535.19
DINDOR	71.59	54.64	313.60
PARASA	60.69	11.11	200.80
VIKRAM	53.53	68.75	429.30
SAKKA	52.86	50.94	444.90
ODHARI	27.30	40.75	481.60
KARANJ	117.83	26.86	374.28
SIMARI	19.66	9.72	596.50

Point kriging option

Generalized covariance function : K(h)= .00000 - 852.40 * |h|

Range of zkrige : min= 212.12 max= 735.08
Range of stdest : min= 26.998 max= 439.31

U-coordinate	V-coordinate	Kriged-value	St. deviation
5.0000	5.0000	632.51	113.46
5.0000	10.000	660.28	81.623
5.0000	15.000	671.93	40.981
5.0000	20.000	590.37	72.300
5.0000	25.000	549.63	87.575
5.0000	30.000	524.96	93.745
5.0000	35.000	503.50	101.81
. . .			
. . .			
. . .			
160.00	135.00	319.23	402.81
160.00	140.00	318.92	410.15
160.00	145.00	318.67	417.47
160.00	150.00	318.46	424.77
160.00	155.00	318.28	432.05
160.00	160.00	318.14	439.31

Areal mean: 370.41

Example : 10.1 : Basic statistics for the actual values of daily rainfall series.

Series code = AV.RAIN(T)PH3 1
First year = 1981
Last year = 1991

Actual values are used

Basic Statistics of series AV.RAIN(T)PH3 1
==

Mean	= .886185E+01
Median	= .467775E+01
Mode	= .500000E+01
Standard deviation	= .124570E+02
Skewness	= .363301E+01
Kurtosis	= .239567E+02
Range	= .101212E+00 to .144088E+03
Number of elements	= 1599

Decile	Value
1	.140212E+01
2	.280424E+01
3	.420636E+01
4	.560849E+01
5	.701061E+01
6	.841273E+01
7	.981485E+01
8	.151225E+02
9	.227760E+02

Statistical table of series AV.RAIN(T)PH3 1 (continued)

Cumulative frequency distribution and histogram

Upper class limit	Probability	Number of elements
.000000E+00	.000000	0.
.100000E+02	.713205	1141.
.200000E+02	.882644	271.
.300000E+02	.945167	100.
.400000E+02	.975178	48.
.500000E+02	.982056	11.
.600000E+02	.988933	11.
.700000E+02	.991434	4.
.800000E+02	.995186	6.
.900000E+02	.997061	3.
.100000E+03	.997687	1.
.110000E+03	.998937	2.
.120000E+03	.998937	0.
.130000E+03	.998937	0.
.140000E+03	.998937	0.
.150000E+03	.999562	1.
		0.

Histogram of series AV.RAIN(T)PH3 1

Class	Limits	Frequency	Relative frequency	Cumulative frequency
	.0000	0	.0000	0
1	10.0000	1141	.7136	1141
2	20.0000	271	.1695	1412
3	30.0000	100	.0625	1512
4	40.0000	48	.0300	1560
5	50.0000	11	.0069	1571
6	60.0000	11	.0069	1582
7	70.0000	4	.0025	1586
8	80.0000	6	.0038	1592
9	90.0000	3	.0019	1595
10	100.0000	1	.0006	1596
11	110.0000	2	.0013	1598
12	120.0000	0	.0000	1598
13	130.0000	0	.0000	1598
14	140.0000	0	.0000	1598
15	150.0000	1	.0006	1599

Example : 9.2 : Basic statistics for the annual maximum of daily rainfall series.

Series code = AV.RAIN(T)PH3 1

First year = 1981
Last year = 1991

Annual maximum values are analysed

Year	Maximum
1981	8.869450E+01
1982	5.656170E+01
1983	8.851519E+01
1984	1.440879E+02
1985	7.233533E+01
1986	1.097205E+02
1987	8.511565E+01
1988	1.016700E+02
1989	7.430786E+01
1990	6.458935E+01
1991	7.644559E+01

Basic Statistics of series AV.RAIN(T)PH3 1

Mean = .874586E+02
Median = .851156E+02
Mode = .750000E+02
Standard deviation= .243170E+02
Skewness = .124929E+01
Kurtosis = .480212E+01
Range = .565617E+02 to .144088E+03
Number of elements= 11

Decile	Value
1	.644000E+02
2	.719333E+02
3	.757333E+02
4	.795333E+02
5	.833333E+02
6	.871333E+02
7	.101400E+03
8	.107100E+03
9	.145600E+03

Statistical table of series AV.RAIN(T)PH3 1 (continued)

Cumulative frequency distribution and histogram

Upper class limit	Probability	Number of elements
.500000E+02	.000000	0.
.600000E+02	.061404	1.
.700000E+02	.149123	1.
.800000E+02	.412281	3.
.900000E+02	.675439	3.
.100000E+03	.675439	0.
.110000E+03	.850877	2.
.120000E+03	.850877	0.
.130000E+03	.850877	0.
.140000E+03	.850877	0.
.150000E+03	.938596	1.
		0.

Histogram of series AV.RAIN(T)PH3 1
==================================

Class	Limits	Frequency	Relative frequency	Cumulative frequency
	50.0000	0	.0000	0
1	60.0000	1	.0909	1
2	70.0000	1	.0909	2
3	80.0000	3	.2727	5
4	90.0000	3	.2727	8
5	100.0000	0	.0000	8
6	110.0000	2	.1818	10
7	120.0000	0	.0000	10
8	130.0000	0	.0000	10
9	140.0000	0	.0000	10
10	150.0000	1	.0909	11

Example : 10.3 : Output of analysis for fitting the GVI distribution to the annual maximum values of the daily areal rainfall of MANOT sub-basin.

```
Series code = AV.RAIN(T)PH3 1
First year  =  1981
Last year   =  1991

Annual maximum values are analysed

         Year        Maximum

         1981   8.869450E+01
         1982   5.656170E+01
         1983   8.851519E+01
         1984   1.440879E+02
         1985   7.233533E+01
         1986   1.097205E+02
         1987   8.511565E+01
         1988   1.016700E+02
         1989   7.430786E+01
         1990   6.458935E+01
         1991   7.644559E+01


Fitting the Extreme Type 1 or Gumbel distribution function

Series code AV.RAIN(T)PH3 1

Maximum likelihood method is used

Number of data      =     11
Scale par. beta     =     17.196
Location par. x0    =     77.151
Nr of parameters    =      2
```

Nr./year	observation	obs.freq.	theor.freq.p	return-per.	st.dev.xp	st.dev.p
0	56.562	.0614	.0365	1.04	6.0569	.0425
2	64.589	.1491	.1254	1.14	5.3319	.0807
0	72.335	.2368	.2663	1.36	5.2169	.1069
0	74.308	.3246	.3073	1.44	5.2883	.1115
4	76.446	.4123	.3528	1.55	5.4097	.1156
5	85.116	.5000	.5330	2.14	6.3017	.1229
5	88.515	.5877	.5967	2.48	6.7879	.1216
0	88.695	.6754	.5999	2.50	6.8151	.1215
8	101.670	.7632	.7864	4.68	9.0959	.1000
10	109.721	.8509	.8603	7.16	10.7055	.0806
4	144.088	.9386	.9798	49.54	18.1996	.0211

```
Results of Binomial goodness of fit test
variate dn = max(¦Fobs-Fest¦)/sd=       .5116 at Fest= .5999
prob. of exceedance P(DN>dn)     =      .6089
number of observations           =     11

Results of Kolmogorov-Smirnov test
variate dn = max(¦Fobs-Fest¦)    =      .1274
prob. of exceedance P(DN>dn)     =      .9941
```

Results of Chi-Square test

variate = chi-square	=	.2727
prob. of exceedance of variate	=	.6015
number of classes	=	4
number of observations	=	11
degrees of freedom	=	1

Values for distinct return periods

Return per.	prob(xi<x) p	value x	st. dev. x	95% confidence intervals lower	upper
2	.50000	83.454	6.088	71.519	95.389
5	.80000	102.944	9.344	84.627	121.262
10	.90000	115.849	11.986	92.351	139.347
25	.96000	132.154	15.531	101.707	162.601
50	.98000	144.250	18.236	108.500	180.000
100	.99000	156.257	20.958	115.172	197.342
250	.99600	172.066	24.576	123.887	220.244
500	.99800	184.003	27.325	130.434	237.571
1000	.99900	195.931	30.083	136.956	254.906
2500	.99960	211.692	33.739	145.550	277.834
5000	.99980	223.616	36.512	152.039	295.193
10000	.99990	235.532	39.286	158.515	312.548

Example : 10.4 : Fitting Normal distribution to annual areal average rainfall values.

Series code = AV.RAIN(T)PH1 1

First year = 1981
Last year = 1991

Actual values are used

Fitting the normal distribution function

Series code AV.RAIN(T)PH1 1

Number of data	=	11
Mean	=	1288.662
Standard deviation	=	169.050
Skewness	=	.830
Kurtosis	=	3.855

Nr./year	observation	obs.freq.	theor.freq.p	return-per.	st.dev.xp	st.dev.p
1	1085.390	.0614	.1146	1.13	66.9070	.0766
0	1111.000	.1491	.1466	1.17	63.5039	.0863
2	1112.610	.2368	.1488	1.17	63.2996	.0869
3	1207.330	.3246	.3152	1.46	53.8346	.1132
5	1218.030	.4123	.3380	1.51	53.1441	.1150
0	1280.250	.5000	.4802	1.92	51.0020	.1202
0	1317.940	.5877	.5687	2.32	51.3499	.1194
7	1378.590	.6754	.7026	3.36	54.4523	.1116
9	1397.700	.7632	.7405	3.85	56.0169	.1074
0	1411.200	.8509	.7657	4.27	57.2716	.1039
10	1655.240	.9386	.9849	66.39	93.3202	.0210

Results of Binomial goodness of fit test
variate dn = max(¦Fobs-Fest¦)/sd= .8200 at Fest= .1488
prob. of exceedance P(DN>dn) = .4122
number of observations = 11

Results of Kolmogorov-Smirnov test
variate dn = max(¦Fobs-Fest¦) = .1434
prob. of exceedance P(DN>dn) = .9775

Results of Chi-Square test
variate = chi-square = .2727
prob. of exceedance of variate = .6015
number of classes = 4
number of observations = 11
degrees of freedom = 1

Values for distinct return periods

Return per.	prob(xi<x) p	value x	st. dev. x	95% confidence intervals lower	upper
2	.50000	1288.662	50.971	1188.739	1388.585
5	.80000	1430.911	59.311	1314.638	1547.183
10	.90000	1505.339	68.790	1370.483	1640.194
25	.96000	1584.682	81.124	1425.647	1743.717
50	.98000	1635.924	89.885	1459.713	1812.135
100	.99000	1682.006	98.136	1489.620	1874.392
250	.99600	1737.062	108.338	1524.676	1949.448
500	.99800	1775.276	115.591	1548.671	2001.880
1000	.99900	1811.117	122.496	1570.977	2051.257
2500	.99960	1855.489	131.157	1598.369	2112.609
5000	.99980	1887.148	137.401	1617.787	2156.509
10000	.99990	1917.375	143.406	1636.242	2198.507

Example : 10.5 : Fitting Normal distribution to annual maximum of the monthly areal average rainfall series.

Series code = AV.RAIN(T)PH2 1

First year = 1981
Last year = 1991

Annual maximum values are analysed

Year	Maximum
1981	4.046297E+02
1982	5.069451E+02
1983	4.223887E+02
1984	7.349725E+02
1985	4.624190E+02
1986	4.644632E+02
1987	3.856572E+02
1988	4.483922E+02
1989	3.566182E+02
1990	4.606122E+02
1991	4.694112E+02

Fitting the normal distribution function

Series code AV.RAIN(T)PH2 1

Number of data = 11
Mean = 465.137
Standard deviation = 99.231
Skewness = 2.206
Kurtosis = 8.036

Nr./year	observation	obs.freq.	theor.freq.p	return-per.	st.dev.xp	st.dev.p
0	356.618	.0614	.1371	1.16	37.8219	.0836
2	385.657	.1491	.2116	1.27	34.3825	.1003
0	404.630	.2368	.2710	1.37	32.5789	.1088
4	422.389	.3246	.3333	1.50	31.2739	.1146
0	448.392	.4123	.4330	1.76	30.1306	.1194
5	460.612	.5000	.4818	1.93	29.9347	.1202
5	462.419	.5877	.4891	1.96	29.9248	.1203
6	464.463	.6754	.4973	1.99	29.9196	.1203
9	469.411	.7632	.5172	2.07	29.9330	.1202
2	506.945	.8509	.6632	2.97	31.2161	.1149
9	734.972	.9386	.9967	305.67	64.8510	.0065

Results of Binomial goodness of fit test
variate dn = max(¦Fobs-Fest¦)/sd= 1.6326 at Fest= .5172
prob. of exceedance P(DN>dn) = .1026
number of observations = 11

Results of Kolmogorov-Smirnov test
variate dn = max(¦Fobs-Fest¦) = .3010
prob. of exceedance P(DN>dn) = .2718

Results of Chi-Square test
variate = chi-square = 5.3636
prob. of exceedance of variate = .0206
number of classes = 4
number of observations = 11
degrees of freedom = 1

Values for distinct return periods

Return per.	prob(xi<x) p	value x	st. dev. x	95% confidence intervals lower	upper
2	.50000	465.137	29.919	406.484	523.791
5	.80000	548.636	34.815	480.385	616.886
10	.90000	592.324	40.379	513.166	671.483
25	.96000	638.898	47.619	545.546	732.250
50	.98000	668.976	52.762	565.542	772.410
100	.99000	696.026	57.605	583.098	808.955
250	.99600	728.343	63.594	603.675	853.012
500	.99800	750.774	67.851	617.760	883.789
1000	.99900	771.813	71.904	630.853	912.773
2500	.99960	797.859	76.988	646.932	948.786
5000	.99980	816.442	80.653	658.330	974.555
10000	.99990	834.185	84.178	669.163	999.207

Example : 10.6 : Statistical Table.

Normal distribution

Mean = 15.000
Standard deviation = 2.500

Variate	Prob(X<x)	Return Period
10.000	.0228	1.02
19.113	.9500	20.00
19.378	.9600	25.00

Example : 10.7 : Random data generation.

Mean = 15.000
Stdv = 2.500
Number = 100
Print format: 8f10.3

16.927	15.258	19.029	16.759	15.134	13.647	12.281	12.217
15.434	17.017	16.924	15.551	18.394	13.262	13.193	13.832
17.402	14.157	18.462	14.870	16.073	15.900	17.001	16.849
13.336	10.897	16.216	19.529	18.449	13.057	14.953	14.186

11.831	17.881	15.695	12.782	9.895	14.989	16.682	13.194
21.065	10.903	13.163	17.558	16.678	16.628	13.913	14.667
10.839	15.013	15.227	18.647	11.519	17.756	18.146	16.460
14.882	19.610	13.598	17.391	18.247	13.290	14.588	17.137
15.474	15.588	13.829	14.955	15.236	16.248	12.484	17.036
17.539	17.032	16.639	17.269	17.600	17.379	12.740	12.322
15.490	19.179	14.480	17.306	15.932	17.013	12.749	15.192
12.490	13.929	15.218	20.369	14.821	15.918	10.655	15.317
15.016	11.580	13.479	19.442				

Example : 10.8 : Computation of frequency and duration curves.

Compilation of frequency and duration curves
==

INPUT:

Series code AV.RAIN(T)PH2 1
Start date 1981 1 0 0 1
No. of values in period 12

Number of frequencies 5
Frequencies: .10 .25 .50 .75 .90

Frequency curves AV.RAIN(T)PH2 1

Element	Nr.data	Frequency .10	.25	.50	.75	.90
1	11	.00	.31	24.68	58.45	97.89
2	11	.05	13.08	31.95	48.86	109.69
3	11	.30	.59	8.60	15.57	34.05
4	11	.15	1.40	2.37	7.89	22.30
5	11	.44	2.84	9.42	21.84	59.59
6	11	76.07	100.88	130.01	255.60	394.85
7	11	259.10	290.35	385.66	462.42	468.42
8	11	219.03	264.38	372.08	448.39	689.37
9	11	43.73	119.10	144.63	290.56	452.97
10	11	4.51	6.67	29.80	57.24	78.13
11	11	.00	.00	.19	10.50	47.22
12	11	.00	.00	1.36	13.13	63.53

Duration curves AV.RAIN(T)PH2 1

N.elements	Frequency .10	.25	.50	.75	.90
1	.00	.00	.19	7.89	22.30
2	.00	.00	1.36	10.50	34.05
3	.00	.31	2.37	13.13	47.22
4	.05	.59	8.60	15.57	59.59
5	.15	1.40	9.42	21.84	63.53
6	.30	2.84	24.68	48.86	78.13
7	.44	6.67	29.80	57.24	97.89
8	4.51	13.08	31.95	58.45	109.69
9	43.73	100.88	130.01	255.60	394.85
10	76.07	119.10	144.63	290.56	452.97
11	219.03	264.38	372.08	448.39	468.42
12	259.10	290.35	385.66	462.42	689.37

Average duration curve AV.RAIN(T)PH2 1

Nr.exc. = average number of excedances per period

Level	Nr.exc.	Level	Nr.exc.
.00	1.09	350.00	10.55
23.33	5.55	373.33	10.73
46.67	7.00	396.67	10.91
70.00	7.73	420.00	11.00
93.33	8.09	443.33	11.36
116.67	8.45	466.67	11.73
140.00	8.91	490.00	11.82
163.33	9.18	513.33	11.91
186.67	9.36	536.67	11.91
210.00	9.36	560.00	11.91
233.33	9.45	583.33	11.91
256.67	9.82	606.67	11.91
280.00	10.00	630.00	11.91
303.33	10.27	653.33	11.91
326.67	10.45	676.67	11.91
		700.00	11.91

Example : 11.1 : Autocovariance and autocorrelation analysis

Autocovariance and autocorrelation analysis
==

Series = AV.RAIN(K)PH2 1

Date of first element = 1981 1 0 0 1
Date of last element = 1991 12 0 0 1

COV = autocovariance function
COR = autocorrelation function
CLP = upper conf. limit zero correlation (95 %)
CLN = lower conf. limit zero correlation (95 %)

LAG	COV	COR	CLP	CLN
0	.2379E+05	1.0000	.1605	-.1755
1	.1247E+05	.5243	.1611	-.1762
2	.1162E+04	.0489	.1616	-.1769
3	-.6186E+04	-.2601	.1622	-.1776
4	-.8494E+04	-.3571	.1628	-.1783
5	-.7157E+04	-.3009	.1634	-.1790
6	-.5930E+04	-.2493	.1640	-.1797
7	-.6135E+04	-.2579	.1646	-.1805
8	-.7929E+04	-.3334	.1652	-.1812
9	-.5423E+04	-.2280	.1658	-.1819
10	.2243E+04	.0943	.1664	-.1827
11	.1307E+05	.5494	.1671	-.1835
12	.1686E+05	.7089	.1677	-.1842
13	.1197E+05	.5031	.1683	-.1850
14	.1355E+04	.0570	.1690	-.1858
15	-.5953E+04	-.2503	.1697	-.1866
...				
...				
...				
62	.3097E+03	.0130	.2136	-.2418
63	-.4056E+04	-.1705	.2149	-.2435
64	-.4865E+04	-.2045	.2163	-.2453
65	-.3965E+04	-.1667	.2177	-.2471

Example : 11.2 : Crosscovariance and crosscorrelation analysis

Crosscovariance and crosscorrelation analysis
==

Series X = AV.RAIN(K)PH2 1
Series Y = DINDOR PH2 1

Date of first element = 1981 1 0 0 1
Date of last element = 1991 12 0 0 1

COV-XY = covariance of X(i) and Y(i+lag)
COV-YX = covariance of Y(i) and X(i+lag)
COR-XY = correlation of X(i) and Y(i+lag)
COR-YX = correlation of Y(i) and X(i+lag)

48	.5000	.4414E+04	3.6449	.1881

LAG	COV-XY	COV-YX	COR-XY	COR-YX
0	.2249E+05	.2249E+05	.9711	.9711
1	.1181E+05	.1191E+05	.5099	.5144
2	.1356E+04	.8758E+03	.0586	.0378
3	-.5652E+04	-.5762E+04	-.2440	-.2488
4	-.8098E+04	-.8288E+04	-.3496	-.3578
5	-.6878E+04	-.6967E+04	-.2970	-.3008
6	-.5814E+04	-.5887E+04	-.2510	-.2542
7	-.6189E+04	-.5625E+04	-.2672	-.2428
8	-.7768E+04	-.7546E+04	-.3354	-.3258
...				
...				
...				
58	.2440E+04	.1715E+04	.1053	.0741
59	.7568E+04	.6909E+04	.3267	.2983
60	.1003E+05	.8822E+04	.4332	.3809
61	.7408E+04	.6147E+04	.3199	.2654
62	.5469E+03	.4396E+03	.0236	.0190
63	-.4230E+04	-.3692E+04	-.1826	-.1594
64	-.5078E+04	-.4421E+04	-.2192	-.1909
65	-.4147E+04	-.3848E+04	-.1791	-.1661

Example : 11.3 : Spectral analysis

Spectral analysis
=================

Series =AV.RAIN(T)PH2 1

Date of first element = 1981 1 0 0 1
Date of last element = 1991 12 0 0 1

Truncation lag = 24
Number of frequency points= 48

Bandwith = .0556
Degr.frdom = 14

ASPEC = variance spectrum
LOG SPEC = logaritm of ASPEC
DSPEC = spectral density

NR	FREQUENCY	ASPEC	LOGSPEC	DSPEC
0	.0000	.3467E+04	3.5400	.1478
1	.0104	.4784E+04	3.6798	.2039
2	.0208	.4315E+04	3.6350	.1839
3	.0313	-.2484E+02	-100.0000	-.0011
4	.0417	.7758E+04	3.8897	.3306
5	.0521	.5321E+05	4.7260	2.2675
6	.0625	.1403E+06	5.1470	5.9783
7	.0729	.2329E+06	5.3672	9.9271
...				
...				
...				
44	.4583	.1604E+05	4.2052	.6836
45	.4688	.1296E+05	4.1125	.5522
46	.4792	.8883E+04	3.9485	.3785
47	.4896	.5631E+04	3.7506	.2400
48	.5000	.4414E+04	3.6449	.1881

Example : 11.4 : Range analysis

Range analysis

==============

Series =AV.RAIN(T)PH2 1

Date of first element = 1981 1 0 0 1
Date of last element = 1991 12 0 0 1

Conversion factor (intensities > volumes)= 1.000

Surplus = .4288E+03
Deficit = -.7389E+03
Adjusted range = .1168E+04
Rescaled adjusted range = .7622E+01

Example : : Run analysis

Run analysis

============

Series =AV.RAIN(T)PH2 1

Date of first element = 1981 1 0 0 1
Date of last element = 1991 12 0 0 1

Conversion factor (intensities > volumes)= 1.000

Crossing levels 50.00 300.00

Crossing level = 50.000

Nr. of upcrossings = 17
Nr. of downcrossings = 17
Nr. of runs = 35

Run	Positive run Length	To maximum	Sum	Negative run Length	To minimum	Sum
1				5	2	.1688E+03
2	4	2	.8115E+03			
3				3	2	.1301E+03
4	1	1	.8454E+01			
5				4	3	.1566E+03
6	4	3	.8601E+03			
7				8	4	.2905E+03
8	5	4	.1087E+04			
9				2	1	.9025E+02
10	1	1	.5422E+02			
11				4	2	.1342E+03
12	4	3	.1021E+04			
13				3	2	.1433E+03
14	1	1	.2256E+02			
15				4	2	.1659E+03
16	4	2	.8738E+03			
17				4	2	.1585E+03
18	1	1	.7202E+02			

Run	Positive run Length	To maximum	Sum	Negative run Length	To minimum	Sum
19				3	2	.1312E+03
20	4	2	.8498E+03			
21				2	2	.4738E+02
22	1	1	.2077E+02			
23				1	1	.7924E+01
24	1	1	.1037E+02			
25				3	2	.1066E+03
26	6	2	.9318E+03			
27				6	1	.2166E+03
28	4	3	.9856E+03			
29				8	2	.3530E+03
30	4	3	.8067E+03			
31				7	4	.2553E+03
32	6	5	.1298E+04			
33				7	1	.2895E+03
34	3	2	.8507E+03			
35				4	4	.1442E+03
MAXIMUM =	6	5	.1298E+04	8	4	.3530E+03

Crossing level = 300.000

Nr. of upcrossings = 12
Nr. of downcrossings = 12
Nr. of runs = 25

Run	Positive run Length	To maximum	Sum	Negative run Length	To minimum	Sum
1				6	2	.1551E+04
2	1	1	.1046E+03			
3				12	4	.2630E+04
4	1	1	.2069E+03			
5				10	5	.2647E+04
6	3	3	.2814E+03			
7				10	2	.2343E+04
8	1	1	.4350E+03			
9				10	3	.2751E+04
10	2	1	.2843E+03			
11				10	3	.2443E+04
12	1	1	.1645E+03			
13				11	9	.2594E+04
14	2	1	.9939E+02			
15				10	4	.2202E+04
16	2	2	.1550E+03			
17				11	3	.2616E+04
18	1	1	.5662E+02			
19				9	5	.2383E+04
20	2	1	.1501E+03			
21				1	1	.4540E+02
22	1	1	.1606E+03			
23				9	2	.2474E+04
24	2	1	.2998E+03			
25				4	4	.1144E+04
MAXIMUM =	3	3	.4350E+03	12	9	.2751E+04

Example : 12.1 : Report of daily rainfall series at Githori station.

Station Characteristics of station : GITHOR

Station name : GITHORI	Latitude : 22 43' 30" North	Longitude : 080 59' 15" East
River : NARMADA	Altitude : .00 m	Catchment area : .000 km2
Province : MANDLA	Country : INDIA	Agency : WRD, M.P.

GITHORI

Rainfall historical mm, year 1981

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	101.6	5.1	7.6	22.9	.0	.0
2	.0	.0	.0	.0	.0	.0	53.3	83.8	20.3	2.5	.0	.0
3	.0	.0	.0	.0	.0	.0	5.1	.0	1.3	.0	.0	.0
4	.0	.0	.0	.0	7.6	.0	.0	10.2	.0	.0	.0	.0
5	.0	.0	.0	.0	30.5	.0	.0	2.5	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	33.0	30.5	.0	.0	.0	.0
7	7.6	.0	.0	.0	2.5	.0	17.8	12.7	.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	2.5	5.1	5.1	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	5.1	6.3	3.8	.0	.0	.0
10	.0	.0	6.3	.0	.0	.0	10.2	2.5	.0	.0	.0	.0
11	5.1	.0	.0	.0	.0	.0	.0	.0	3.8	.0	.0	.0
12	.0	.0	.0	.0	.0	.0	.0	.0	7.6	.0	.0	.0
13	.0	.0	17.8	.0	.0	.0	.0	2.5	3.8	.0	.0	.0
14	.0	.0	10.2	.0	.0	.0	10.2	10.2	1.3	.0	.0	.0
15	.0	.0	5.1	.0	.0	.0	30.5	20.3	2.5	.0	.0	.0
16	.0	.0	10.2	.0	.0	.0	5.1	21.6	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	7.6	11.3	.0	.0	.0	.0
18	7.6	.0	5.1	.0	.0	.0	17.8	2.5	.0	.0	.0	.0
19	.0	.0	2.5	.0	.0	.0	27.9	.0	5.1	.0	.0	.0
20	.0	.0	2.5	.0	.0	.0	30.5	2.5	3.8	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	10.2	17.8	10.2	.0	.0	.0
22	.0	.0	1.3	.0	.0	.0	5.1	12.7	7.6	.0	.0	33.0
23	.0	.0	3.8	.0	.0	223.5	20.3	10.2	25.4	.0	.0	.0
24	15.2	.0	.0	.0	.0	.0	21.6	.0	.0	.0	.0	.0
25	45.7	.0	.0	.0	.0	25.4	15.2	.0	1.3	.0	.0	.0
26	.0	.0	.0	.0	.0	2.5	.0	20.3	2.5	.0	.0	.0
27	.0	.0	.0	.0	.0	5.1	66.0	.0	24.1	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	33.0	.0	27.5	.0	.0	.0
29	.0		.0	.0	.0	.0	7.6	.0	7.6	.0	.0	.0
30	.0		.0	.0	.0	25.4	.0	.0	.0	.0	.0	.0
31	.0		.0		.0		39.4	.0		.0		.0
Total	81.2	.0	64.8	.0	40.6	281.9	576.6	290.6	172.2	25.4	.0	33.0
Mean	2.6	.0	2.1	.0	1.3	9.4	18.6	9.4	5.7	.8	.0	1.1
Max.	45.7	.0	17.8	.0	30.5	223.5	101.6	83.8	27.5	22.9	.0	33.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1566.3 Mean: 4.3 Maximum: 223.5 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1982

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	.0	60.0	13.0	.0	.0	.0
2	.0	.0	7.6	.0	.0	.0	.0	15.0	1.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	9.0	.0	.0	.0	.0
4	.0	17.8	.0	.0	.0	.0	.0	20.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	17.0	1.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	5.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	12.7	4.0	67.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	2.5	40.0	12.0	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	40.6	20.0	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	2.5	20.0	2.0	.0	6.0	.0
11	17.8	.0	.0	.0	.0	.0	1.3	20.0	12.0	.0	1.0	.0
12	.0	.0	.0	.0	.0	.0	2.5	20.0	34.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	.0	20.0	8.0	.0	.0	.0
14	.0	.0	.0	.0	.0	38.1	7.6	15.0	.0	.0	.0	.0
15	1.3	.0	.0	.0	9.2	35.6	1.3	5.0	.0	.0	.0	3.0
16	.0	.0	.0	.0	.0	.0	2.5	40.0	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	12.7	40.6	8.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	.0	16.0	.0	7.0	.0	.0
19	.0	.0	.0	.0	.0	.0	22.9	40.0	.0	3.0	.0	.0
20	.0	.0	.0	.0	.0	33.6	2.5	7.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	5.1	5.1	44.0	.0	4.0	.0	.0
22	2.5	.0	.0	.0	.0	.0	38.1	10.0	.0	8.0	.0	.0
23	.0	.0	.0	.0	.0	.0	30.5	32.0	1.0	.0	.0	.0
24	.0	.0	.0	.0	.0	30.5	58.4	16.0	.0	.0	.0	.0
25	3.8	.0	11.4	.0	.0	.0	86.3	11.0	.0	.0	.0	.0
26	6.3	.0	.0	.0	.0	.0	17.8	15.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	17.8	5.1	8.0	.0	.0	.0	.0
28	.0	19.3	.0	.0	.0	.0	17.8	3.0	.0	.0	.0	.0
29	.0		.0	.0	.0	.0	10.0	.1	.0	.0	.0	.0
30	.0		.0	.0	.0	.0	14.0	2.0	.0	.0	.0	.0
31	8.9		.0		.0		6.0	30.0		.0		.0
Total	40.6	37.1	19.0	.0	9.2	173.4	428.6	572.1	151.0	22.0	7.0	3.0
Mean	1.3	1.3	.6	.0	.3	5.8	13.8	18.5	5.0	.7	.2	.1
Max.	17.8	19.3	11.4	.0	9.2	38.1	86.3	60.0	67.0	8.0	6.0	3.0
Min.	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0

Sum: 1463.0 Mean: 4.0 Maximum: 86.3 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm. year 1983

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	13.0	80.3	16.0	6.0	.0	.0
2	.0	.0	.0	.0	.0	.0	35.0	62.0	.0	2.0	.0	.0
3	.0	.0	.0	.0	.0	.0	27.0	51.0	9.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	39.0	20.0	26.0	1.0	.0	.0
5	.0	.0	.0	.0	.0	.0	13.0	.0	18.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	17.0	.0	1.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	26.0	38.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	.0	126.0	13.0	.0	.0
9	.0	.0	.0	.0	.0	.0	.0	.0	26.0	.0	.0	.0
10	.0	.0	.0	.0	3.0	.0	.0	2.0	10.0	13.0	.0	.0
11	.0	.0	.0	.0	2.0	.0	14.0	.0	10.0	1.0	.0	.0
12	.0	.0	.0	.0	7.0	.0	30.0	.0	11.0	.0	.0	.0
13	.0	10.0	.0	.0	.0	.0	25.0	4.0	1.0	.0	.0	.0
14	.0	1.0	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0
15	.0	60.0	.0	.0	.0	.0	.0	37.0	.0	.0	.0	.0
16	.0	.0	.0	.0	.0	.0	23.0	14.0	9.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	.0	4.0	11.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	2.0	10.0	3.0	.0	.0	.0
20	.0	.0	.0	.0	3.0	.0	.0	37.0	4.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	28.0	9.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	2.0	3.0	.0	.0	.0	.0
23	.0	.0	.0	.0	11.0	23.0	6.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	1.0	.0	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	9.0	62.0	.0	2.0	.0	.0	.0
26	.0	.0	.0	.0	.0	3.0	11.0	.0	2.0	.0	.0	10.0
27	.0	.0	.0	.0	.0	4.0	7.0	1.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	13.0	18.0	.0	24.0	.0	.0	.0
29	.0		.0	.0	.0	12.0	32.0	2.0	55.0	.0	.0	.0
30	.0		.0	.0	.0	6.0	37.0	4.0	.0	.0	.0	.0
31	.0		.0		.0		12.0	8.0		.0		12.0
Total	.0	71.0	.0	.0	26.0	70.0	454.0	376.3	412.0	36.0	.0	22.0
Mean	.0	2.5	.0	.0	.8	2.3	14.6	12.1	13.7	1.2	.0	.7
Max.	.0	60.0	.0	.0	11.0	23.0	62.0	80.3	126.0	13.0	.0	12.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1467.3 Mean: 4.0 Maximum: 126.0 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1984

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12.0	.0	.0	.0	.0	.0	1.0	4.0	4.0	.0	.0	.0
2	36.0	6.0	.0	.0	.0	.0	7.0	7.0	1.0	.0	.0	.0
3	21.0	.0	.0	.0	.0	.0	3.0	23.0	2.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	2.0	5.0	11.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	7.0	.0	.0	.0
6	14.0	.0	.0	.0	.0	20.0	45.0	.0	10.0	.0	.0	.0
7	.0	2.0	.0	.0	.0	.0	.0	4.0	6.0	.0	.0	.0
8	3.0	6.0	.0	.0	.0	.0	11.0	40.0	.0	.0	.0	.0
9	3.0	.0	.0	.0	.0	4.0	13.0	112.0	.0	.0	.0	.0
10	.0	.0	.0	8.0	.0	5.0	5.0	51.0	3.0	.0	.0	.0
11	.0	5.0	.0	.0	.0	.0	43.0	2.0	.0	.0	.0	.0
12	.0	9.0	.0	.0	.0	.0	.0	1.0	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0
14	.0	.0	.0	.0	.0	.0	2.0	9.0	.0	.0	.0	.0
15	.0	.0	.0	.0	.0	69.0	24.0	54.0	.0	.0	.0	.0
16	6.0	.0	.0	.0	.0	13.0	4.0	11.0	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	1.0	.0	62.0	.0	.0	.0	.0
18	.0	4.0	.0	.0	.0	.0	37.0	208.0	.0	.0	.0	.0
19	.0	8.0	.0	.0	.0	4.0	17.0	12.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	1.0	40.0	4.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	5.0	2.0	.0	.0	.0	.0
22	.0	.0	.0	6.0	.0	.0	2.0	2.0	.0	.0	.0	.0
23	.0	.0	.0	22.0	.0	.0	.0	38.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	5.0	89.0	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	.0	.0	1.0	.0	.0	.0	.0
26	2.0	.0	.0	.0	.0	.0	2.0	2.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	8.0	.0	3.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	6.0	.0	3.0	.0	.0	.0	.0
29	10.0	.0	.0	.0	.0	10.0	.0	7.0	.0	.0	.0	.0
30	.0		.0	.0	.0	8.0	.0	55.0	.0	.0	.0	.0
31	.0		.0		.0		.0	31.0		.0		.0
Total	107.0	40.0	.0	36.0	.0	149.0	270.0	842.0	44.0	.0	.0	.0
Mean	3.5	1.4	.0	1.2	.0	5.0	8.7	27.2	1.5	.0	.0	.0
Max.	36.0	9.0	.0	22.0	.0	69.0	45.0	208.0	11.0	.0	.0	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1488.0 Mean: 4.1 Maximum: 208.0 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1985

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	21.0	28.0	.0	.0	.0	.0	.0	1.0	4.0	.0	.0	.0
2	5.0	3.0	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0
3	2.0	.0	.0	.0	.0	.0	5.4	49.2	.0	11.6	.0	.0
4	.0	.0	.0	.0	.0	.0	10.4	2.4	6.4	1.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	9.2	.0	.0	.0	.0
6	.0	.0	.0	9.0	.0	.0	29.8	6.2	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	11.4	40.4	.0	.0	.0	.0
8	3.0	.0	.0	.0	.0	.0	4.4	100.8	.0	.0	.0	.0
9	2.0	.0	.0	.0	.0	.0	16.8	35.2	.0	.0	.0	.0
10	3.0	.0	.0	.0	.0	.0	.0	18.4	.0	.0	.0	.0
11	20.0	.0	.0	.0	.0	.0	44.2	3.8	.0	12.0	.0	.0
12	3.0	.0	.0	.0	.0	.0	25.8	18.6	80.2	14.0	.0	.0
13	1.0	.0	.0	.0	.0	.0	19.6	4.0	25.4	.0	.0	.0
14	.0	.0	.0	.0	.0	.0	.0	2.2	1.0	.0	.0	.0
15	2.0	.0	.0	.0	.0	.0	40.8	42.8	28.8	.0	.0	.0
16	6.0	.0	.0	.0	.0	.0	32.6	28.2	7.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	69.4	60.2	10.2	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	2.8	17.8	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	40.0	18.8	20.2	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	.0	18.0	.0	.0	.0	.0
21	7.0	.0	.0	.0	.0	.0	27.8	2.0	23.8	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	17.4	1.0	24.0	.0	.0	.0
23	11.0	.0	.0	.0	.0	.0	19.2	9.8	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	42.6	.0	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	5.0	29.4	.0	.0	.0	.0	.0
26	.0	.0	.0	.0	.0	.0	53.2	.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	20.0	.0	.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	10.0	.0	.0	.0	.0	.0	.0
29	.0		.0	.0	.0	.0	5.2	.0	.0	.0	.0	.0
30	.0		.0	.0	.0	.0	9.2	10.8	.0	.0	.0	.0
31	20.0		.0		.0		14.2	6.0		.0		.0
Total	106.0	31.0	.0	9.0	.0	75.0	550.4	510.2	210.8	38.6	.0	.0
Mean	3.4	1.1	.0	.3	.0	2.5	17.8	16.5	7.0	1.2	.0	.0
Max.	21.0	28.0	.0	9.0	.0	40.0	69.4	100.8	80.2	14.0	.0	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1531.0 Mean: 4.2 Maximum: 100.8 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1980

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	17.0	.0	37.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	3.2	.0	.0	.0	.0	10.6	.0	.0	.0	.0
3	.0	.0	.0	.0	20.2	.0	.0	2.2	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	4.2	26.0	.0	3.2	.0	.0
5	.0	4.2	.0	.0	.0	.0	.0	10.0	.0	9.2	.0	.0
6	.0	5.4	.0	.0	.0	.0	.0	24.0	.0	.6	.0	.0
7	.0	9.4	.0	.0	.0	.0	20.2	1.2	.6	.0	.0	.0
8	.0	10.0	.0	.0	.0	.0	79.6	.0	.0	.0	.0	.0
9	.0	38.2	.0	.0	.0	.0	17.0	6.6	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	19.6	23.6	.0	.0	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	8.4	.0	.0	.0	.0
12	.0	11.4	.0	.0	.0	.0	.0	.0	20.2	.0	.0	.0
13	.0	13.0	.0	.0	.0	.0	.0	26.2	.0	.0	.0	27.2
14	.0	20.4	.0	.0	.0	.0	31.2	2.0	13.8	.2	.0	.0
15	.0	.0	.0	.0	.0	.0	15.2	.0	6.2	.0	.0	.0
16	.0	.0	.0	.0	.0	22.8	34.4	8.8	.0	.0	.0	.0
17	.0	.0	.0	.0	20.2	17.2	8.2	.6	.0	.0	.0	14.4
18	.0	.0	.0	.0	.0	10.0	15.2	1.2	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	20.2	5.8	1.8	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	21.4	.0	2.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	18.8	.0	7.2	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	10.2	20.0	10.4	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	7.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	19.4	36.0	.0	35.0	.0	.0	.0
25	.0	.0	.0	.0	.0	50.6	17.0	.0	.0	.0	.0	58.4
26	.0	.0	.0	.0	.0	7.0	31.4	.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	20.4	14.2	.0	.0	.0	.0	.0
28	.0	14.0	.0	.0	.0	15.0	21.0	.0	.0	.0	.0	.0
29	.0		.0	.0	.0	.0	3.0	.0	.0	.0	.0	.0
30	.0		.0	.0	.0	31.0	.0	.0	.0	.0	.0	.0
31	.0		.0		.0		.0	.0		.0		.0
Total	.0	126.0	20.2	.0	77.4	264.0	400.2	172.8	75.8	13.2	.0	100.0
Mean	.0	4.5	.7	.0	2.5	8.8	12.9	5.6	2.5	.4	.0	3.2
Max.	.0	38.2	17.0	.0	37.0	50.6	79.6	26.2	35.0	9.2	.0	58.4
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1249.6 Mean: 3.4 Maximum: 79.6 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1987

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	.0	.0	8.2	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	19.2	.0	2.2	.0	.0	.0
3	.0	.0	.0	.0	8.2	.0	2.0	.0	6.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	8.8	.0	2.0	10.0	.0	.0
5	.0	.0	.0	.0	.0	.0	36.0	10.2	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	18.2	17.8	32.4	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	2.2	1.2	12.2	.0	.0
8	.0	.0	.0	.0	.0	.0	7.2	4.0	13.2	.0	.0	.0
9	.0	.0	.0	.0	.0	10.2	.0	10.2	21.2	.0	.0	.0
10	10.2	.0	.0	.0	.0	9.2	26.0	.0	22.2	.0	.0	.0
11	5.8	.0	.0	.0	.0	7.4	11.2	.0	26.4	.0	.0	.0
12	7.2	.0	16.4	.0	.0	.0	32.4	6.4	8.0	.0	.0	.0
13	.0	.0	8.2	.0	.0	.0	41.0	7.0	7.2	.0	.0	.0
14	8.6	.0	.0	.0	7.8	.0	120.4	10.2	18.0	.0	.0	.0
15	.0	8.0	.0	.0	.0	.0	1.0	15.0	140.4	.0	22.2	.0
16	.0	12.2	.0	.0	.0	.0	.0	1.2	80.2	.0	.0	.0
17	.0	40.8	.0	.0	.0	.0	.0	6.2	3.0	25.2	.0	.0
18	5.2	4.2	.0	.0	.0	.0	.0	.0	1.2	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	4.2	4.2	2.0	38.6	54.4	.0
20	.0	.0	.0	.0	.0	.0	10.0	24.4	3.6	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	14.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	7.4	3.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	3.2	6.2	.0	.0	.0	.0
24	.0	8.4	.0	20.4	.0	.0	.0	64.2	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0
26	.0	3.4	.0	.0	.0	.0	.0	15.2	.0	.0	.0	.0
27	.0	16.3	.0	.0	.0	.0	44.2	6.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	31.2	7.2	.0	.0	.0	.0
29	.0		.0	.0	.0	.0	17.0	26.0	.0	.0	.0	.0
30	.0		.0	.0	.0	.0	20.0	22.2	.0	.0	.0	.0
31	.0		.0		.0		.0	8.4		.0		.0
Total	37.0	93.3	24.6	20.4	16.0	45.0	460.2	306.4	366.2	86.0	76.6	.0
Mean	1.2	3.3	.8	.7	.5	1.5	14.8	9.9	12.2	2.8	2.6	.0
Max:	10.2	40.8	16.4	20.4	8.2	18.2	120.4	64.2	140.4	38.6	54.4	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1531.7 Mean: 4.2 Maximum: 140.4 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1988

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	.0	66.2	.0	.0	.0	.0
2	.0	.0	.0	.0	4.2	.0	12.2	80.4	62.2	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	18.2	3.4	5.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	82.4	9.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	26.0	17.2	.0	10.0	.0	.0
6	.0	.0	.0	.0	.0	.0	8.0	.0	4.2	6.6	.0	.0
7	.0	.0	.0	.0	.0	.0	24.0	.0	7.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	2.0	.0	1.4	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	27.4	6.4	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	.0	2.0	7.2	5.4	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	35.2	12.0	.0	.0	.0
12	.0	.0	.0	.0	.0	.0	5.4	12.4	.0	.0	.0	.0
13	54.8	.0	.0	.0	.0	.0	48.4	5.0	4.6	.0	.0	.0
14	10.6	32.6	3.2	.0	.0	.0	1.0	2.6	.0	.0	.0	.0
15	.0	.0	.0	.0	.0	.0	2.6	.0	.0	.0	.0	.0
16	.0	.0	.0	.0	.0	8.8	.0	.0	3.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	.0	11.2	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	70.6	18.2	40.6	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	2.2	23.0	.0	.0	.0	.0
21	.0	.0	.0	14.8	.0	.0	3.2	.0	3.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	23.2	.0	.0	.0	.0	.0
23	.0	27.4	.0	.0	.0	71.6	3.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	30.2	2.0	14.2	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	25.8	24.0	14.4	.0	.0	.0	.0
26	.0	.0	.0	.0	.0	105.4	22.0	20.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	39.2	86.0	50.4	.0	.0	.0	.0
28	.0	16.8	.0	3.2	.0	122.2	10.6	15.0	25.4	.0	.0	.0
29	.0	.0	.0	.0	.0	10.0	.0	12.4	.0	.0	.0	.0
30	.0		.0	.0	.0	2.2	.0	.0	.0	.0	.0	.0
31	.0		.0		.0		20.4	33.6		.0		.0
Total	65.4	76.8	3.2	18.0	4.2	486.0	390.0	548.0	144.0	22.0	.0	.0
Mean	2.1	2.6	.1	.6	.1	16.2	12.6	17.7	4.8	.7	.0	.0
Max.	54.8	32.6	3.2	14.8	4.2	122.2	86.0	82.4	62.2	10.0	.0	.0
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1757.6 Mean: 4.8 Maximum: 122.2 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1989

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	.0	2.8	5.2	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	8.2	.0	7.4	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	5.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	21.2	.0	11.4	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	5.0	5.4	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	5.0	25.2	44.4	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	1.2	28.4	.0	.0	.0	.0
8	.0	.0	7.0	.0	.0	.0	.0	5.0	.0	.0	.0	.0
9	.0	.0	8.0	.0	.0	.0	.0	4.4	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	9.0	.0	19.2	8.2	.0	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	8.2	16.4	.0	.0	.0
12	.0	.0	.0	.0	.0	34.0	.0	4.4	9.6	.0	.0	.0
13	.0	.0	.0	.0	.0	20.0	.0	46.2	30.2	.0	.0	.0
14	.0	.0	.0	.0	.0	22.0	.0	12.2	45.4	.0	.0	.0
15	.0	.0	.0	.0	.0	18.6	19.2	.0	11.6	.0	.0	.0
16	.0	.0	.0	.0	.0	14.2	4.2	.0	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	38.4	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	14.2	.0	.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	9.4	.0	.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	.0	.0	47.2	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	20.2	.0	14.2	.0	.0	.0
22	.0	.0	.0	.0	.0	55.2	2.4	16.4	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	.0	10.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	5.2	.0	18.2	.0	.0	.0	.0
25	.0	.0	5.0	.0	.0	45.2	3.4	10.8	5.0	.0	.0	10.0
26	.0	.0	.0	.0	.0	.0	.0	9.2	.0	.0	.0	20.6
27	.0	.0	.0	.0	.0	.0	.0	21.2	1.0	.0	.0	.0
28	.0	.0	8.0	.0	.0	.0	.0	5.0	.0	.0	.0	.0
29	.0		5.0	.0	.0	.0	4.4	.0	.0	.0	.0	.0
30	.0		.0	.0	.0	6.4	.0	21.8	.0	.0	.0	.0
31	.0		.0		.0		.8	10.2		.0		.0
Total	.0	.0	33.0	.0	.0	258.4	120.4	341.8	212.8	.0	.0	30.6
Mean	.0	.0	1.1	.0	.0	8.6	3.9	11.0	7.1	.0	.0	1.0
Max.	.0	.0	8.0	.0	.0	55.2	25.2	46.2	47.2	.0	.0	20.6
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 997.0 Mean: 2.7 Maximum: 55.2 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1990

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	.0	.0	.0	.0	.0	.0	12.2	12.6	17.6	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	17.0	3.8	4.2	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	36.6	.0	15.6	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	5.8	.0	16.4	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	11.4	5.4	29.8	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	4.8	.0	10.2	23.2	.0	.0
7	.0	.0	.0	.0	.0	.0	31.4	3.0	6.0	5.2	.0	.0
8	.0	.0	.0	.0	.0	.0	4.2	.0	.0	10.4	.0	.0
9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	14.2	.0	8.6
11	.0	9.2	.0	.0	.0	.0	.0	.0	.0	15.2	.0	.0
12	.0	.0	.0	.0	.0	.0	.0	7.4	.0	.0	.0	.0
13	.0	.0	.0	.0	10.0	.0	13.6	20.4	7.2	.0	.0	.0
14	.0	10.0	.0	.0	.0	.0	7.4	1.2	20.6	.0	.0	.0
15	.0	30.2	.0	.0	.0	50.2	76.2	.0	86.4	.0	.0	.0
16	.0	.0	.0	.0	15.2	3.2	23.6	.0	13.8	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	.0	7.4	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	5.0	.0	5.0	.0	.0	.0
19	.0	.0	.0	.0	.0	30.6	4.0	24.2	73.6	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	7.2	.0	31.2	.0	.0	.0
21	.0	.0	.0	.0	.0	30.4	20.6	8.6	11.0	.0	.0	.0
22	.0	.0	.0	.0	.0	30.6	40.4	8.2	7.2	.0	.0	.0
23	.0	.0	.0	.0	.0	18.8	6.2	4.6	20.8	.0	.0	.0
24	.0	.0	.0	.0	.0	40.4	4.8	.0	7.0	.0	.0	.0
25	.0	.0	.0	.0	.0	120.6	.0	.0	25.2	.0	.0	.0
26	.0	.0	.0	.0	.0	1.0	4.2	.0	39.6	.0	.0	.0
27	.0	.0	.0	.0	20.4	20.4	5.4	.0	6.2	.0	.0	.0
28	.0	.0	.0	.0	.0	60.6	3.2	.0	7.6	.0	.0	.0
29	.0		.0	.0	40.2	7.0	.0	.0	.0	.0	.0	.0
30	.0		.0	.0	.0	2.2	2.6	15.8	.0	.0	.0	.0
31	.0		.0		.0		19.6	17.8		.0		1.2
Total	.0	49.4	.0	.0	85.8	416.0	367.4	133.0	469.6	68.2	.0	9.8
Mean	.0	1.8	.0	.0	2.8	13.9	11.9	4.3	15.7	2.2	.0	.3
Max.	.0	30.2	.0	.0	40.2	120.6	76.2	24.2	86.4	23.2	.0	8.6
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1599.2 Mean: 4.4 Maximum: 120.6 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

GITHORI

Rainfall historical mm, year 1991

DAY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12.6	.0	.0	.0	.0	.0	.0	16.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	6.0	.0	.0	.0	.0
4	.0	.0	5.2	.0	.0	.0	.0	27.0	.0	.0	.0	.0
5	.0	.0	.0	6.8	.0	.0	.0	5.0	.0	.0	.0	.0
6	.0	.0	.0	15.6	.0	.0	.0	6.2	.0	.0	.0	.0
7	.0	.0	.0	3.0	.0	12.2	.0	3.2	.0	93.0	.0	.0
8	.0	.0	.0	.0	.0	.0	56.4	5.6	.0	1.6	.0	.0
9	1.8	.0	.0	.0	.0	.0	.0	30.2	.0	24.4	.0	.0
10	.0	.0	.0	.0	.0	.0	.0	4.0	.0	.0	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	8.2	.0	.0	.0	.0
12	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	10.2	.0	.0	.0	.0	.0
14	.0	.0	.0	.0	.0	.0	26.4	42.2	.0	.0	.0	.0
15	.0	.0	.0	.0	.0	71.0	8.0	5.0	.0	.0	.0	.0
16	.0	.0	.0	.0	.0	.0	50.4	16.2	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	30.2	1.6	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	76.4	3.6	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	53.4	.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	56.8	6.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	43.0	60.4	5.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	28.0	12.6	6.2	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	.0	50.4	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	118.2	185.2	.0	.0	.0	.0
25	.0	.0	.0	.0	.0	.0	10.0	17.6	.0	.0	.0	10.6
26	.0	.0	.0	.0	.0	.0	5.0	23.2	.0	.0	.0	.0
27	.0	21.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	5.2	.4	.0	.0	.0	.0
29	.0		.0	.0	.0	.0	10.2	17.2	.0	.0	.0	.0
30	.0		.0	.0	.0	28.0	12.6	150.4	.0	.0	.0	.0
31	.0		.0		.0		.0	5.4		.0		.0
Total	14.4	21.0	5.2	25.4	.0	182.2	602.4	647.0	.0	119.0	.0	10.6
Mean	.5	.8	.2	.8	.0	6.1	19.4	20.9	.0	3.8	.0	.3
Max.	12.6	21.0	5.2	15.6	.0	71.0	118.2	185.2	.0	93.0	.0	10.6
Min.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Sum: 1627.2 Mean: 4.5 Maximum: 185.2 Minimum: .0

Legend:
(-) Signifies missing data
T Signifies traces

DIRECTOR	:	S M SETH

STUDY GROUP

DIVISIONAL HEAD	:	R D SINGH
SCIENTIST	:	HEMANT CHOWDHARY