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RAINFALL – RUNOFF PROCESS AND RAINFALL ANALYSIS FOR NABLUS BASIN

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Dedicated to my parents,
Brothers and wife

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My sincere gratitude to Mr. Khalil Ashour for his continuos support.

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List of Abbreviations

Symbol	The Meaning
A	Area
CMC	Computed Mean Precipitation
IDF	Intensity Duration Frequency
NWB	Northern West Bank
PHG	Palestinian Hydrology Group
Q	Flowrate
Tr	Return Period

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Abstract

The analysis of precipitation is essential for the hydrological studies and design. For the West Bank, there is no enough precipitation data available especially for short duration, hourly and daily precipitation. Therefore it is essential to develop the required plots and relations and made their available for use. This should be achieved depending on the available rainfall data of specific durations such as producing the IDF curves. In order to contribute to this need, the rainfall data used for the Nablus district were collected from the Nablus Meteorological station and were used for the rainfall-runoff relationship as one other important issue was also discussed for one catchment area in Nablus district basing on the available rainfall data.

The annual, monthly and daily precipitation data for Nablus Meteorological station were used in the analysis. Gumble distribution shows the best fit for annual rainfall. The analysis also included the development of the Intensity Duration Frequency curves for Nablus district. The most rainy month of January and the monthly rainfall distribution have the same style for the period of 1954-1998.

Using the developed rainfall-runoff relation, Synthetic Unit Hydrograph was developed for Rujeep catchment near Nablus. It was found that the runoff occurs when the rainfall exceeds 48.5 mm for a period of 15-hr.

It is proposed that efforts must be further invested into data gathering especially for stream flow data, intensity and duration of rainfall. These data should be used in the development of rainfall- runoff relationship for the different catchment areas.

1. Introduction

1.1 Background

It is hardly necessary to state that water is one of the most important minerals and vital for all life. It has played an important role in the past and in the future it will play the central role in the well- being and development of our society. This most precious resources is sometimes scarce, sometimes plentiful and always very unevenly distributed, both in space and time.

Hydrology can be seen as a scientific examination and appraisal of the whole continuum of a hydrologic or water cycle. The hydrologic cycle describes the endless movement of water from the earth to the atmosphere through evaporation and transpiration and return by precipitation as shown in figure 1.1.

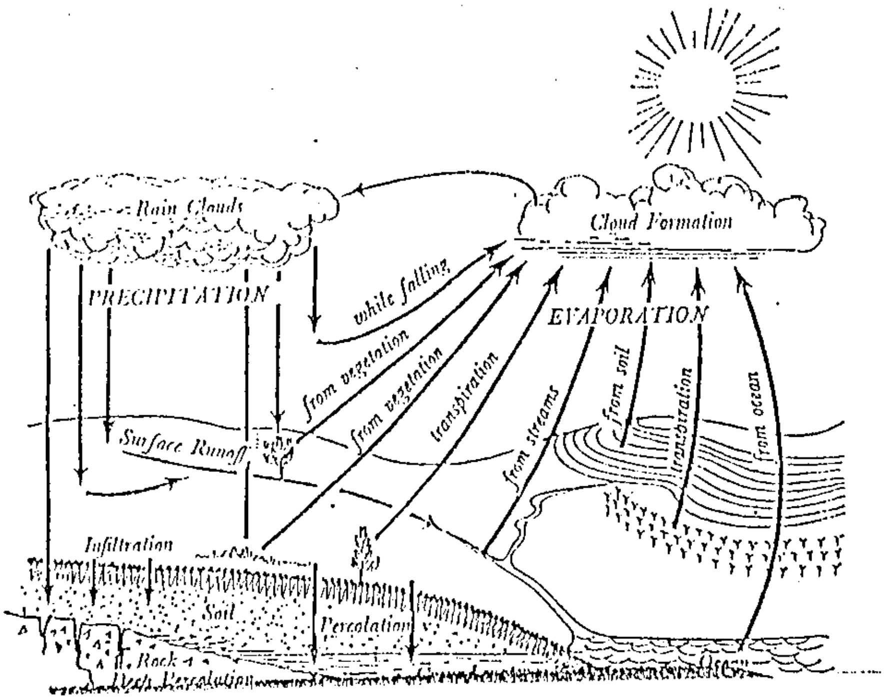
In customary usage, however, hydrology has come to mean studies of precipitation and runoff, that is, it has been linked with problems associated with design and management of water resources projects, such as water supply, flood control, or recreational use of water. Water resources management has established itself as almost self-contained discipline concerned with seeking optimal solutions to problems associated with demand and availability of water. These two components, although essential do not alone constitute the water resources management problem. Political, social and ecological considerations play a very important role.

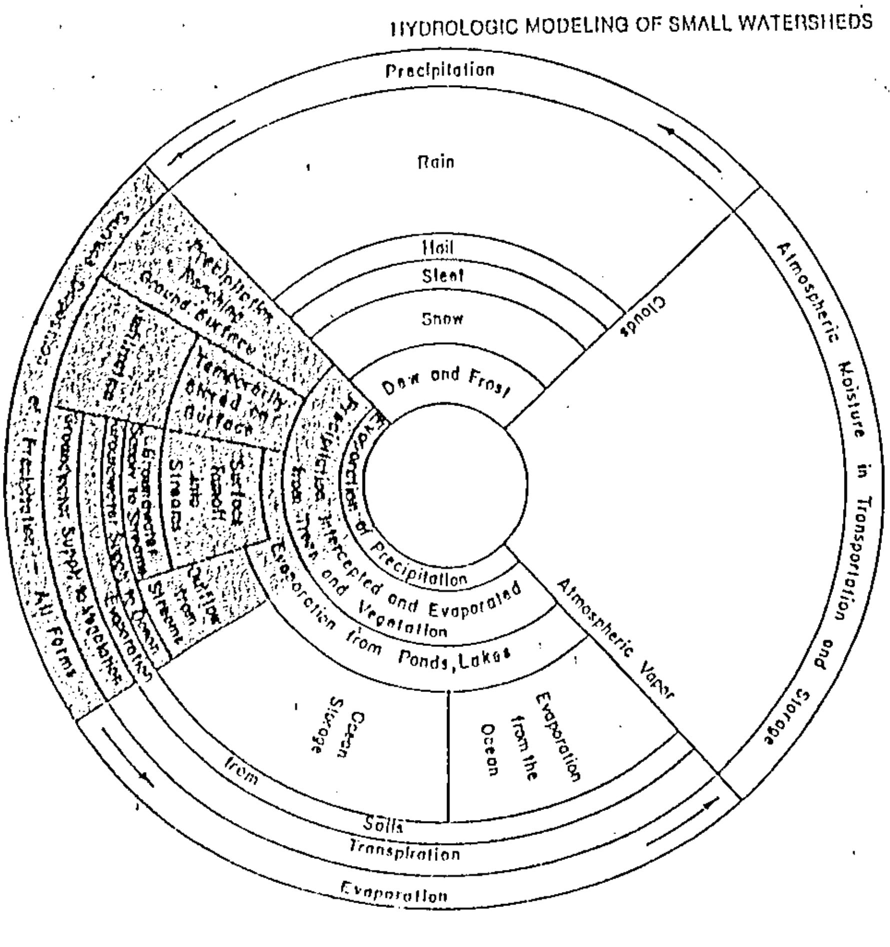
An important part of hydrological work is concerned with analysis of information and decision making. The techniques of analysis are not strictly part of hydrology, but do form a very important part of the hydrologist's toolkit.

1.2. Objectives of the study

Precipitation data are utilized for the estimation of available surface and groundwater resources in a certain catchment. Precipitation data was used to estimate the water

Figure 1.1 The hydrologic cycle – a qualitative representation { from Horton, 1931}





budget for the basin. Precipitation records help to predict the runoff volume. For the above benefits, the objectives of this study are:

- Provide documentation of rainfall quantities and intensity by means of analyzing the available rainfall data. Frequency analysis is the tool followed or used to conduct the analysis.
- To examine the possibility of depending on limited data in producing intensity – duration – frequency curves.
- Study the rainfall – runoff relation and develop ideas for modeling the rainfall – runoff process.

Frequency analysis of point rainfall rules and is used for many purposes: design of storm sewers in urban development, culvert design on highway, drainage design on air fields and others. In hydrologic analysis and design, it is often necessary to develop relations between precipitation and runoff, possibly using some of the factors affecting runoff as parameters and variables.

In order to achieve the above objectives, historical rainfall data were collected from Nablus meteorological station. Frequency analysis for annual, monthly and daily rainfall was done. From the available data, intensity – duration – frequency curves were developed. Although, a rectangular crested weir was designed and installed in Rujib wadi to measure runoff, there was no measured flow in the two years 1996-1997 and 1997-1998. For this reason synthetic unit hydrograph was developed. The results are affected by the lack of data because of the Israeli occupation that keeps the data and prevents releasing them to the Palestinian. During the last years, the data were made available by the Palestinian Meteorological office in Hebron who are managing and controlling the stations located in the West Bank.

1.3. Study Area

The following are some specific information about Nablus including Rujib. The study area is part of Nablus district called Rujib.

1.3.1 Topography:

Figure 1.2 shows the contour map of Nablus district. The highest point in the district reaches 918 m above sea level at Jabal'Ibal, while the lowest elevation is 349 m below sea level at the southeast corner of the district. The topography of Nablus district can be divided into four parts: Jordan Valley, the eastern slopes, mountain crests and western slopes.

Two main drainage systems are distinguished in Nablus district. The first system runs to the west such as Wadi Qana, Wadi Rabah, Wadi Khalifa and Wadi Masuha. While the second system runs to the east or south east, such as wadi El-Maleh, wadi Dura, wadi el Far'a and wadi el Ahmar. The distance between the meteorological station in Nablus and wadi Rujib is about two kilo meter. The area that feeds the wadi with water can be divided into two parts. The first part is mountainous and the second part is residential.

1.3.2 Climate:

Nablus district is located at the northern latitude earth grid 32 13. It has hot, dry summer and moderate, rainy winter. Figures 1.3, 1.4, 1.5, and 1.6 show long term variations of different climatic parameters in Nablus district.

1.3.2.1 Wind:

During summer, wind moves with relatively cooler air from the Mediterranean towards, the north with an average wind speed of 298.71 km per day in June (Areej, 1997). At night, the land areas become cooler, causing diurnal fluctuations in wind speed, due to the reduction of the pressure gradient. In winter, the wind moves from west to east over the Mediterranean, bringing westerly rain bearing winds of average wind speed 209.19 km per day in January. The Khamasean, desert storm, may occur during the period from April to June. During the Khamasean, the temperature increases, the humidity decreases and the atmosphere becomes hazy with dust of desert origin. Figure 1.3 shows the long term average of wind speed in Nablus district, 1970-1992.

1.3.2.2 Temperature:

As Nablus district is part of the north of West Bank, it has comparatively lower temperature range than other districts. The average maximum temperature reaches 13.1° c and average minimum temperature reaches 6.2° c during the coldest month, January. During August, the hottest month, the average maximum temperature is 29.4° c and the average minimum temperature is 19.5° c. Figure 1.4 shows the long term average minimum and maximum temperature in Nablus district, 1970-1992.

1.3.2.3 Humidity:

The annually average humidity of Nablus district is 62%. Maximum humidity of 67% is usually registered in December, January and February. This value increases gradually at night. During the Khamasean, the relative humidity decreases to reach its minimum value of 50.72% in May.

1.3.2.4 Rainfall:

Rainfall in Nablus district is limited to the winter and spring months, from October to May. The annual rainfall varies between 600 to 700 mm. Figure 1.5 shows the variation in the average monthly rainfall from the period 1954-1998.

No data is available on hail or snow in Nablus district. It does periodically snow and hail but these events are rare.

1.3.2.5 Evaporation:

Pan evaporation is used to reflect the evaporation rate in Nablus district. In summer it can reach 237.9 mm/month during July while in the winter it reaches only 48.6 mm/month during December. During the spring and autumn the evaporation rate is 100-150 mm per month. In December, January, February and March, precipitation exceeds the rate of evaporation. Figure 1.6 shows the long term average of evaporation in Nablus district, 1970-1992.

Figure 1.2 The contour map of Nablus district (ARIJ, 1995)

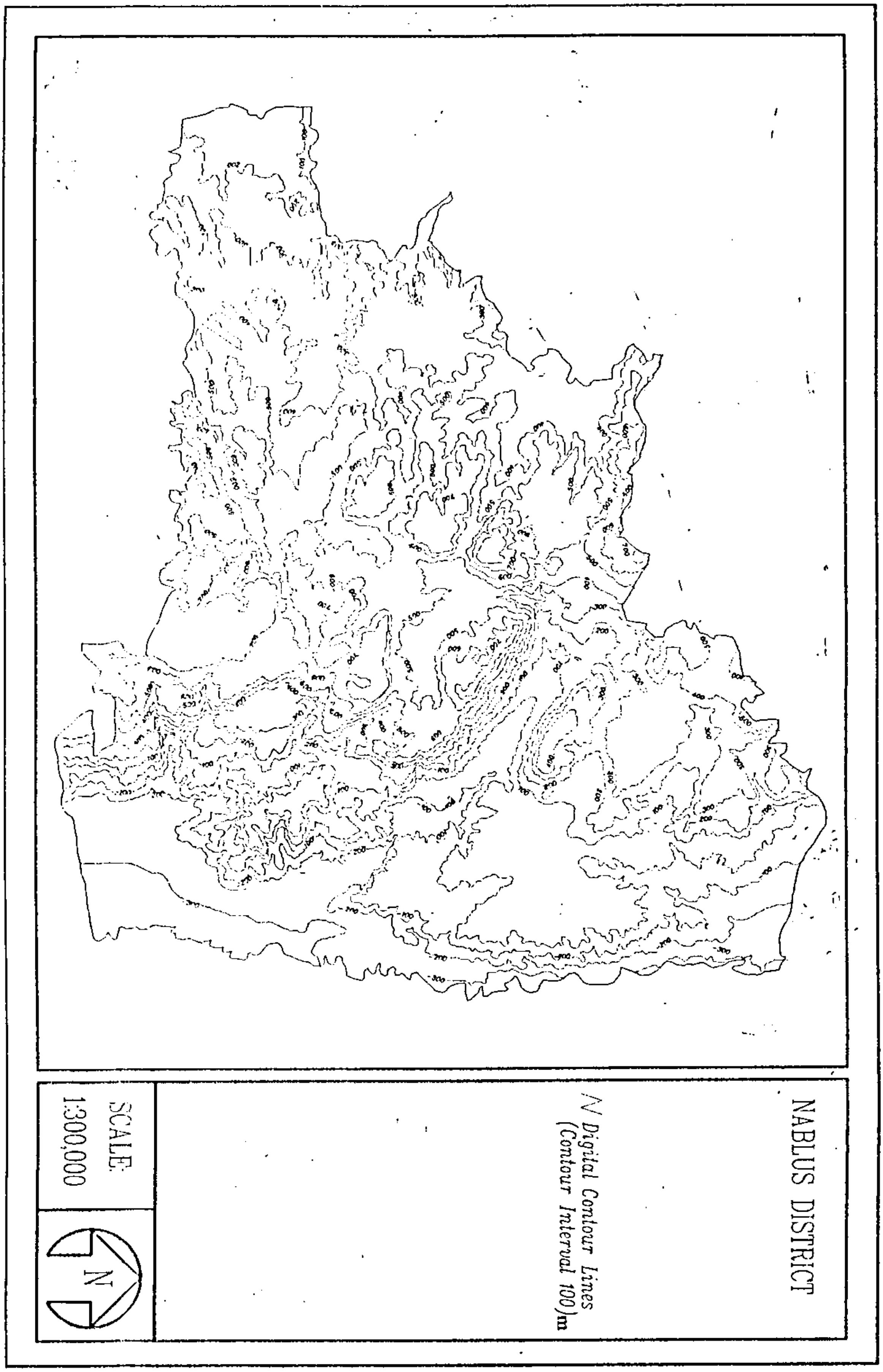


Fig 1.3 Long term variation of average wind speed for Nablus district for the period 1970-1993.

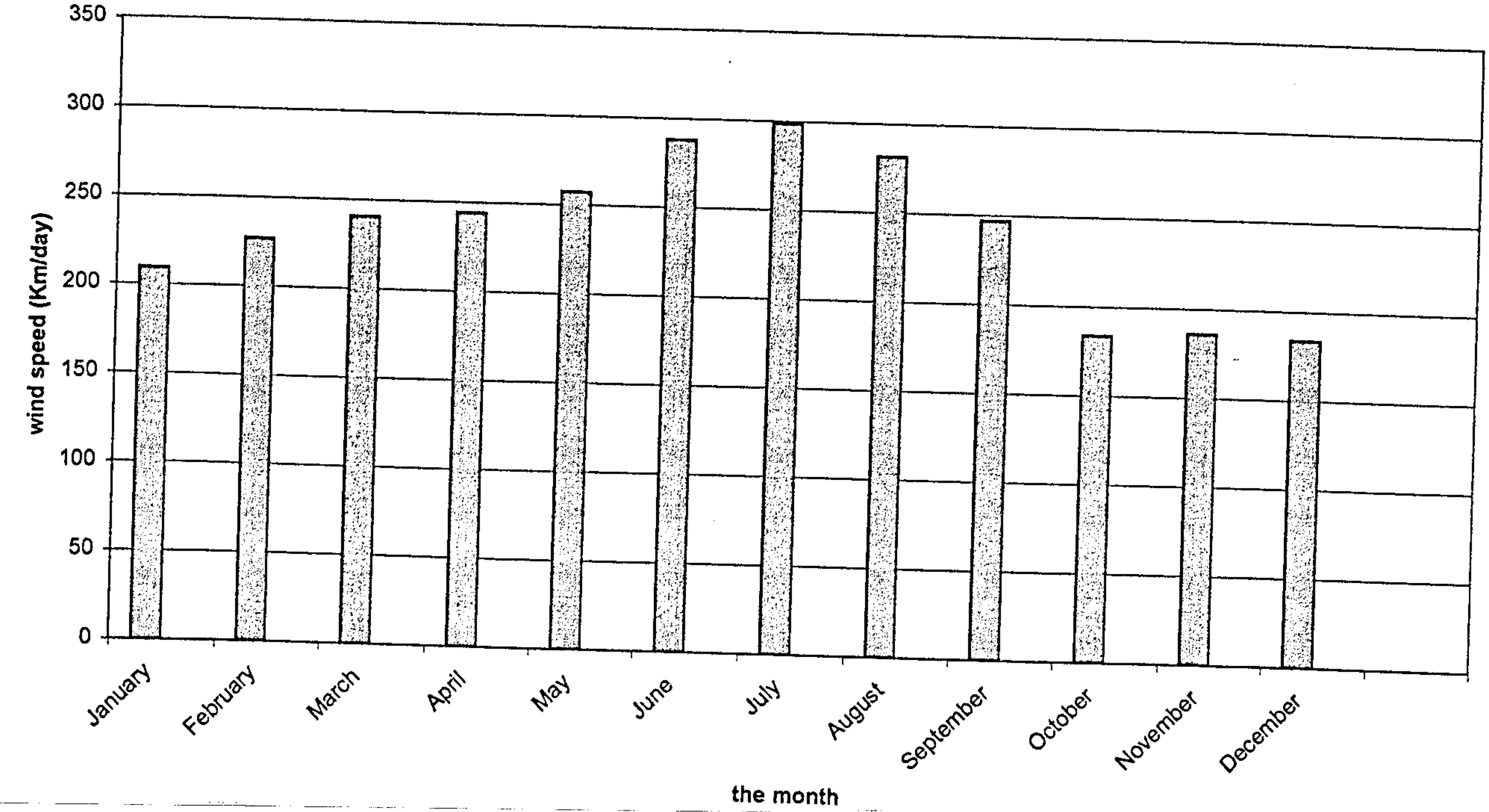


Fig 1.4 Long term variation of average maximum and minimum temperature.

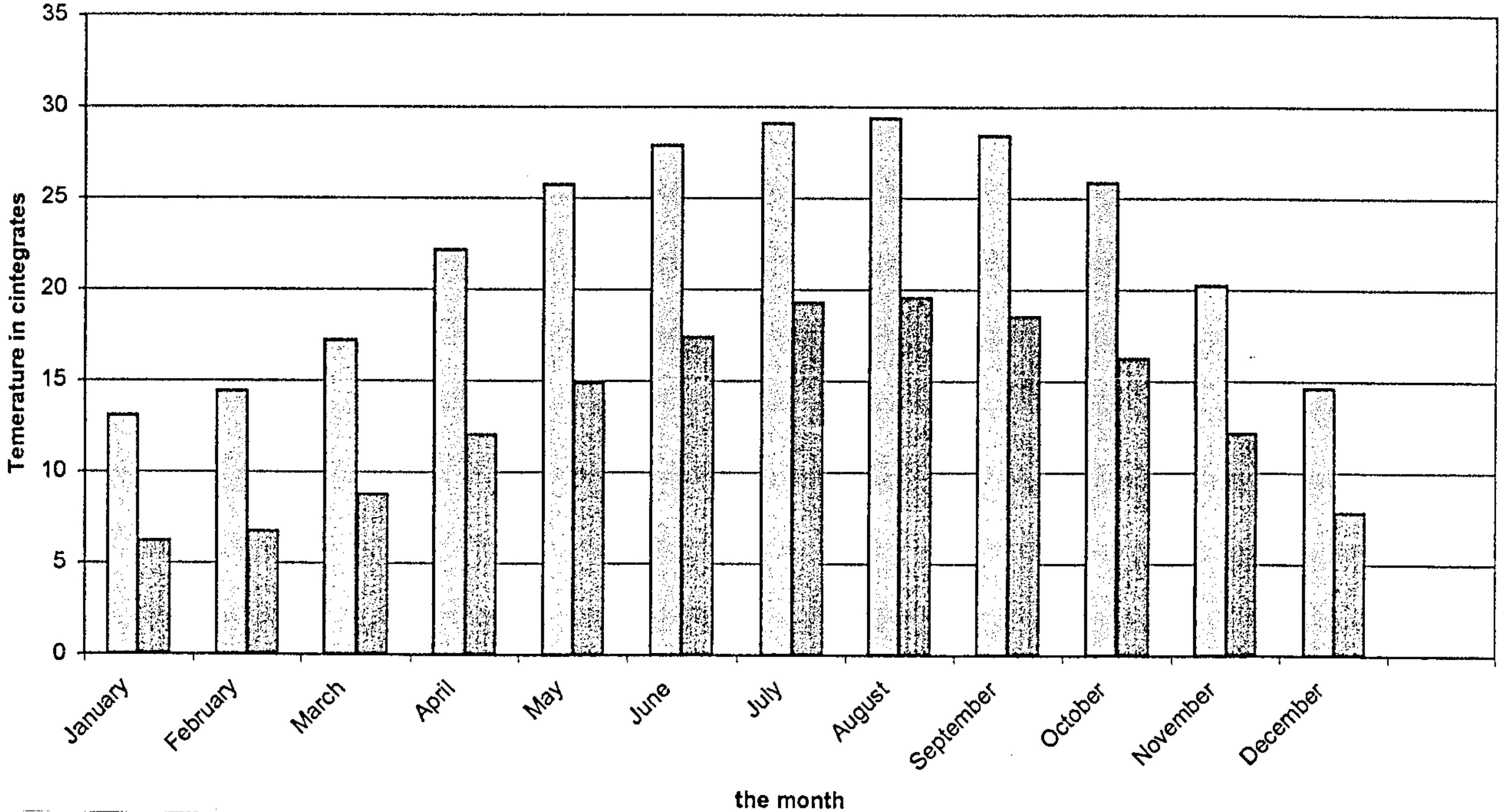


Fig 1.5 Long term variation of average monthly rainfall for Nablus district for the period of 1954-1998.

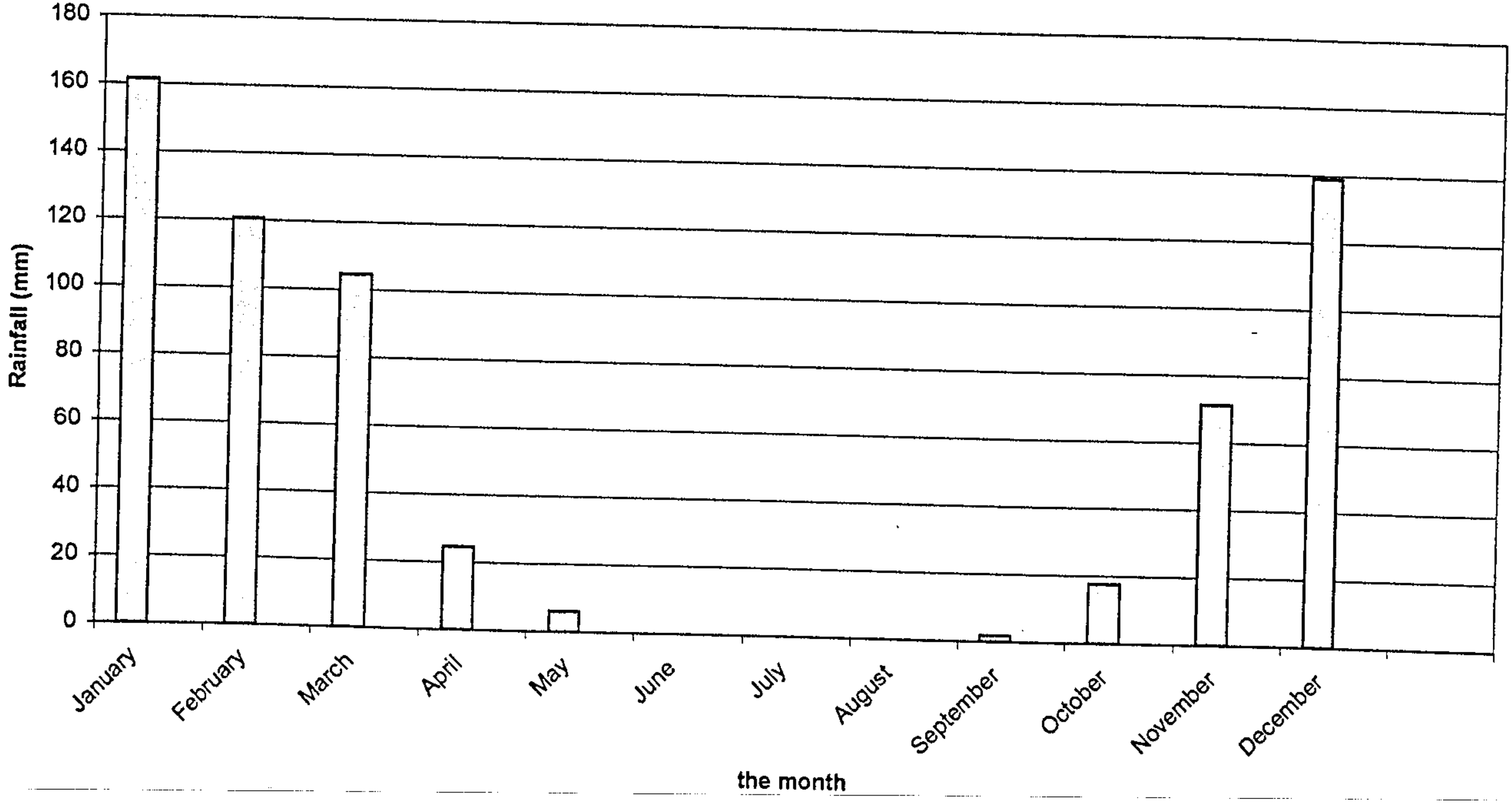
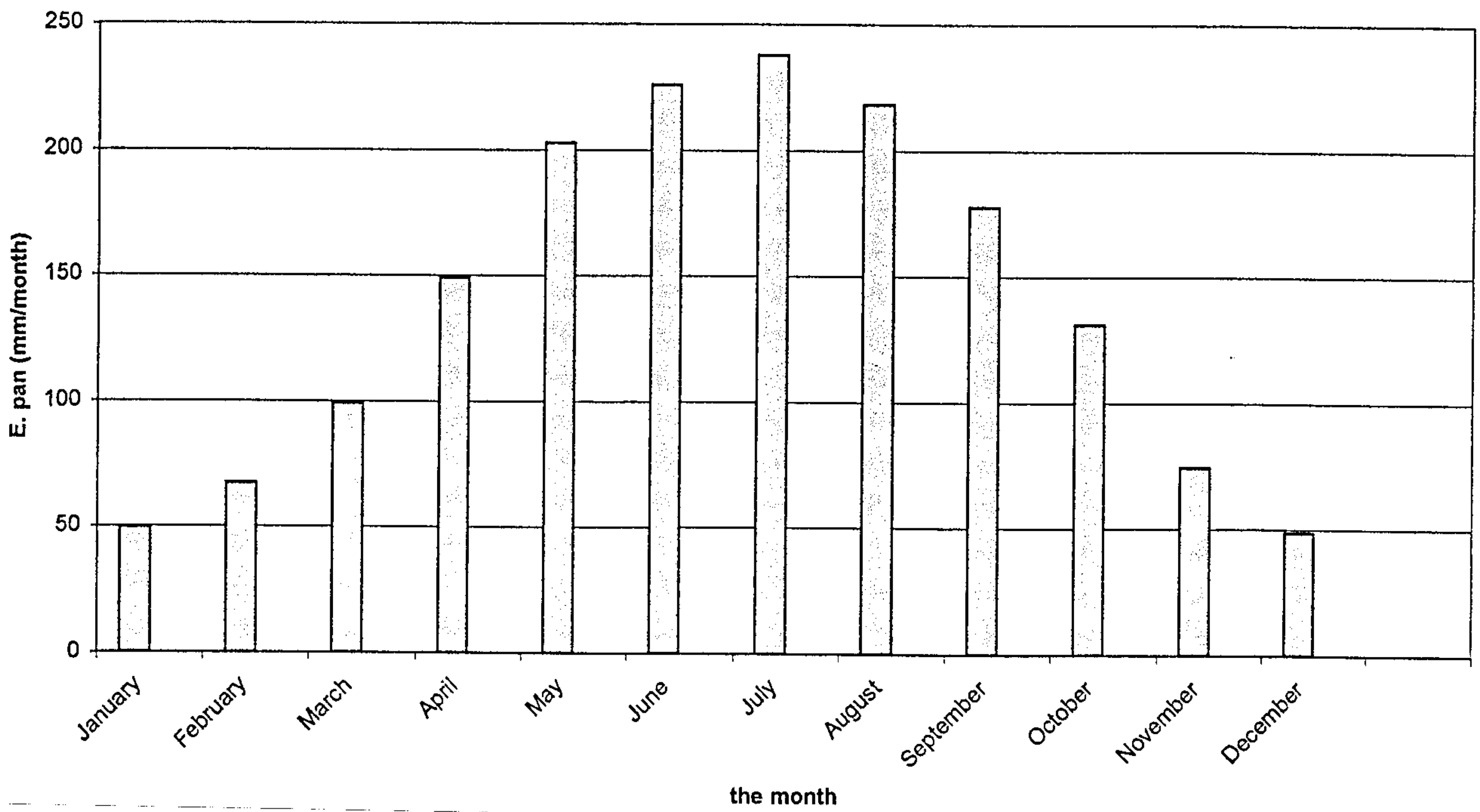


Fig 1.6 Long term variation of average Evaporation for Nablus district for the period of 1970-1993.



2. Literature Review

2.1 Precipitation

Precipitation is the input to any rainfall runoff model, therefore it is important to interpolate and predict precipitation based on time and space. Prediction is based on historical data at a given site depending on near sites and meteorological stations. Time variation of rainfall can be achieved by rainfall analysis.

Palestinian Hydrology Group (PHG) in 1995 studied the rainfall in many meteorological stations in the northern West Bank. The title of their study was Analysis of Secondary Source Rainfall Data from the Northern West Bank (NWB). The study provides a comprehensive overview and analysis of the available rainfall data for the NWB. In that study, rainfall data for the NWB is accessible for twenty-nine stations in the following form: daily data for thirteen stations, monthly data for two stations and annual data for fourteen stations. It is found that the number of wet days ranges from 38 days in Beit Dajan station to 60 days in Tulkarm station. In this study the wet day is the day where the rainfall depth is greater than 0.5 mm. The analysis of daily rainfall shows that the Exponential and Gumble distributions provide good fits to recorded rainfall. The highest averages of rainfall occur in the months of January and December.

In hydrological studies, it is important to know the equivalent uniform depth of precipitation over an area. The question appears " For the sites that are unguaged or where the data are missing, "what is the precipitation ?". At such sites, precipitation can be computed by spatial interpolation of data available at other sites. There are a number of techniques used. One of the simplest technique to estimate the area averages of precipitation is the classical works of Thiesen (1911). The Thiesen method assumes that precipitation at any point in the watershed is the same as that at the nearest gauged location, therefore the depth recorded at a given gauge is applied out to a distance halfway to the next station in any direction. The relative weights for each gage are determined from the corresponding areas for application in a thiesen polygon network, the boundaries of the polygon being formed by the perpendicular bisectors of the lines joining adjacent gages. The average precipitation for the watershed is

$$P = \sum Aj \; Pj / A \qquad (1.1)$$

Where the watershed area $A = \sum Aj$

and J represents the number of the gages and Pj is the rainfall recorded at the jth gage. Thiesen method is inflexible as the need of construction of many thiesen networks when there is a change in the gage network such as when data is missing from one of the gages. Thiesen method doesn't directly account for orographic influences on rainfall. To overcome some of these difficulties, Isohyetal method is used by taking observed depths at rain gages and interpolation between adjacent gages. Isohytal maps which need a dense network of rain gages can be constructed by using programs for automated contouring. Knowledge of the storm pattern can influence the drawing of the isohyets.

Many researches and literature have tackled the time variation of rainfall at different locations in the world. Unfortunately and due to special circumstances in the Palestinian territories, there are little published works that handle this issue and have deep investigated the spatial and temporal variations of rainfall. For the precipitation in the Northern West Bank, there are two studies for the spatial interpolation of rainfall that have been traced.

From the first study, PHG(1995), analysis of secondary source rainfall data from the northern west bank, the spatial modeling (correlation) of monthly rainfall data shows that there is no strong evidence to suggest that the rate of decay of correlation (in rainfall among adjacent stations within the same hydrological region) is dependent on distance or orientation. Also it shows that there is evidence of good correlation between the stations of each catchment. Ali, 1998 studies the spatial interpolation of precipitation in the Northern West Bank. Several spatial interpolation techniques for the precipitation of 28 stations were investigated. This task aim to develop a reasonable model that best fits the actual precipitation. These interpolation techniques could be classified into three groups:

1. Local Models where the study area is divided into subareas including the nearest 4 stations to the point of interest. The precipitation of the interest point can be estimated by different methods such as unweighted mean of the nearest points precipitation like the arithmetic mean of the nearest four stations or by weighted mean models which depend on the distance between the interpolation and reference points.
2. Global Models: These models consider the whole stations in the study area. Such models include all of the local models in addition to three proposed models that are Bilinear, Cubic and Bicubic models. These models involve the fitting of a single three-dimensional surface defined by a high order polynomial through all measured precipitation points existing within the model. Once the global surface has been defined and the specific values of the polynomial coefficient have been determined, the values of the precipitation for each point in the study area can be interpolated.

3. Optimal and Krigging Models:

These two models estimate the precipitation for a certain point depending on the weights of other stations. The weights for the two techniques are related to the spatial correlation and variograms consequently. These two parameters are functions of distances between the station and other neighboring stations.

From the second study, Ali, 1998, it was observed that the Bicubic Model is the best model that estimates precipitation in the study area. Figures 2.1 and 2.2 shows the contour maps of observed precipitation and estimated precipitation using modified Bicubic Model respectively. From these figures, the good symmetry can be noticed. Bicubic Model contains 16 parameters as shown in equation 2.1

$$P = a_1 + a_2Y + a_3X + a_4XY + a_5X^2 + a_6Y^2 + a_7X^2Y + a_8XY^2 + a_9X^2Y^2 + a_{10}X^3 + a_{11}Y^3$$
$$+ a_{12}X^3Y + a_{13}XY^3 + 3a_{14}X^3Y^3 + a_{15}X^3Y^2 + a_{16}X^2Y^3 \quad (2.1)$$

where

p is point precipitation, X and Y are local coordinates for a certain point while a's are the coefficients of the polynomial model.

None of the available studies have tackled the temporal variation of rainfall in the West Bank. In this study, the time variation of rainfall is studied. Nablus is taken as a case study to evaluate the temporal variation of the rainfall data.

Figure 2.1 Contour map of the observed mean precipitation in Northern West Bank (mm) {Ali, 1999}

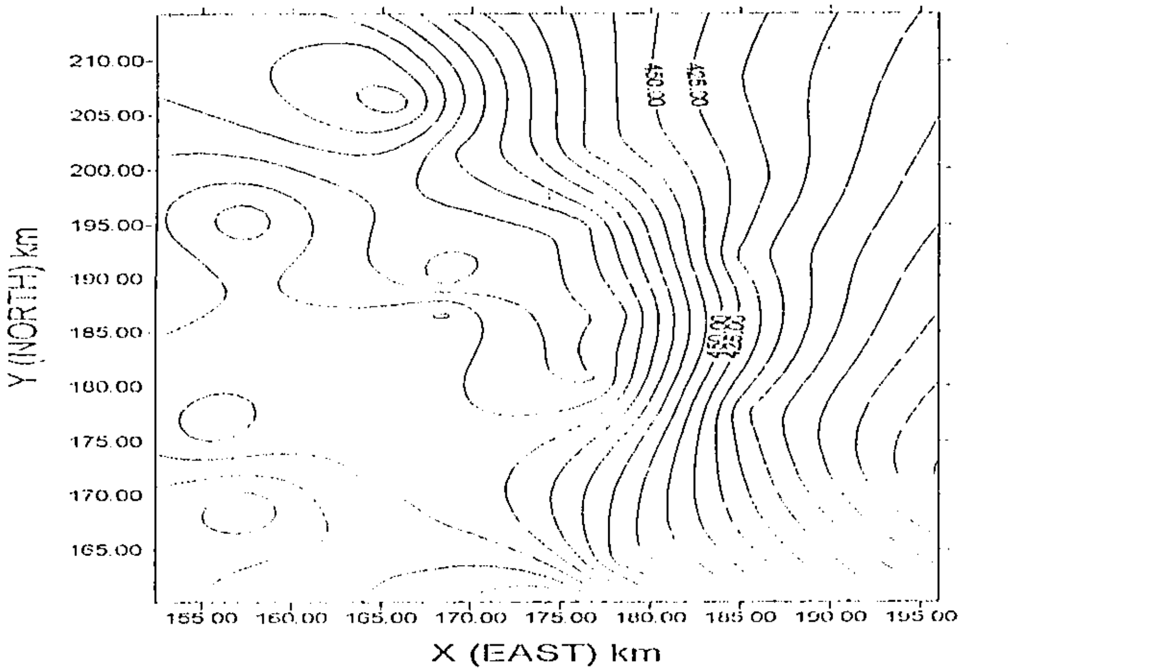
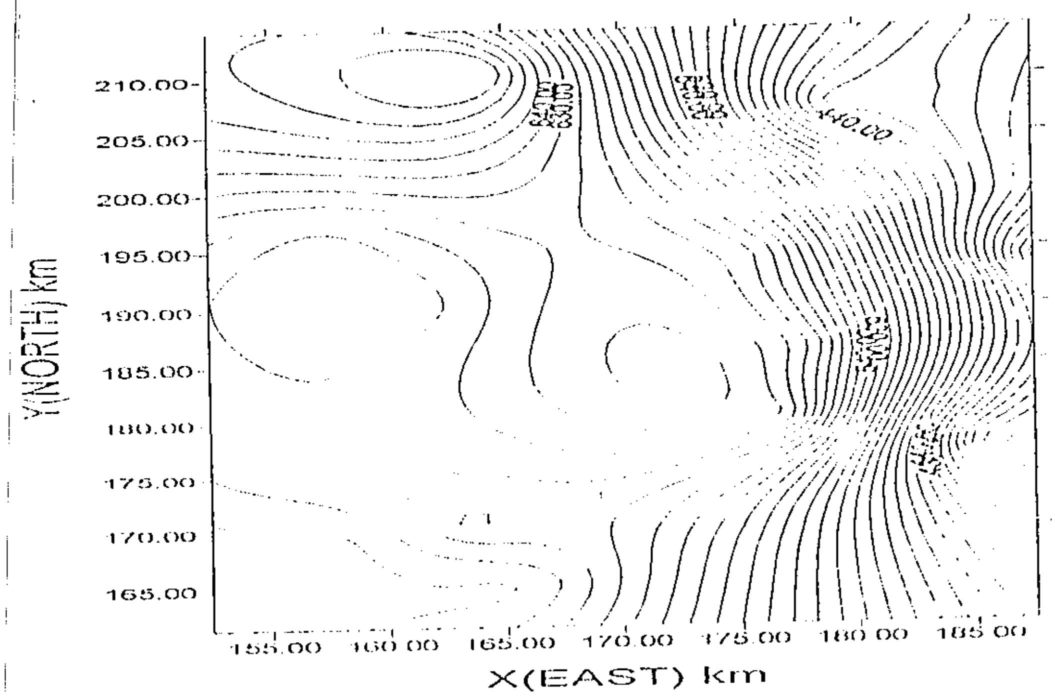


Figure 2.2 Contour map of the estimated mean precipitation in Northern West Bank (mm) {Ali, 1999}



2.2 Rainfall-Runoff process

2.2.1 Introduction

Watershed hydrologic models obviously represent the hydrologic cycle in various and appropriate ways. The laws of conservation of mass, energy and momentum are included in the set of the theoretical principles used to explain the hydrologic cycle. One or more of these principles, along with several empirical relationships, form the basis for most models of small watersheds. If we consider an arbitrary volume of soil with surface area A and depth d as shown in figure 2.3, we can write an equation expressing the integral of the conservation of mass equation from some arbitrary, t, as

water input = water output $\pm$ change of water storage

$$P = Qs + Qb + D + S + EA \tag{2.2}$$

Where

P: precipitation received on area A

Qs: net surface runoff

Qb: net surface outflow as unsaturated or saturated porous media flow

D: change in surface storage (depression and detention stored)

S: change in soil water storage

E: evaporation per unit area including evaporation from plants

All dimensions should be expressed in units of mass then are given in units in volume or volume per unit surface area.

Over short periods of time, the conservation of mass equation, although necessary, is not sufficient to accurately describe dynamic hydrologic phenomena such as surface runoff.

In overland flow, for example, the rain drops falling on the surface are accelerated by the following water, and gravitational and resistance forces accelerate the flow. A second equation based on the principles of conservation energy or momentum is required. For example, a linear reservoir has its storage S related to its outflow Q by

$$S = k * Q \tag{2.3}$$

where k is a constant having the dimensions of time . By continuity, the time rate of change storage ds/dt is equal to the difference between the input and the output

$$\frac{ds}{dt} = I(t) - Q(t) \tag{2.4}$$

The two equations, along with initial and boundary conditions, then describe the flow dynamics.

The conversion of rain to runoff has been studied by engineers to design hydraulic systems and by scientists to develop an understanding of the processes involved.

2.2.2 Factors Affecting Runoff

From the hydrologic point of view, the runoff from a drainage basin may be considered as a product in the hydrologic cycle, which is influenced by two major groups of factors: climatic factors and physiographic factors. Physiographic factors may be further classified into two kinds: basin characteristics and channel characteristics. Basin characteristics include such factors as size, shape, and slope of drainage area, permeability and capacity of groundwater formations, presence of lakes and swamps, and land use. Channel characteristics are related mostly to hydraulic properties of the channel which govern the movement of streamflows and determine channel storage capacity. Climatic factors include mainly the effects of various forms and types of precipitation, interception, evaporation, and transpiration, all of which exhibit seasonal variations in accordance with the climatic environment.

2.2.2.1 Basin Characteristics

Effectiveness of catchment systems to collect and convey water is related to topography. Area is the dominate feature affecting the quantity of runoff, whereas other topographic features affect the time distribution. Drainage area, usually expressed in square kilometers, is obtained by outlining and planimetering the boundary on a topographic map. When an area has a high infiltration rate, such as the Jerusalem, precipitation percolates to the water table and emerges as a base flow in a nearby stream. Mazen, 2000 found that the percentage of runoff to rainfall about 4%.
Channel slope also affects time of concentration. With other factors being constant, channel slope of the principal stream and tributaries has a direct effect on the peak flow. Velocity of the stream varies directly with the square root of slope, and the time of concentration varies inversely with the velocity. The slope parameter of the channel is computed by dividing the difference in stream elevation at 85 percent and 10 percent of the length, above the point of interest, by the length of channel between these two points.

The concentration of runoff from drainage basins of equal size is greatly influenced by the distribution of the area with respect to distribution from the outlet. A compact basin with short streams from all sub areas converging near the outlet has a high peak, whereas a basin of equal size with remote sub areas has a longer concentration time and lower peak.

2.2.2.2 Climatic Factors

The climatic factors that influence runoff are:

1. Nature of precipitation (rain, snow, sleet). The effect of a rainfall event is felt immediately but that of snow is delayed for more time.

2. Evapotranspiration and interception. These factors will be affected by geologic and topographic nature of the area, this includes temperature, solar radiation, wind, humidity, soil moisture and kinds of vegetation.
3. Rainfall intensity. Only if the rainfall intensity exceeds the infiltration loss will any surface runoff occur.
4. Duration of rainfall. The duration of the rainfall and its intensity are obviously the most important climatic factors.
5. Areal distribution of rainfall. The areal distribution of a rainfall event affects the shape of the hydrograph. High intensity rain near the outlet leads to rapidly rising and falling hydrograph with a sharp peak.
6. The distribution of rainfall with time. This parameter is significant on small catchments. On large catchments, the equalizing effect makes the hydrograph insensitive to rainfall distribution with time. In principle, a hyetograph which starts at a high intensity and decreases gradually to zero, produces a hydrograph with an upward convex rising limb. A rainfall excess distribution, which gradually increases from zero to a maximum and stops, leads to a hydrograph with an upward concave rising limb. On small catchments the rising limb is frequently followed by a flat peak (saturation segment). The recession limb of the hydrograph from a decreasing rainfall is concave upward, and convex for an increasing hyetograph.
7. Direction of storm movement. The direction of storm movement has the greatest effect on elongated catchments. It is obvious that the same amount of rain over the same period produces a much greater peak when the storm is moving down the valley. The rainfall from a storm moving up the valley becomes runoff long before the storm reaches the top of the catchment.

2.2.3 Procedures for Estimating Runoff

Procedures used in estimating runoff magnitude and frequency can be generally categorized as:

1- empirical approaches

2- statistical or probability methods

3- methods relating rainfall to runoff

For empirical approaches, many empirical equations have been developed to be used for the prediction of runoff. Many are applicable only to specific locations. Statistical analysis provide good results if sufficient records are available if no significant changes in stream regimen are experienced in the future. Some of the methods relating rainfall to runoff are the unit hydrograph method, the rational method and various simulation methods.

2.2.4 Hydrologic Models

Hydrologic models may be divided into two categories: physical models include scale models represent the system on a reduced scale models of a dam spillway; and analog models which use another physical system having properties similar to those of the prototype. Abstract models represent the system in mathematics form. The system operation is described by a set of equations linking the input and the output variables. These variables may be functions of space and time and they may also by probabilistic or random variables which do not have a fixed value at a particular point in space and time but instead are described by probability distributions.

Concepts such as infiltration, interflow and surface flow are shown in Fig. 2.4(a), applied to natural or rural catchment. The real processes are quite complex, and the concepts combine and gloss over many different mechanisms. Processes are frequently simplified to the forms shown in Fig. 2.4(b) and 2.4(c). The black box model in Fig. 2.4(b) focuses upon inputs and does not deal explicitly with physical workings of the transformation process. This process may be described by a relatively simple, intuitive model (such as the rational method) or a complex, statistical time-series procedure. In both cases the model can be calibrated by establishing a statistical regression relationship between the rainfall input and the runoff output.

The model shown in Fig. 2.4(c) has two parts. The *loss model* describes the removal or abstraction of "losses", those portions of the rainfall which are infiltrated or evaporated, and so are not directly converted to runoff. The remaining "rainfall excess" is then inputted to a routing model, which describes the attenuation of flow rates due to the delays and storage effects which occur as runoff is concentrated and transported from various parts of the catchment. In Fig. 2.4*(d), a physical process model* is shown, which is intended to represent real processes mathematically. This identifies and closely describes particular mechanisms, such as interception of rainfall on grass and leaves of trees.

To allow for aerial distribution of flows, catchments can be divided into sub-catchments arranged as cascade or series, or as branched network. Human developments cause significant modifications to catchment surfaces and flow paths. Impervious areas reduce infiltration, thus increasing surface runoff and depleting sub-surface flows.

Until the 18th century, drains and canals were designed by trial and error because there were insufficient information to derive methods to specify appropriate design flowrates. Progress came with the development of the Chezy channel friction formula in France in 1770s and the collection of the meteorological data in Europe in the early 19th century. In the 1840s the Mulvaneys developed the rational method for flow

Figure 2.3 An Arbitrary volume represents the conservative of mass

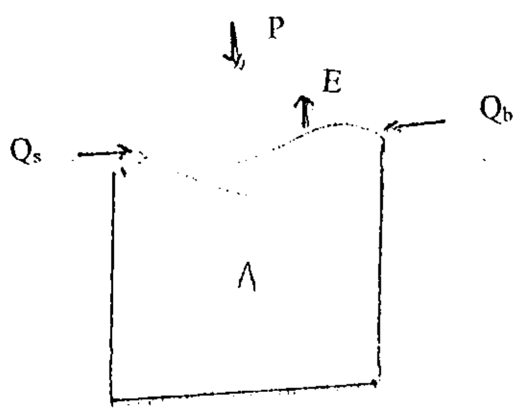
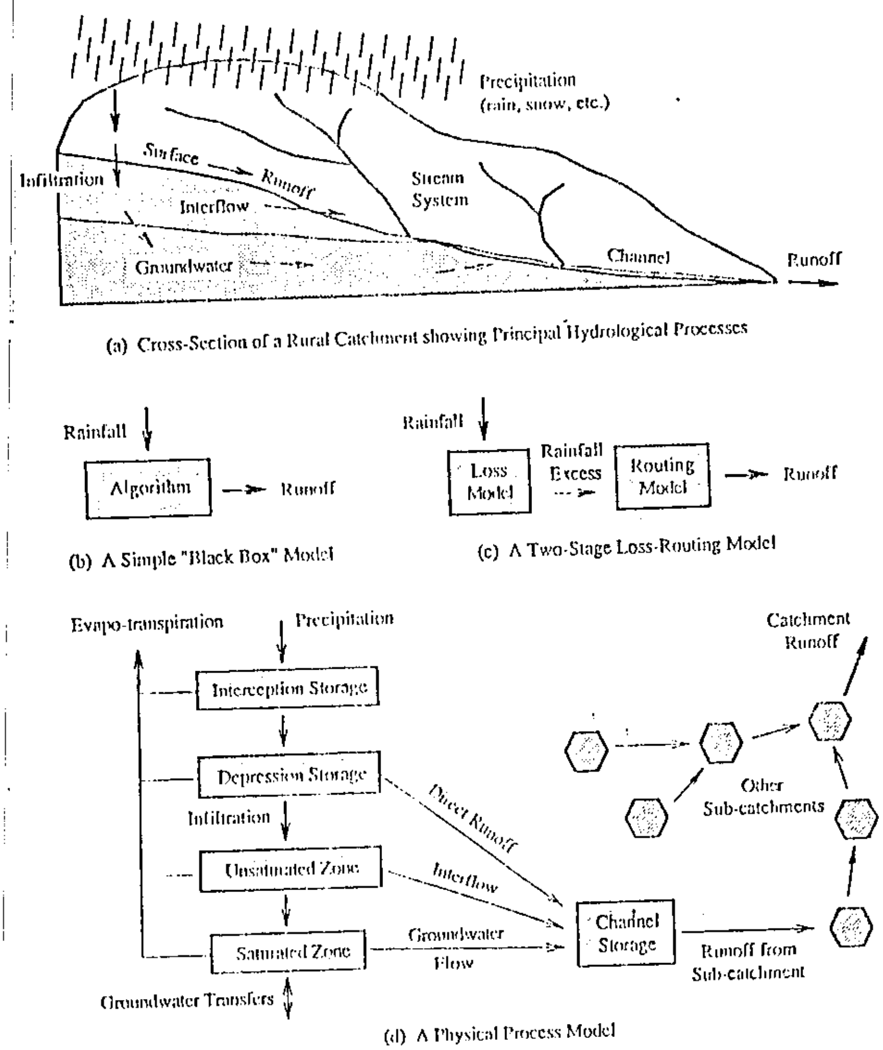


Figure 2.4 General rainfall – runoff processes of models



estimation, inventing a recording raingauge to measure intensities. From the design flowrates, a channel or pipe size could be established using hydraulic equations such as the Chezy or Manning formulae.

For design of sewers in the 19th century, several formulae (Journal of Hydraulic Research, volume 34- 1996) were devised to determine rates of stormwater runoff ingress. These all related flows to catchment area and had the general form:

$$Q = c.\ A^{b} \qquad (2.5)$$

where Q is the flowrate or discharge (m^3/s), A is the catchment area (ha or km^2), c is a factor dependent on land-use, slope or other characteristics, and b is a constant between 0.5 and 1.

Empirical formulas of this type were developed from observations at particular locations, and some were published as general procedures. Since rainfall intensities were the main input, the method was portable to any location where rainfall data was available. The method allowed for catchment effects when selecting the time of concentration and runoff coefficient. It employed the formula:

$$Q = \frac{C.\ I.\ A}{360} \qquad (2.6)$$

where Q is the calculated flowrate (m^3/s), C is the dimensionless runoff coefficient, I is the rainfall intensity (mm/h) corresponding to a particular duration and average recurrence interval (ARI), and A is the area of the catchment involved (ha).

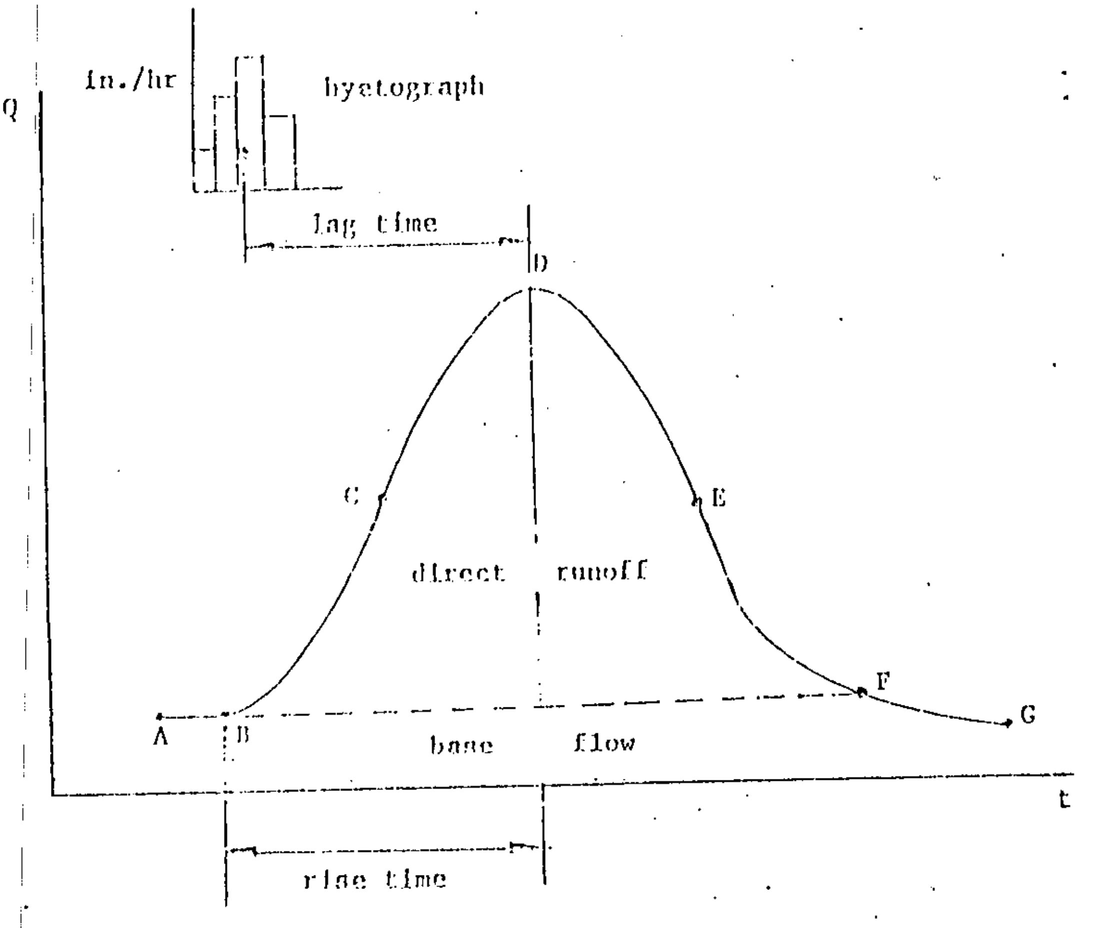
Associated with the rational method was the development of design rainfall data. As information accumulated, a strong relationship between intensity and storm duration became apparent. Talbot in the U. S. and others developed the intensity- duration-frequency (I-D-F) relationship which provided the basic probabilistic rainfall information for the rational method, and established a statistical basis for design, using the average recurrence interval or return period as the measure of frequency of failure.

Research on rainfall-runoff theory from the 1930s to the 1960s provided a strong foundation for the development of watershed hydrology. Notable advances included Sherman's unit hydrograph method (1932), synthetic unit hydrographs, Horton's infiltration theory (1933), the development of time- area procedures, and the routing models.

2.2.5 Hydrograph Analysis and Unit Hydrograph:

Most practical techniques of forecasting runoff from rainfall are based on either correlation techniques between observed volumes of runoff and rainfall or on the unit hydrograph technique. The hydrograph method depends on an observed response function. It is therefore not a tool that will aid in the understanding and development of the physics involved. The method relies on the separation of the hydrograph into at least two components and this is at its best an empirical separation. It is indeed questionable whether there are any distinct components. The entire runoff may just be the sum of flows that reach the stream through a large number of different paths. Nevertheless the hydrograph technique has been one of the principal tools in hydrology and is likely to continue to give useful service, provided its limitations are understood. Figure 2.5 shows the components of hydrograph. The unit hydrograph is the unit pulse response function of a linear hydrologic system. First proposed by Sherman (1932), the unit hydrograph of a watershed is defined as a direct runoff hydrograph (DRH) resulting from 1 in or 1 cm of excess rainfall generated uniformly over the drainage area at a constant rate for an effective duration. The unit hydrograph procedure can be applied to data from small watersheds. However, the

Figure 2.5 The hydrograph components



AB = approach limb

BC = rising limb

CE = crest segment

EF = recession limb

FG = groundwater depletion

C = inflection point related to basin shape and hyetograph

D = peak – usually occurs after rainfall has ended but not necessarily

E = inflection point where surface flow into the channel system stop

F = point where surface runoff, interflow and channel storage effects end relatively small time units required (sometimes as small as 2 or 3 min) make the derivation of unit hydrographs a difficult task, and as a result, a synthetic hydrograph approach is more often used.

2.2.6 Previous Work on Runoff in West Bank

In Palestine, two studies have been traced that present some estimates for runoff which are Rofe and Raffety (1965) and special gauging network was designed and illustrated and data for ten wadis was recorded for the year 1962/63 only. The results of the study of Roff and Raffety show that the overall percentage of the runoff - rainfall was 0.2 % and Rofe and Raffety concluded that runoff was negligible in NWB. After the occupation of the West Bank in 1967, the runoff has continued to be measured by the Israelis from many gauging stations located outside the boundaries of the West bank. There are some stations located near the Green Line (the border between the occupied Palestinian Territories in 1967 and 1948) which may provide reliable historic records on surface runoff.

The second study was the study of Palestinian Hydrology Group "analysis of secondary source rainfall data from the northern west bank". The results of PHG,1995 gives the relationship between rainfall and runoff in Hadera catchment was found that the ratio of runoff to rainfall ranges from 0.1 % to 16.2 % with an average of 4.5 % for the period of 1982/83 – 1991/92. PHG, 1997 shows that for example surface runoff was found to be 0.8 percent of average rainfall (433) in 1985 and 0.4 percent of average rainfall (485) in 1986, as recorded at Alexander flow gauging station (grid ref. 141.95/197.95), which has a catchment area of 492 km^2.

3. Analysis of Rainfall Intensities for Nablus Area

3.1 precipitation

3.1.1 Introduction

The input to most hydrologic models is precipitation, and rain and snow are the forms of precipitation of primary interest in the hydrologic modeling of small watersheds. The reasons for precipitation modeling include estimating annual and seasonal water yields, engineering design based on predicting flood peaks, erosion, sedimentation and chemical transport, and estimating crop yields from dry and irrigated croplands, and from range and pasture lands. Precipitation can be in liquid form, including rain and dew, and frozen solid form including snow, hail, and sleet. Precipitation is measured in terms of depth of water that would accumulate on a plane, (mm or in.) or its time rate, called intensity (mm/hr or in./hr). The precipitation on earth varies greatly with time and space.

3.1.2 Types of precipitation

Precipitation is caused by water vapor condensing on small foreign particles in the air called hydroscopic nuclei. The condensation is caused by a rapid temperature decrease generated when the air ascends from the surface region to the atmosphere. Precipitation can be classified according to the factors responsible for this rising of the air as follows:

1. Convective precipitation is caused by the natural local lifting of warmer, lighter air in colder denser surrounding resulting in dynamic cooling and condensation. The temperature difference may result from local heating at the surface or cooling in the top air layers. This type of precipitation is usually associated with high intensity, short duration storms or thunderstorms over relatively small areas. In Palestine, this may be occurred in the Palestinian coast and Tulkarm.

2. Cyclonic precipitation results from the movement of the air masses converging into a low pressure area. Most cyclonic precipitation is of the frontal type that generates significant quantities of precipitation over a wide area for a relatively long duration. This may occurred in the north of Palestine.

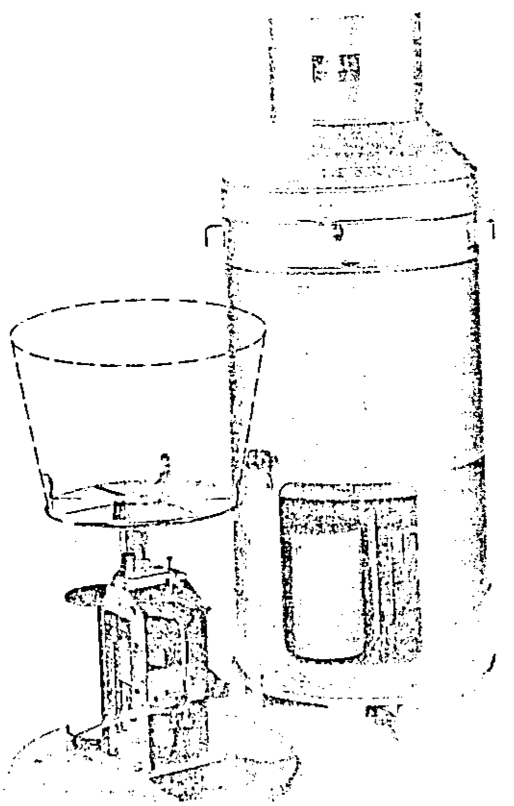
3. Orographic precipitation is due to topographic conditions resulting from the mechanical lifting of the air over barriers such as mountains. This type of precipitation is quite evident on the western slopes of the serial mountains of Palestine between Nablus and Jerusalem.

3.2.2 Measurement of Precipitation

Precipitation is measured in both nonrecording and recording gages as water depth with respect to time. Standard precipitation measurement gages vary from nation to nation and from agency to agency. In the United States the most widely used rain gage is the National Weather Service standard gage which has a receiver of 203 mm (8 in.) diameter. Rainfall is measured to the nearest 0.01 in. (0.25 mm). Rainfall less than 0.01 in. are marked as "trace" on the record. There are also storage gages that measure the cumulative depth. Special requirements exist for setting up these gages. These gages may require manual reading, or they may record automatically. Three common types of recording gages are the tipping bucket gages, weighing gages and float gages. Some of the recording gages can transmit digitized signals for direct magnetic tape recording. Figure 3.1 shows a weighing type recording precipitation gage used in Nablus meteorological station. Precipitation is collected in the cylinder on top and falls into bucket resting on a scale platform. As the weight of the precipitation increases, the pen on the arm projecting from the weighing mechanism moves across the chart from bottom to top. Snow measurements are reported as depth of snow and as water equivalent. Approximately 250 mm fresh snow is equivalent to 25 mm of rainfall. In Palestine, snow storms are rare because of the relatively warm climate prevailing in climate the Middle East. The West Bank has a Mediterranean type. Various other techniques have also been developed for precipitation measurement, including using radar and other high frequency waves, and satellites. However, these

techniques have their respective drawbacks and are used only in special cases.

Figure 3.1: A weighing type recording precipitation



3.2 Intensity-Duration-Frequency curves

3.2.1 Introduction:

In many hydrologic design projects and in many urban drainage design, one of the main considered steps is the determination of the rainfall events to be used. The most common and reliable approach is to use a design storm or event that involves a relation between rainfall intensity, duration and the frequency or return period that is appropriate for the facility and site location. In many cases, standard intensity-duration-frequency (IDF) curves are available for the site and there is not need to perform this analysis. The information for such curves is presented as a graph with duration plotted on the horizontal axis, intensity on the vertical axis and a series of curves, one for each design return period.

The intensity is the time rate of precipitation, that is, depth per unit time (mm/h or in/h). It can be either the instantaneous intensity or the average intensity over the duration of the rainfall.

The average intensity is commonly used and can be expressed as

$$I = \frac{p}{t_d} \tag{3.1}$$

Where p is the rainfall depth (mm or in) and t_d is the duration, usually expressed in terms of return period T, which is the average length of time between precipitation events that equal or exceed the design magnitude.

Because of Israeli occupation, there is lack of accurate for rainfall data. Thus, it is important to develop IDF curves for West Bank depending on the available data.

3.2.2 Intensity-Duration-Frequency curves for Nablus area

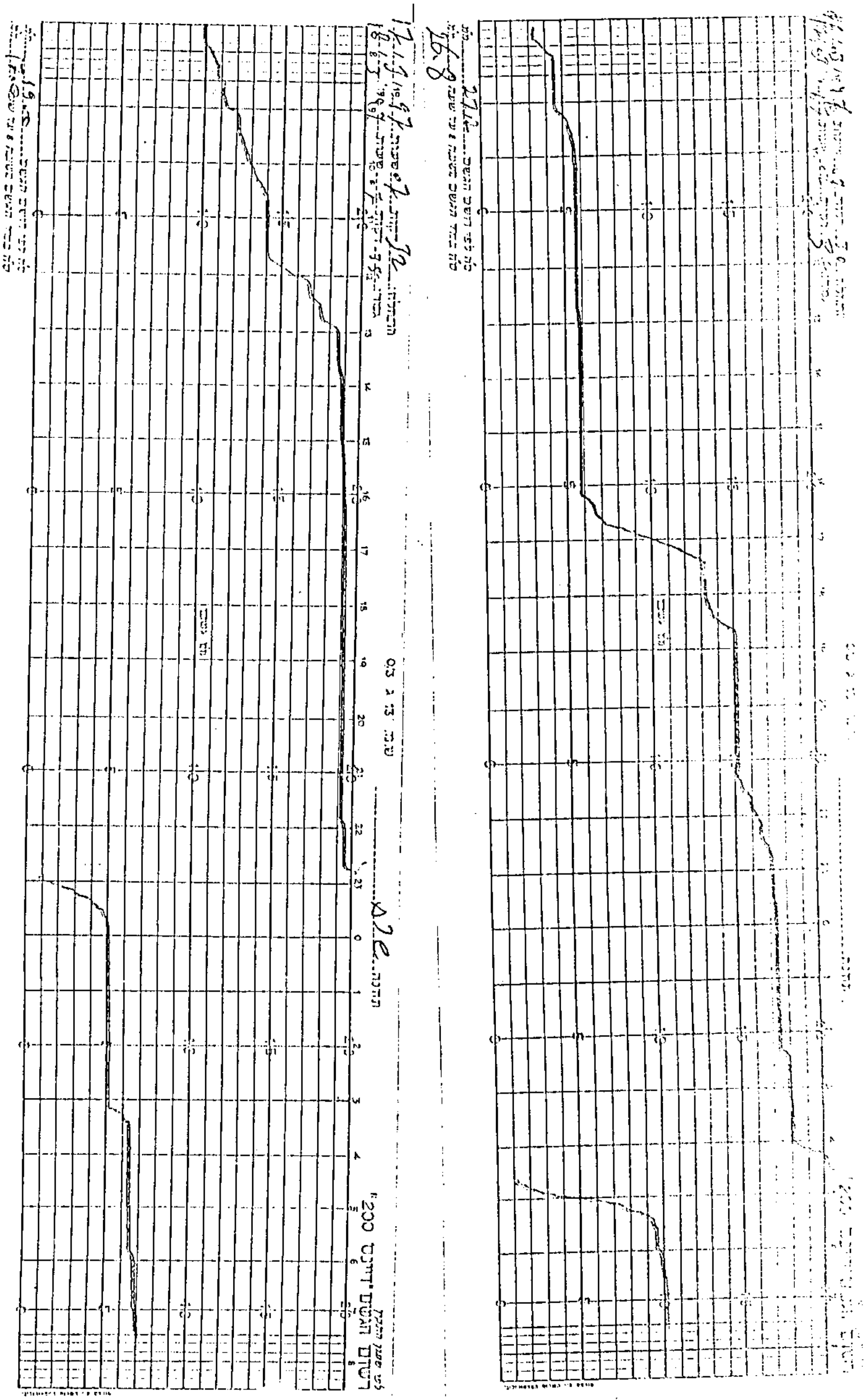
The aim of the analysis of the rainfall intensities for Nablus area is to estimate the rainfall intensity-duration-frequency curves. To develop IDF curves, records of the rainfall recorded by meteorological station must be analyzed. The only available rainfall records of the meteorological station found in Nablus are daily records, except for the winter season of the years 96-97 and 97-98 where there are records of an autographic rain recorder. For these records, 10 minutes rainfall duration can be computed. The records of this autographic rain recorder for the years before 1997 were send to the Israeli meteorological office in Beet-Dajan, and it was not possible to have them.

The autographic recorder gives an output of records on papers that have 24 division, where each division represents one hour duration. In the two sides of this paper the one hour division is divided into six parts, which indicate the autographic can give 10-min. records. Figure 3.2 shows an example of the output of the records on the used paper.

Several rainfall events were taken. Besides the 10 min rainfall, the 30, 60, and 120 min. rainfall was calculated. In each event the maximum magnitude of rainfall for each previous time was found and then the maximum rainfall was determined. The maximum 10, 30, 60, and 120 minutes rainfall of the two winter seasons of the years of 1996-97 and 1997-98 were determined and analyzed. The maximum values of the two years were found and thus enables the construction of the IDE curve for the available 2- years records. Figure 3.3 shows the IDF curve found from the rainfall data of the years 1996-1997 and 1997-1998.

In order to estimate the IDF curves for a specific return periods, the intensities occurring in the year 1996-97 and 1997-98 are to be analyzed based on the analysis of

Figure 3.2 Sample output of the records of rainfall



the annual rainfall of the years 1954-98. To estimate the intensity duration relationship from the available records (data of 1996-1997 and 1997-1998), it is assumed that the return period of the maximum rainfall intensity is the same for the return period of rainfall of the year. The annual rainfalls were arranged in descending order. As shown in Table 3.1, the return period for each each rainfall was calculated using the relation

$$Tr = \frac{n}{m+1} \tag{3.2}$$

where

Tr: return period

m: rank of event

n: number of events

Figure 3.4 shows the return period with rainfall. The best fit between those points was done in this figure using the Excel Microsoft program. The analysis of the annual rainfall data during the period 1954-1998 has resulted a 9 – year return period for the 870 mm that has occured in 1996-97 and 4 return period for the 660 mm rainfall that occurred in 1997-98. The rainfall depths for the different durations of the rainfall event of 1996-97 and 1997-98 can be calculated using the autographic charts available in Nablus meteorological station as shown in Table 3.2. In order to estimate the rainfall intensities of the desired return period, the average values of the intensities for the year 1996-97 and 1997-98 are to be multiplied by a factor F that is to be computed as follows :

1. The annual rainfall for the desired return period can be found from figure 3.4.
2. The factor F1 can be found by dividing 870 mm rainfall of the year 1996-97 to the rainfall according to the specific return period.

Table 3.1 Annual rainfall and its return period

	Annual rainfall	Rank	Return period
	1387.6	1	45.00
	1123.5	2	22.50
	944.3	3	15.00
	895.6	4	11.25
	867.7	5	9.00
	829.8	6	7.50
	818.2	7	6.43
	799.6	8	5.62
	798.9	9	5.00
	774	10	4.50
	763.5	11	4.09
	759	12	3.75
	757.1	13	3.46
	706.9	14	3.21
	702.2	15	3.00
	667	16	2.81
	658	17	2.65
	656	18	2.50
	643.7	19	2.37
	619.5	20	2.25
	606.2	21	2.14
	603	22	2.05
	602.7	23	1.95
	588.7	24	1.88
	580.5	25	1.80
	574	26	1.73
	566.6	27	1.67
	557.7	28	1.60
	556.4	29	1.55
	528.7	30	1.50
	526.8	31	1.45
	525.4	32	1.40
	516.5	33	1.36
	509.2	34	1.32
	508.7	35	1.28
	506.6	36	1.25
	504.9	37	1.22
	504.6	38	1.18
	470	39	1.15
	468.3	40	1.12
	445.3	41	1.10
	405.6	42	1.07
	359.2	43	1.05
	349.2	44	1.02

Fig 3.3 Intensity-Duration-Frequency curve of the available rainfall intensities of Nablus district for the years 1996-1998

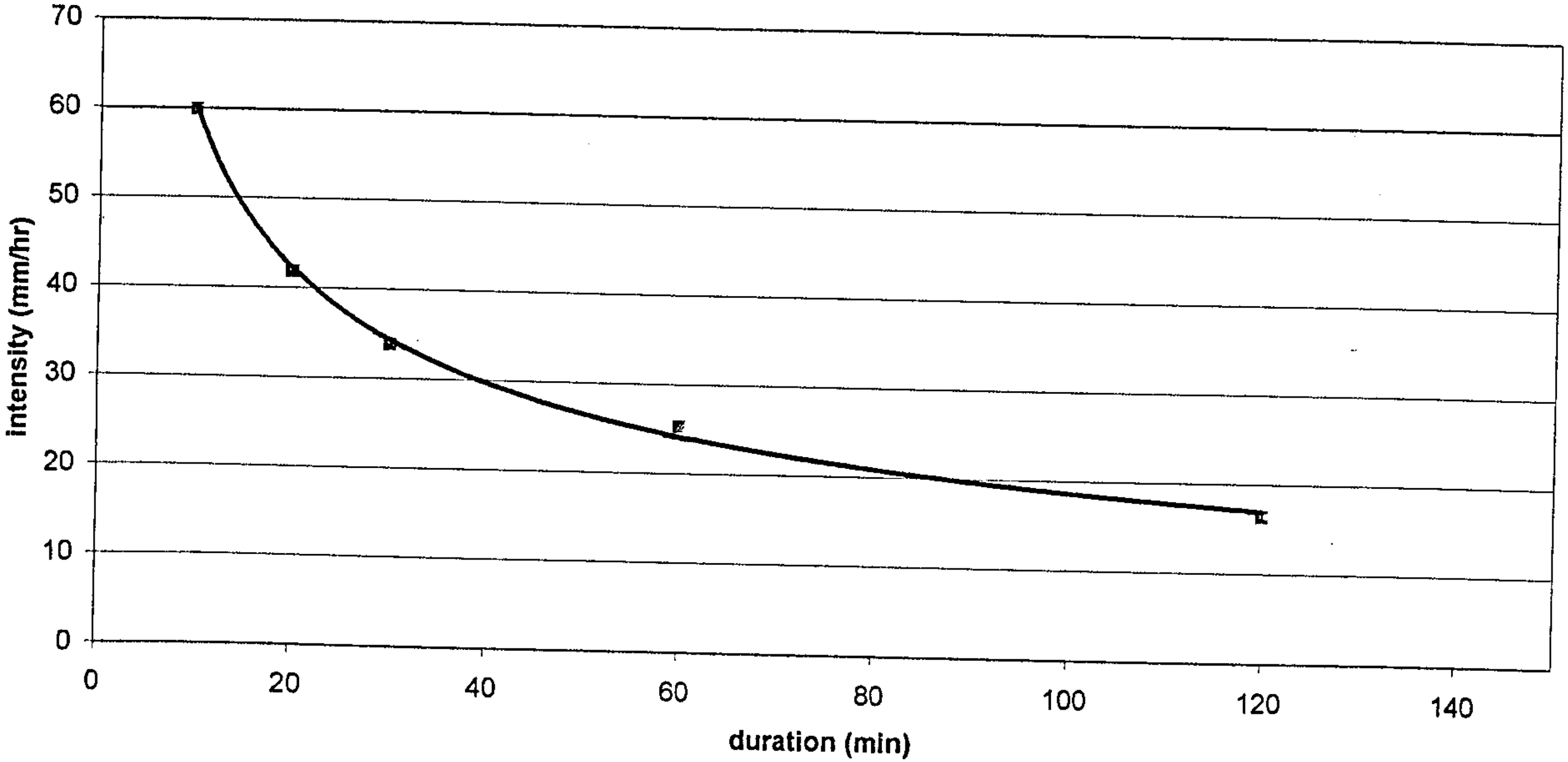
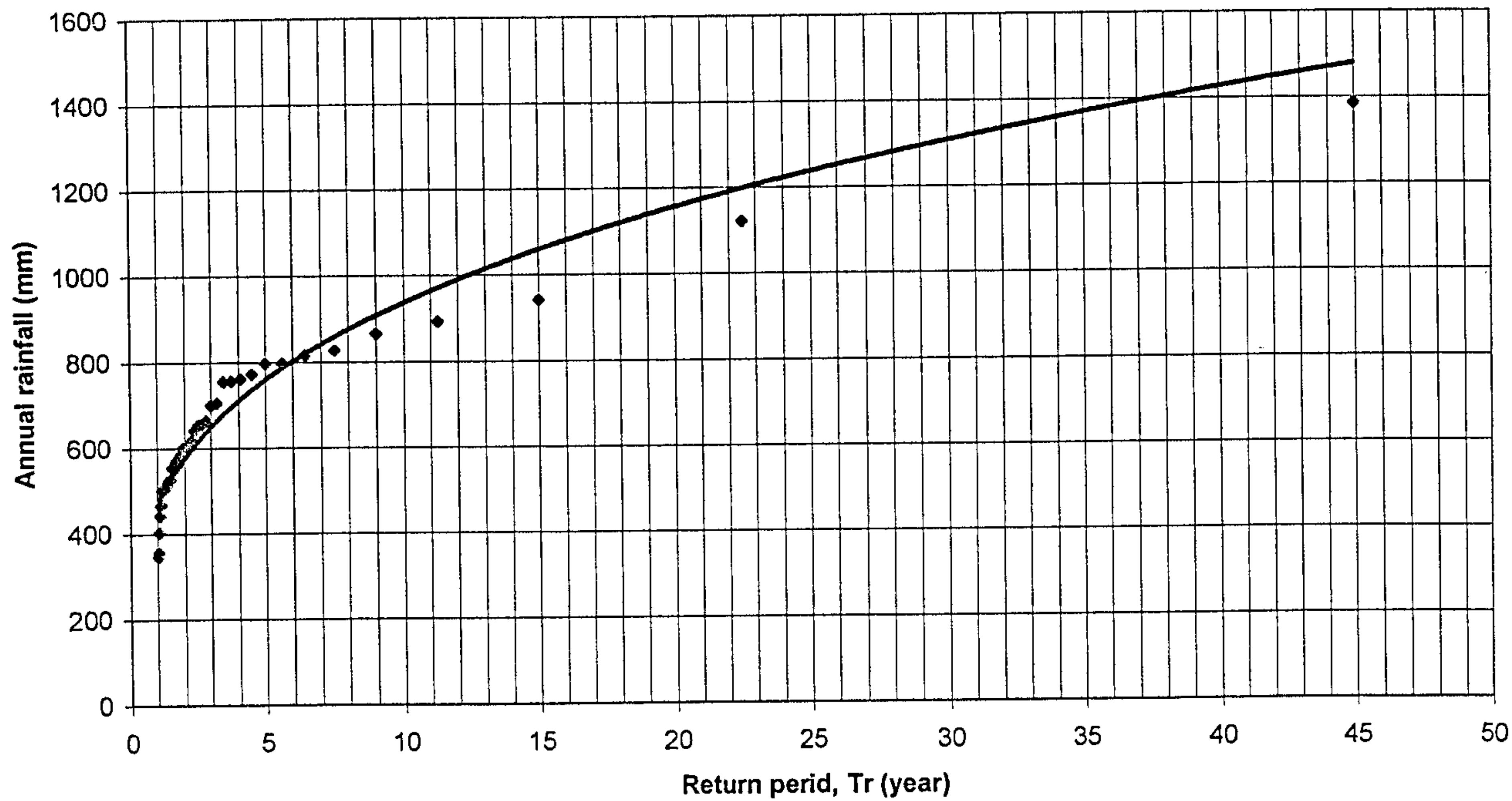


Fig 3.4 The return period vs. rainfall for Nblus district



3. The factor F2 can be found by dividing 660 rainfall of the year 1997-98 to the Rainfall according to the specific return period.
4. The average factor F is the mean between F1 and F2 as shown in table 3.3.
5. The average rainfall intensities for the specific durations of the year 1996-97 and 1997-98 were multiplied by the factor in order to take rainfall intensities for different durations.

Table 3.2 rainfall depths of different durations for the two years 1996-98

Duration time, min	Rainfall depth (mm) for 1996-97	Rainfall depth (mm) for 1997-98	Average rainfall depth (mm)
10	6	10	8
30	7	17	12
60	11.8	25.4	18.6
120	12	33	22.5

Table 3.3 The average factor F for estimating rainfall intensities for different return periods.

Return period	F1	F2	F
2	0.63	0.83	0.73
5	0.86	1.13	0.99
10	1.08	1.42	1.25
20	1.32	1.74	1.53
40	1.64	2.16	1.90

From Table 3.3, it is noted that F1 is larger than F2. This refers to the rainfall of that year which is larger.

Figures 3.5, 3.6, and 3.7 plot the resulting intensities for different durations for the Required return period. These figures are for the rainfall of 1996-1997, 1997-1998 and the average of these rainfalls respectively.

The resulted rainfall – intensity values are compared with the study of Nael, 1996 who gives a table for the rainfall intensities for Nablus in his M.Sc studies at the IHE in the Netherlands. Nael said that this table was taken from the meteorological station at Nablus and analyzed by the Israeli Meteorological Service Department. Therefore they are similar to those taken from the available Israeli data as in figure 3.8 below. Table 3.4 Shows the probability of occurrence of extreme rainfalls in L/sxha as taken from Nael study. The resulted IDF are also compared with figure 3.8 found by the Israeli calculations for the rainfall of 1970-1993. From the comparing, it is noted that for small return periods, there is a slight difference between the intensity values. Table 3.5 shows the comparison between the estimated intensities and those from Israeli calculations and Nael study for only two return periods 2-year and 20-year. The difference between the estimated intensities in this study and those given by Nael Ahmad and Israeli calculations may be referred to the volume of studied data, as the data was available only for two years. There is also an influence for the assumption that the return period of the maximum rainfall intensities is the same for the return period of rainfall of that year. It is noted that the results in figure 3.6 that refers to data 1997 – 1998 is more accurate according to other studies. This may refer to the rainfall of that year which is around the average and its return period is 3.

Fig-3.5 The estimated I-D-F curves depending on the rainfall of 1996-1997 for Nablus district

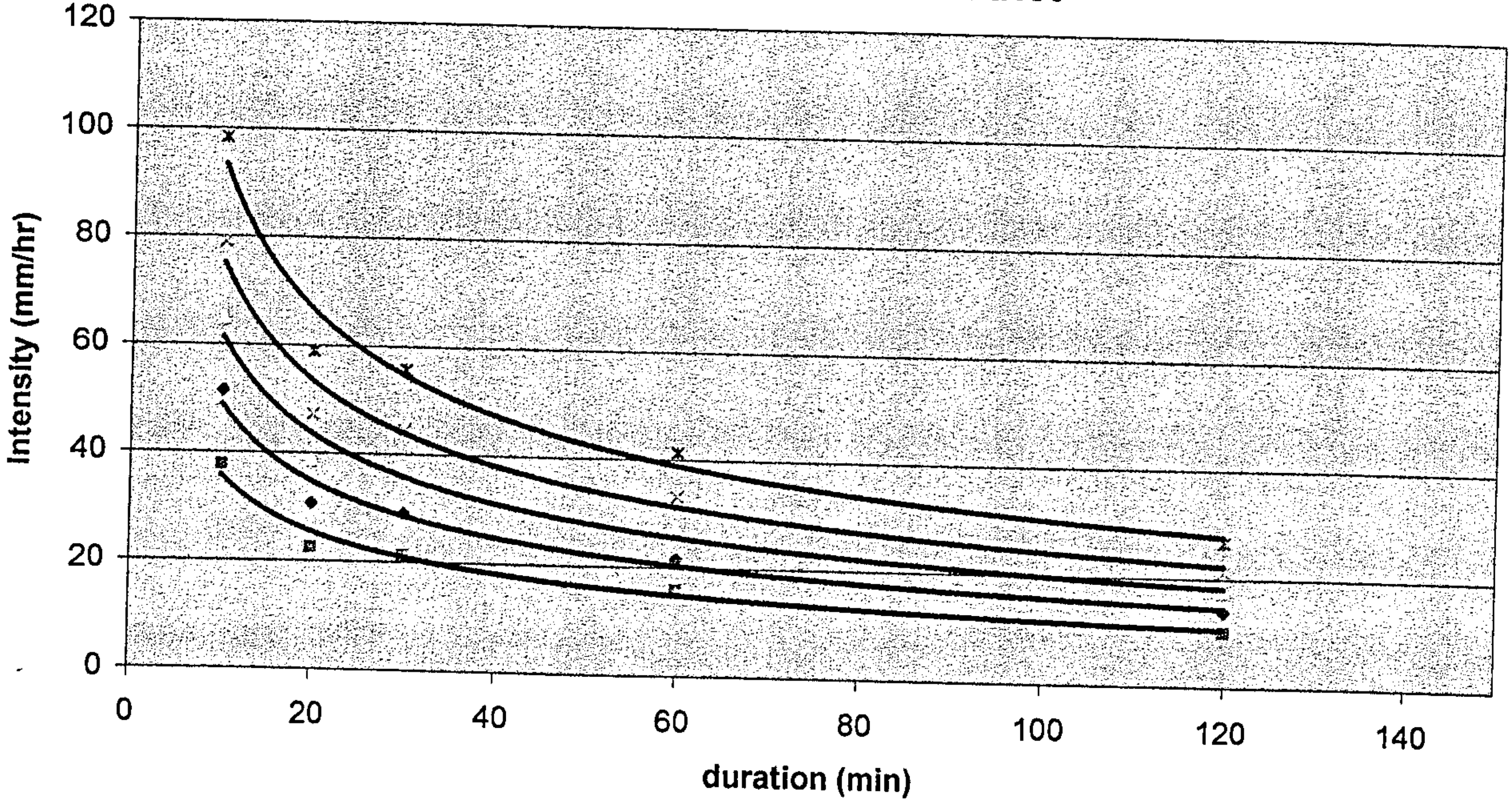


Fig 3.6 The estimated I-D-F curves depending on the rainfall of Nablus for the period 1997-1998

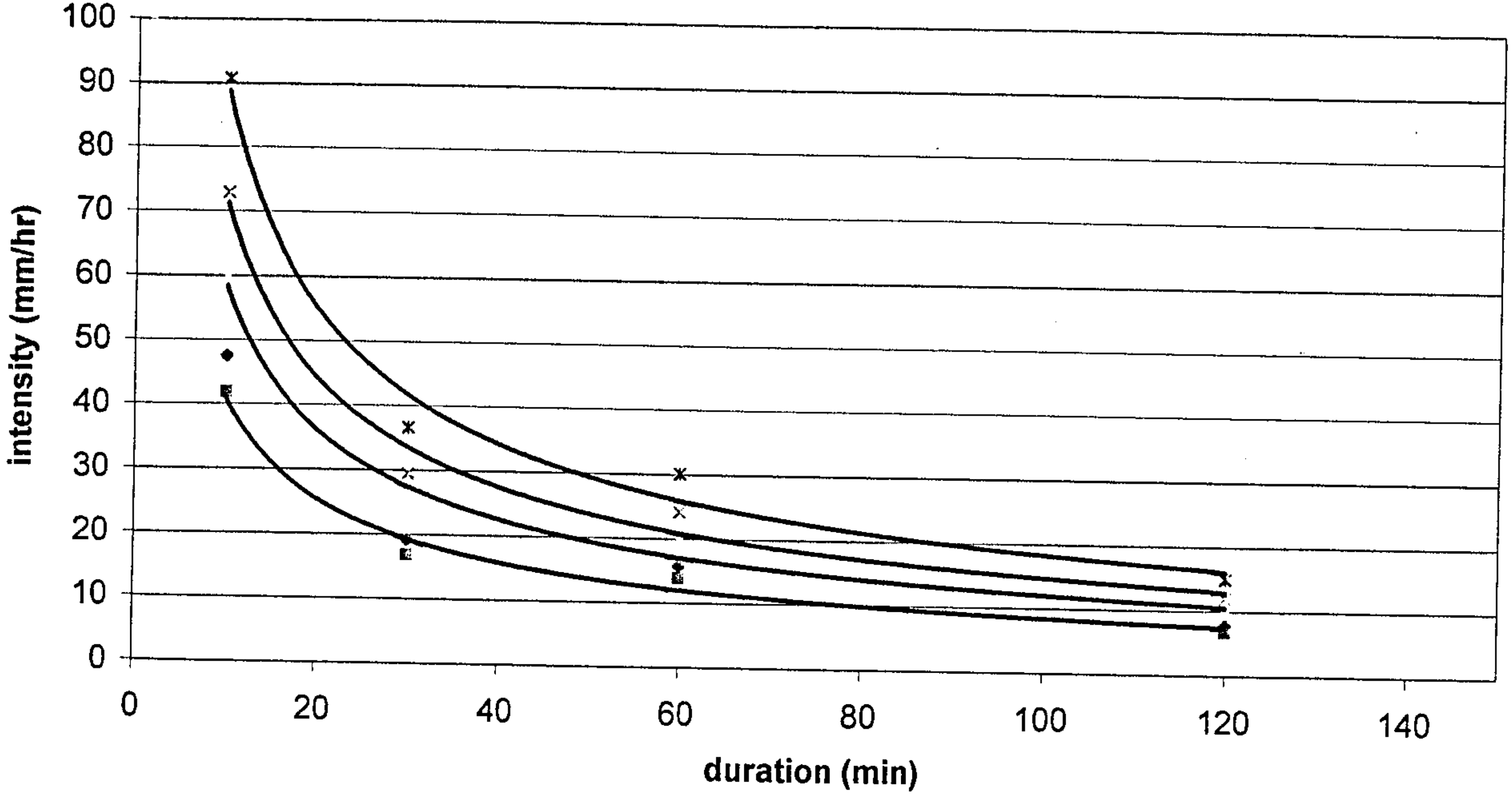


Fig 3.7 The estimated I-D-F curve depending on the average of the rainfall of Nablus of 1996-1998

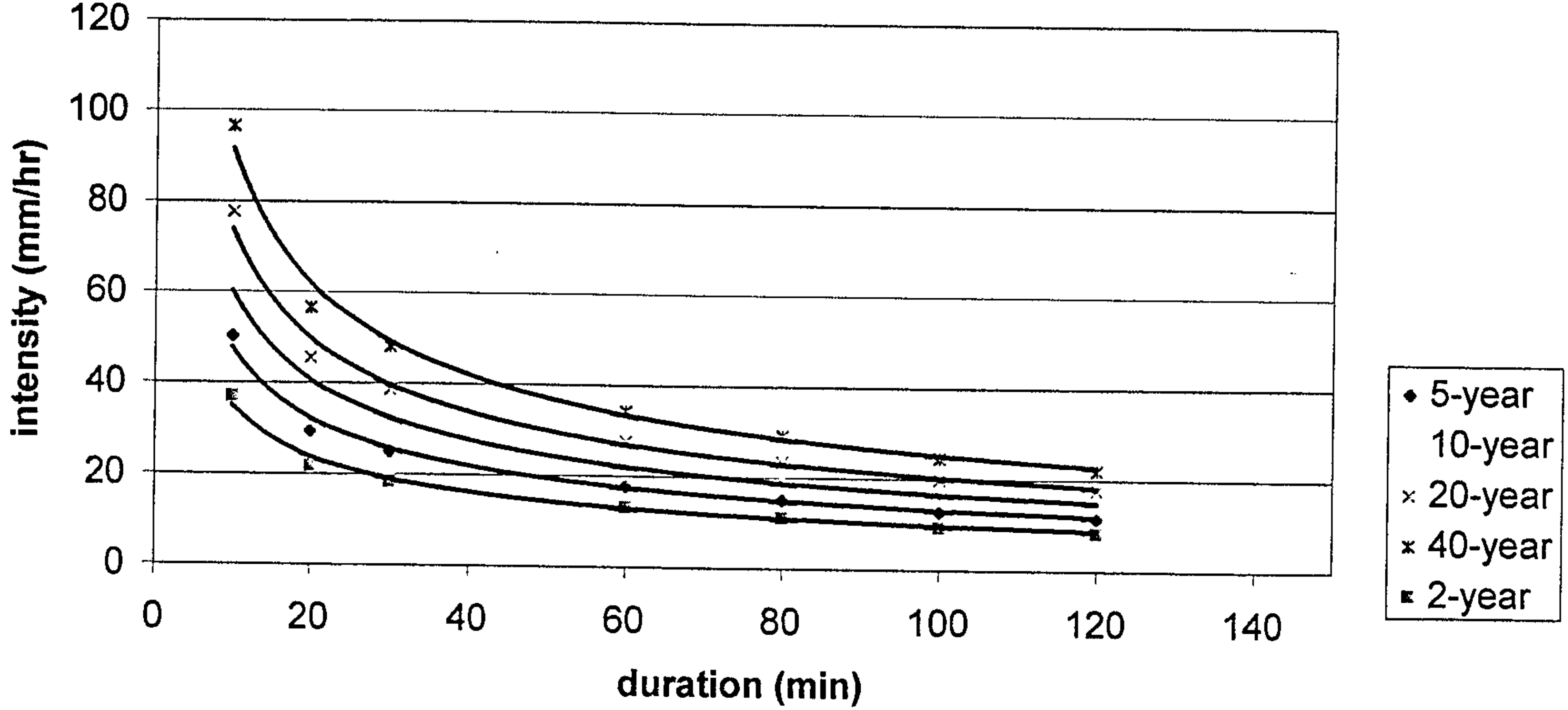


Fig 3.8 Intensity-Duration-Frequency curves for Nablus rainfall, Israeli calculations

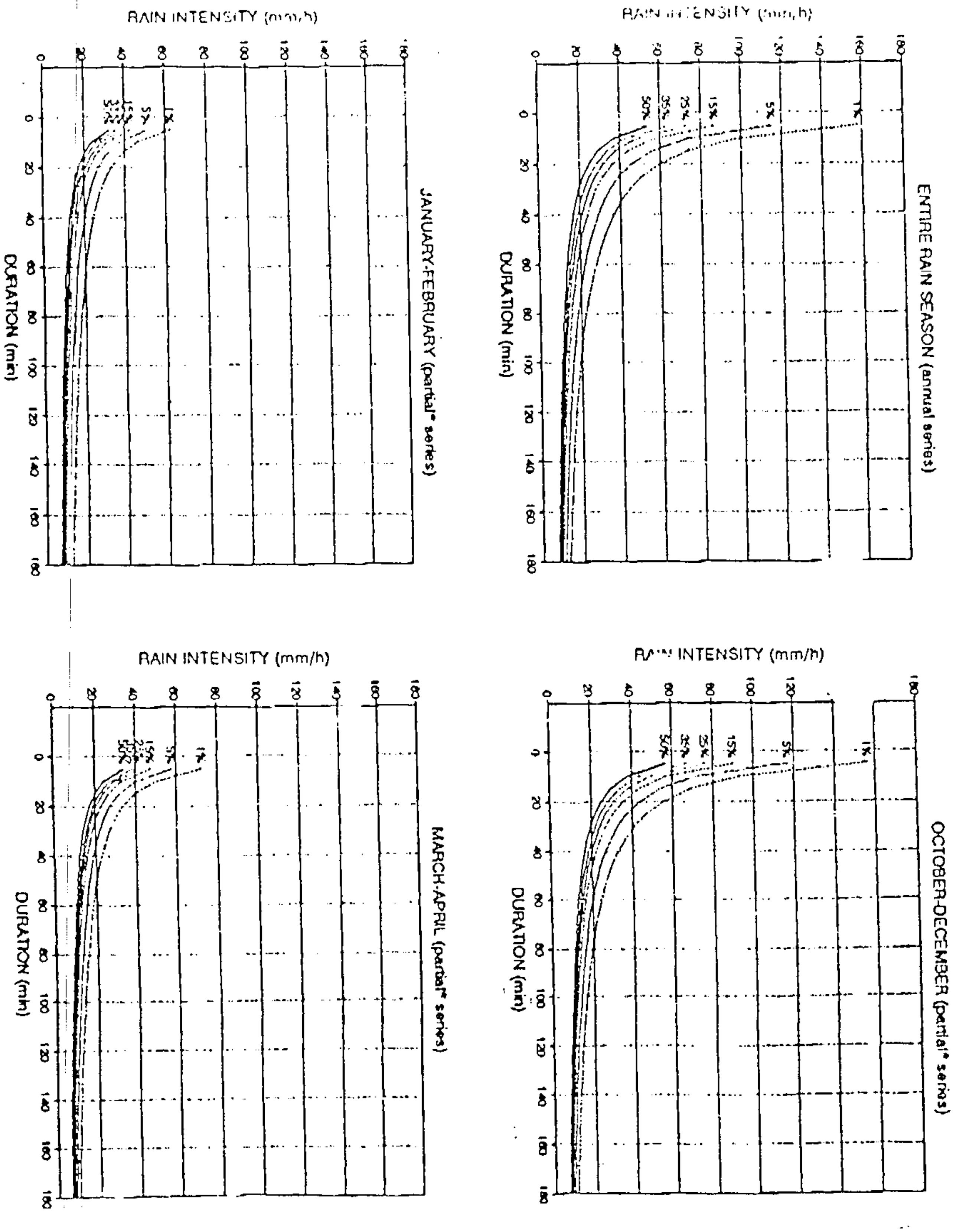


Table 3. 4: Rainfall intensity in Nablus (Nael, 1996)

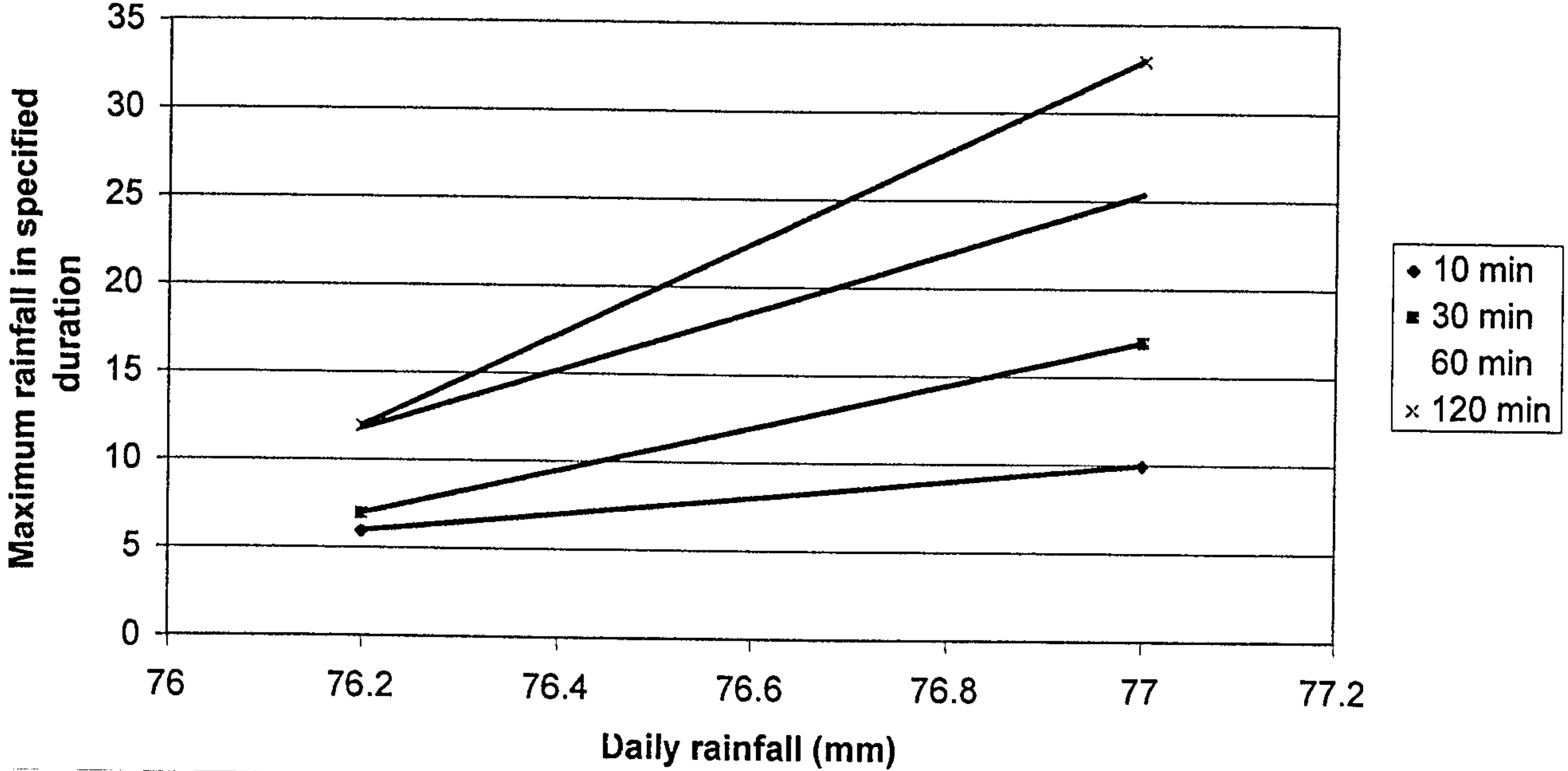
Duration of rainfall (minutes)	Rainfall intensity in L/sxha for an occurrence of:		
	2	4	20
5	139	167	211
10	104	124	160
15	83	100	128
30	60	77	92
60	41	49	66
120	28	34	47

Table 3.5 The rainfall intensities for this study, Nael study and Israeli calculations

Duration of rainfall (min)	Rainfall intensities (mm/hr) for the occurrence of					
	2-year			20-year		
	This study	Nael study	Israeli calculations	This study	Nael study	Israeli calculations
10	35	37.4	37	72.5	57.6	60
20	23	29.8	26	50	46	41
30	20	21.6	21.5	40	33	33
60	13	14.7	12.5	27	23.7	20
120	9.5	10	10	18	16.9	16

The maximum daily rainfall of that two years was determined. There was an attempt to find a relation between the maximum daily rainfall of the two years of 2-year return period. The maximum daily rainfall of the two years and the concerned rainfall for the specific duration which 10, 30, 60, and 120 min were determined. The max. daily rainfall was drawn vs. the 10, 30, 60, and 120 min. max. rainfall of the years 96-97 and 97-98. As shown in figure 3.9. A straight line for each duration was drawn. It is found that the slopes of the lines increased as the duration increased as a trend.

Fig 3.9 The maximum daily rainfall vs. maximum rainfall for different durations for the rainfall of 1996-1998



3.3 Frequency Analysis of the Nablus Rainfall Data:

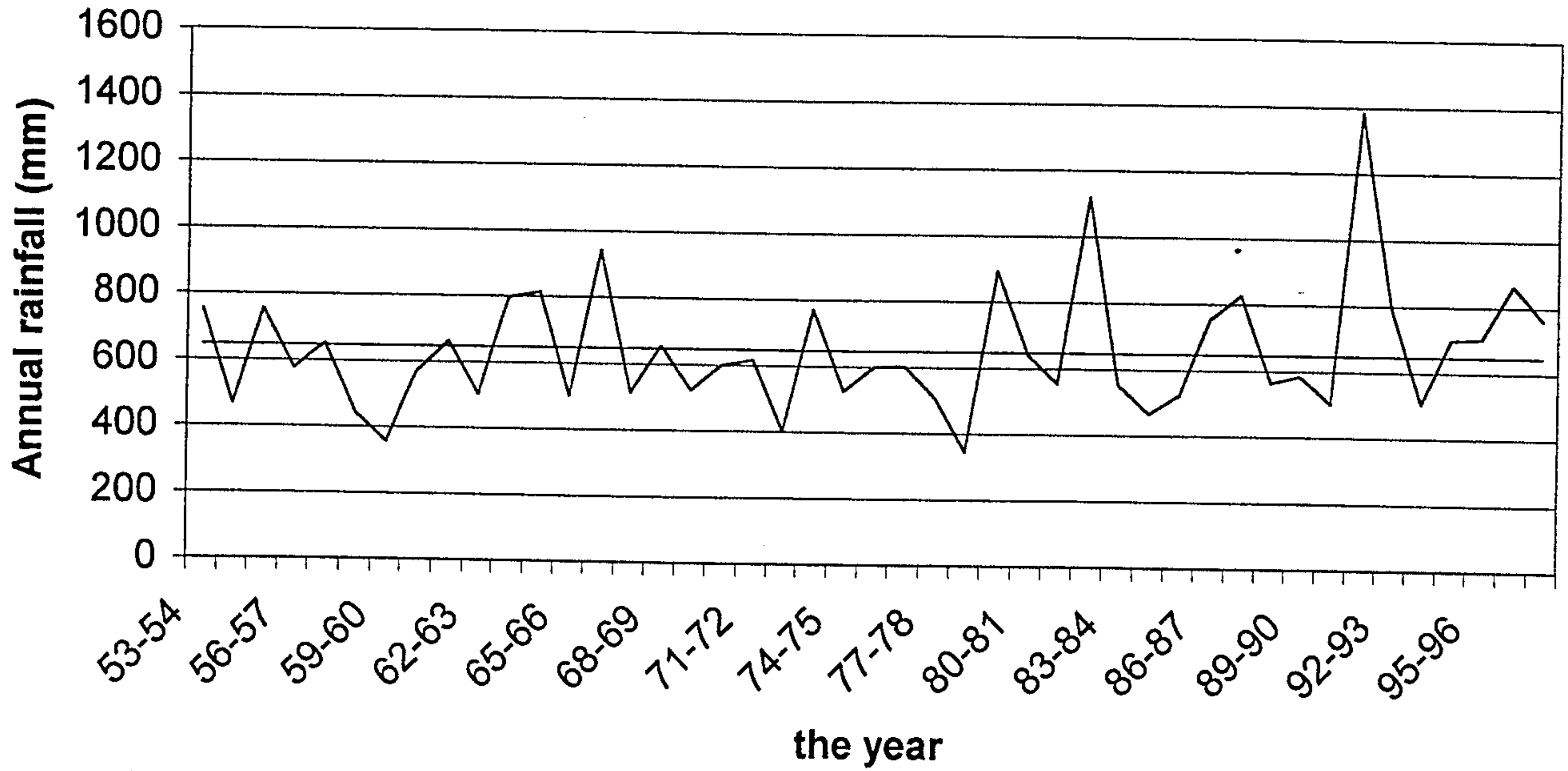
3.3.1 Introduction:

Precipitation is the first source of water. Rainstorms vary greatly in space and time. They can be represented by isohetal maps; an isohyet is a contour of constant rainfall. Isohyetal maps are prepared by interpolating rainfall data recorded at gagged points. The understanding of variations in the amount, timing and location of precipitation is the main factor in study and hydrologic design projects. From the records of an autographic rain records, set of rainfall depths for successive increments in time can be computed. From the available data which is the two years, 1996-1998, the maximum rainfall values for the 10, 30, 60 and 120 min. are 10,17, 25.4 and 33 mm respectively. The maximum daily rainfall from rainfall data of 1954-1998 is 114.8 mm (28, November 1979) and the max. monthly are 472.2 mm (December) and the max. annual is 1387.6 mm (1991 – 1992).

3.3.2. Annual Rainfall Analysis:

The annual rainfall totals for the considered years were determined. First the daily rainfall were copied from the books of the meteorological station in Nablus. The daily rainfalls were simply added for each month and then the monthly totals were added for each hydrological year (i.e from September of any year to August of following year. The average of the annual totals was calculated at 648.57 mm and the standard deviation equals 197.62 and the maximum annual rainfall was 1387.6 mm. Figure 3.10 shows the annual rainfall and its average. From the figure, it is noted that the deviation of the annual rainfall from the average varies from year to year. It is noted that the wet years are 18 years from 44 years, the studied years. The wet year, in this study, is considered to be the year in which rainfall is equal or more than the average annual rainfall. The deviation from the mean in the wet years is higher than the dry

Fig 3.10 The annual rainfall and its average for Nablus district for the period of 1954-1998



years. There are only 3 years where the rainfall did not exceed 400 mm. Also it is noted that the number of the wet years in the second half of the studied years is more than those of the first half where there are 11 year from the 18 wet years. From the rainfall of the years 1954 to 1998, it is noted that for every 10 years there are only 4 wet years and from the rainfall of 1995 to 2000, there are 4 wet years. Also for the rainfall of 1954 to 1994, it is noted that for every 10 years there is an event where 3 excessive years have the rainfall less than the average but for the wet years there is only one event where 2 excessive wet years. From this, it can be said that the rainfall is in the direction of increasing of the amount of rainfall.

Some sequences of hydrologic events, such as the occurrence of precipitation, may be considered Poisson process, in which events occur instantaneously and independently on a time horizon, or along a line. The Exponential distribution is used to describe the time between the wet and dry years. The parameter of the Exponential, λ, is the mean rate of occurrence of the events. It is calculated using the formula

$$\lambda = \frac{1}{\bar{x}} \qquad (3.3)$$

And the formula Probability density function of the Exponential distribution is

$$f(x) = e^{-\lambda x} \text{ for } x > ,0 \qquad (3.4)$$

where x is the variate and $\bar{x}$ is the mean

Figures 3.11 and 3.12 shows the number of excessive wet and dry years. From these figures, it is noted that the number of excessive dry years is larger than those of wet years. Figures 3.13 and 3.14 shows the exponential probability density function of the number of successive wet and dry years.

Fig 3.11 The number of excessive wet years for Nablus for the period of 1954-1998

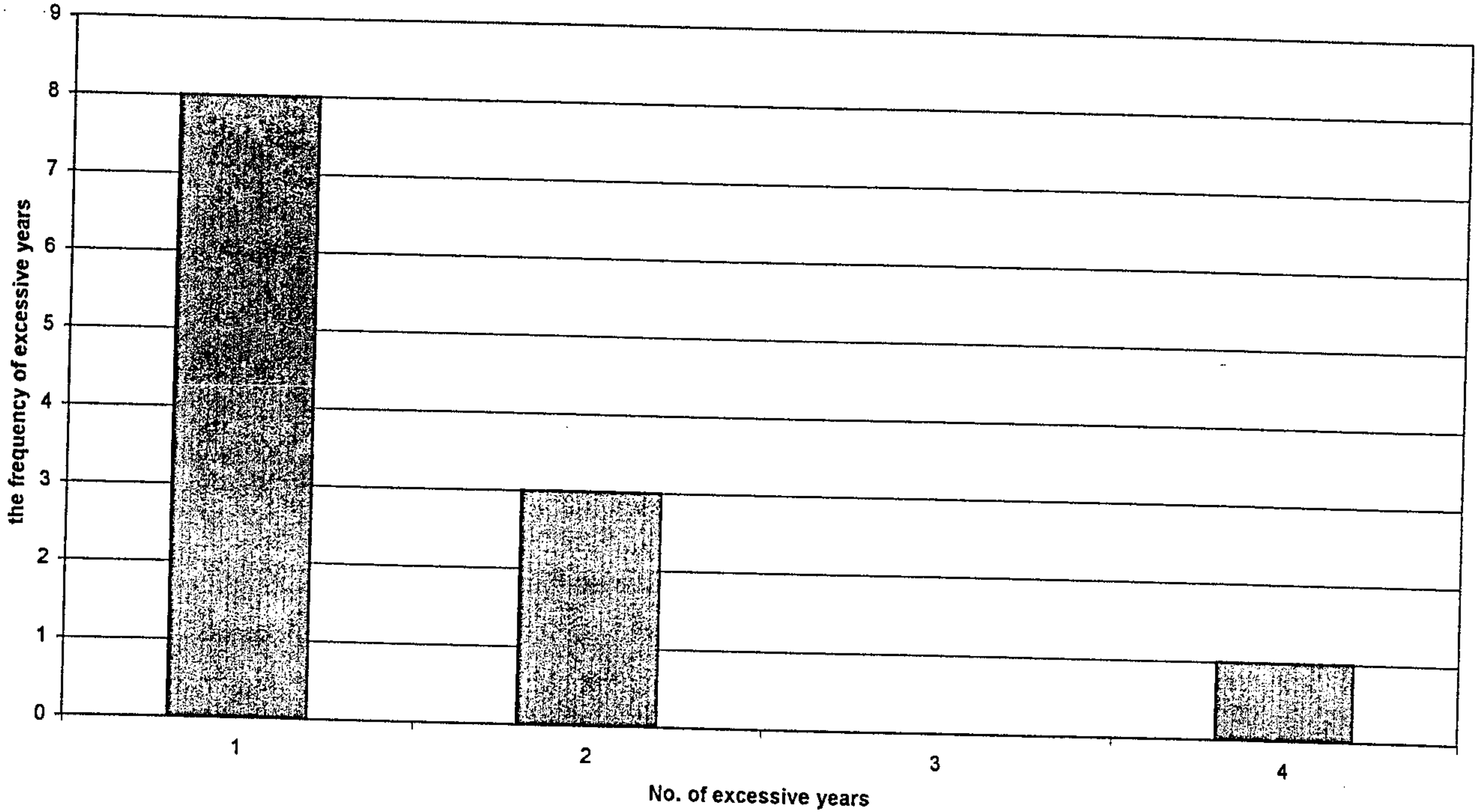


Fig 3.12 The number of excessive dry years for Nablus for the period of 1954-1998

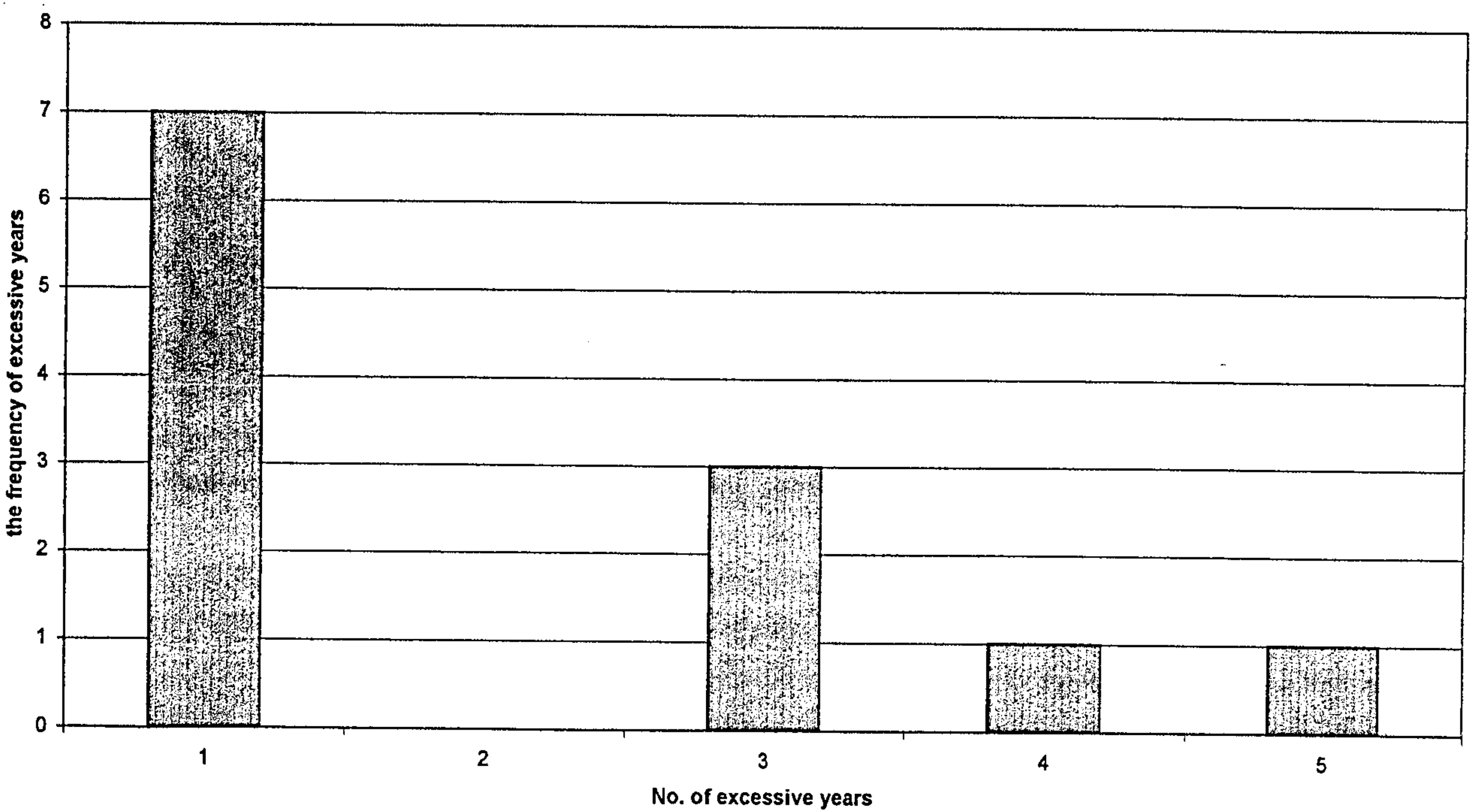


Fig 3.13 The exponential probability density function of the number of excessive wet years

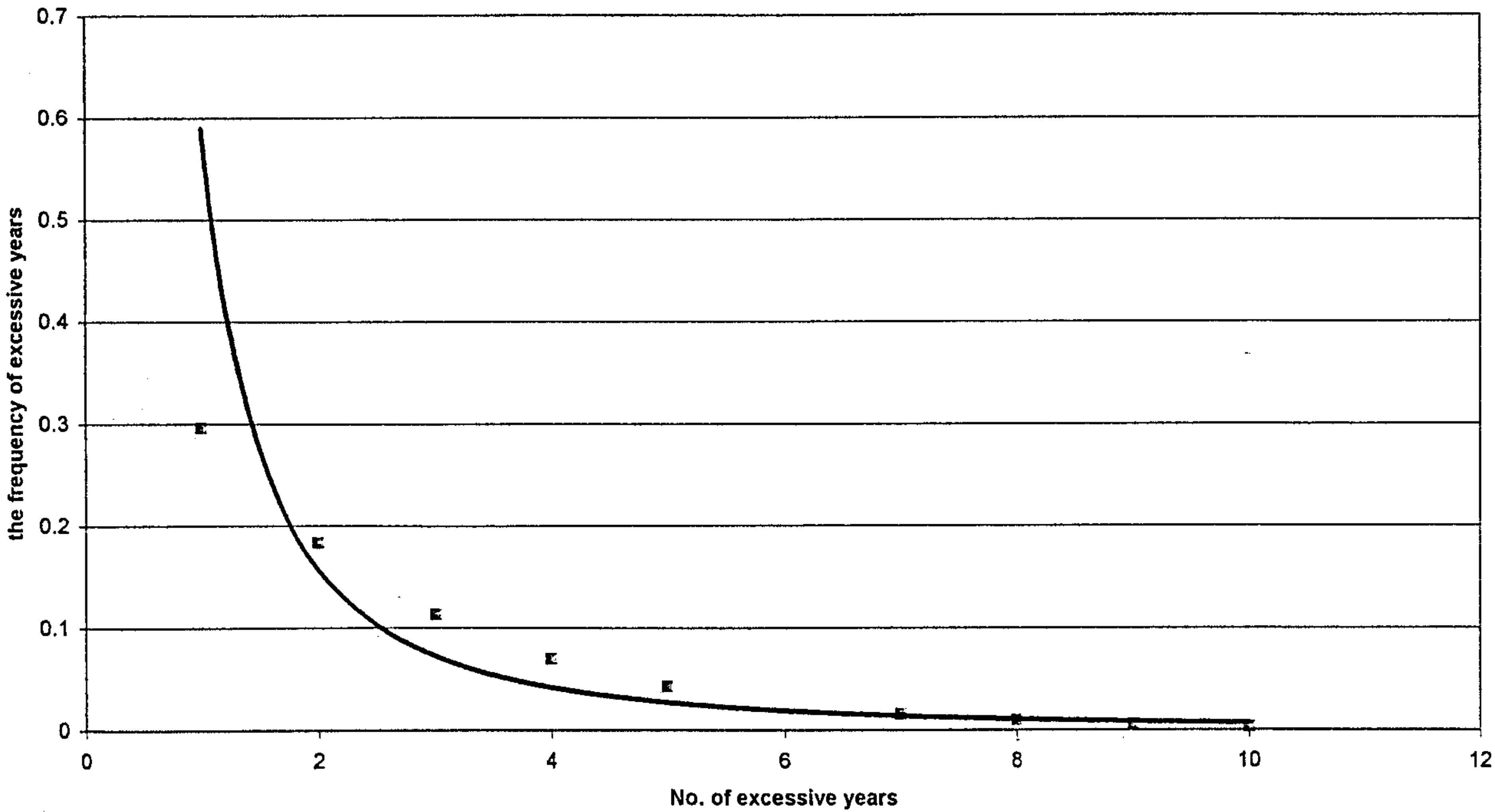
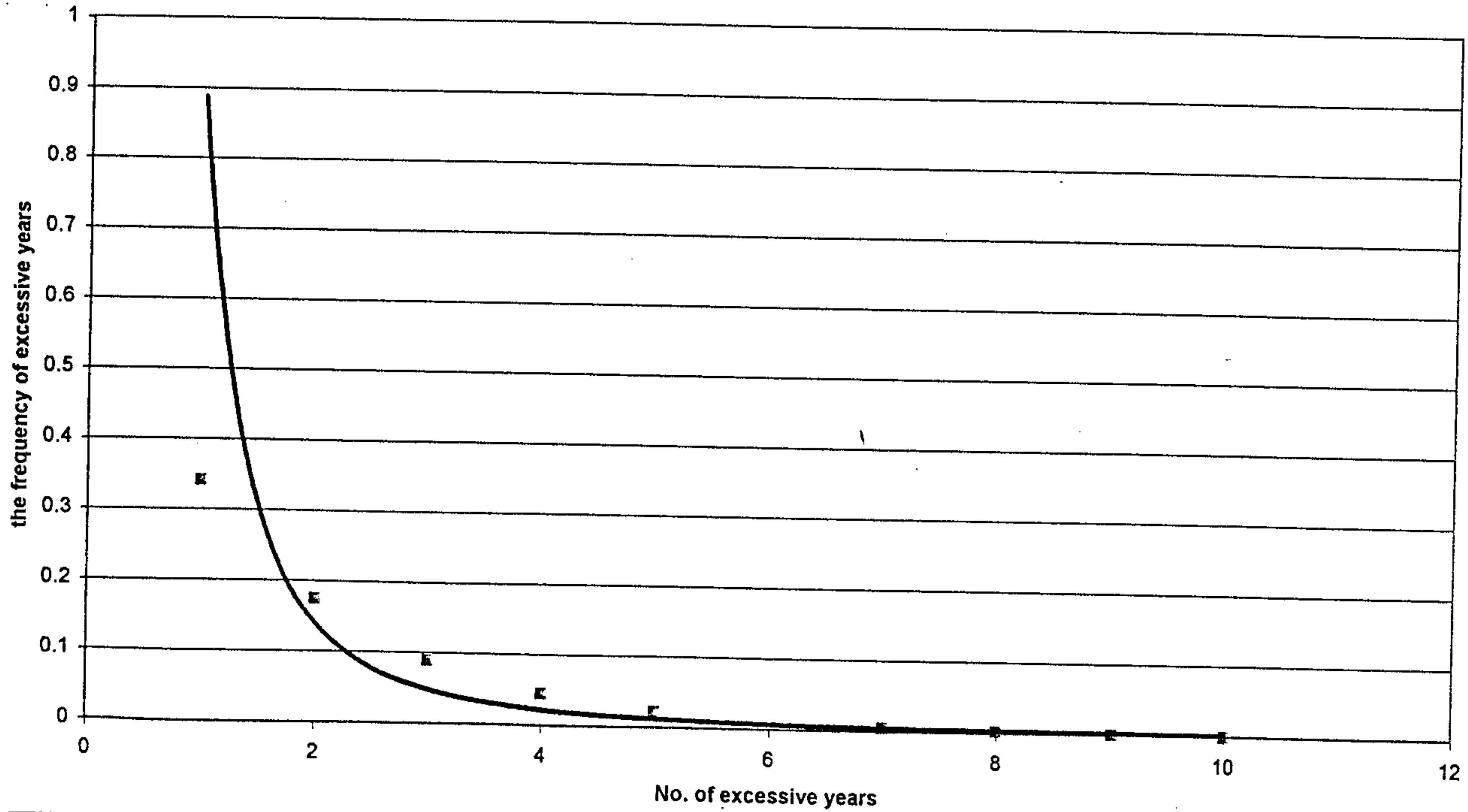


Fig 3.14 The exponential probability density function of the number of excessive dry years



Variations in the amount, timing and location of precipitation are the underlying reason for the need of many water resources project and planning. Our understanding and ability to predict precipitation and its resulting effects such as runoff are far from perfect. How then can the engineer approach the problem of design when he can not be certain of the hydrologic demand that will be placed on the project. An approach that is often used is a statistical or probabilistic one. Such an approach doesn't require a complete understanding of the hydrologic phenomenon involved but examine the relationship between magnitude and frequency of occurrence in the hope of finding some statistical relationship between these variables. In effect the past is extrapolated into the future. As stated, the objective of frequency analysis is to fit hydrologic data to a probability distribution so that a relation between the event magnitude and its probability of being exceeded can be established. The first step in the procedure is to identify the data series (i.e event magnitude). In order to fit a probability distribution To the data series estimates of probability (or equivalent return period) must be assigned to each magnitude in the series.

3.3.3 Useful Probability Distributions in Hydrology

There is no physical rule that requires the use of any specific PDF in the analysis of Hydrologic data. However, since usually the maximum or minimum values of hydrologic events are of interest, extreme value distributions have been found to be most useful. The following is a summary of the more common distributions used in hydrologic analysis:

The normal distribution is the most familiar but it is usefulness in hydrology is limited Because it is symmetrical while most hydrologic data exhibit some skewness. This is because it varies over a continuos range ($-\infty$, ∞), while most hydrologic variables are

Because it is symmetrical while most hydrologic data exhibit some skewness. This is because it varies over a continuos range $(-\infty, \infty)$, while most hydrologic variables are nonnegative. The lognormal distribution is useful and is applied using the logarithm of the variates instead of the variates themselves. Type-1 External distribution or more commonly called the Gumble distribution is mainly common in the analysis of floods. There are many probability distributions such as Binomial distribution, Exponential distribution, Pearson Type 111 distribution and others. In this study Two distributions were used.

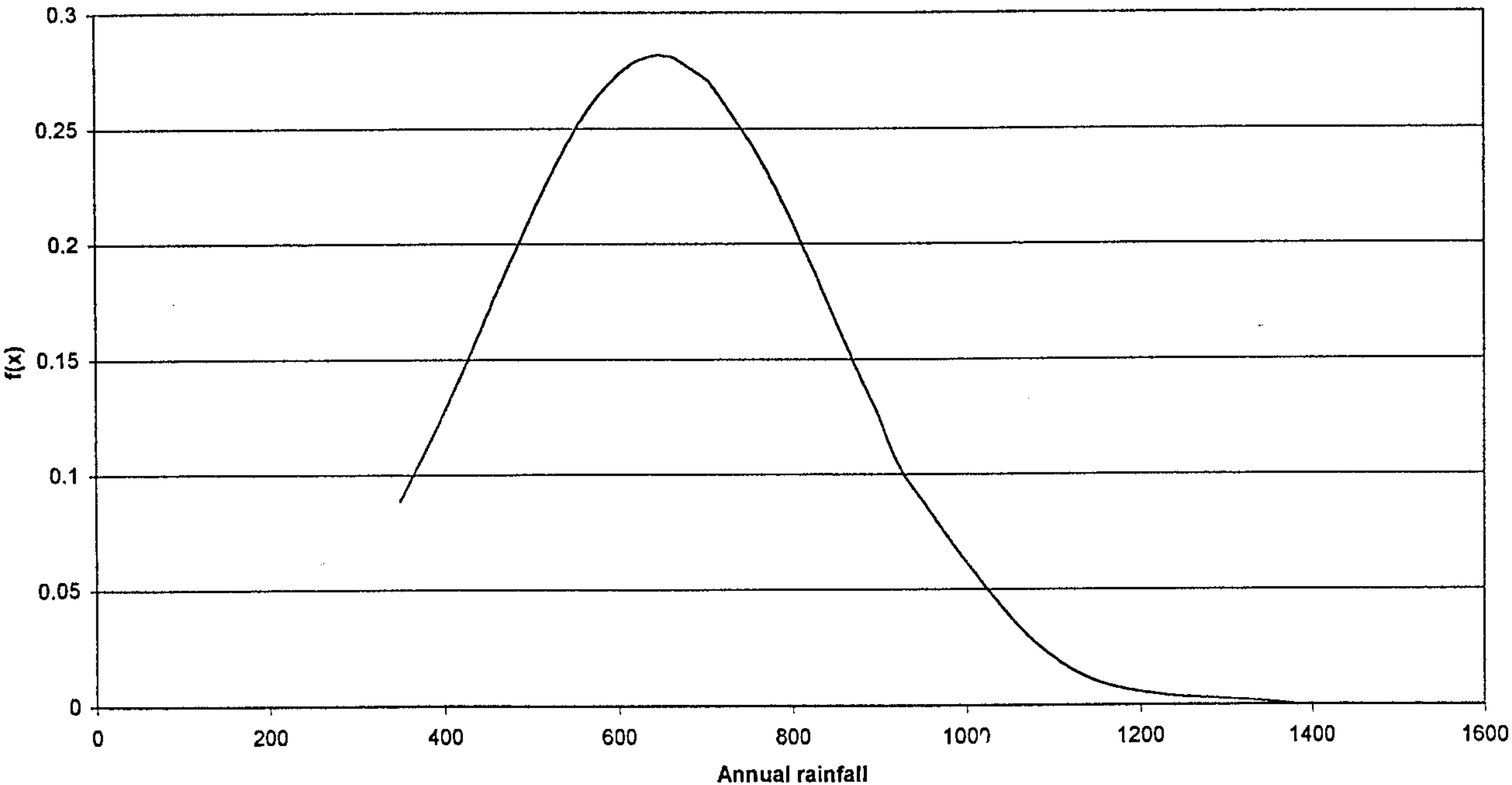
These are Normal and Gumble distribution. From those distributions, the best fit was Appeared in Gumble distribution.

The probability density function of the Normal distribution is expressed by the equation:

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\left\{\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right\}} \quad (3.5)$$

where x is the variate, μ is the mean of the variates and is the standard deviation. Figure 3.15 shows the fitting of data using the Normal distribution and it shows the skewness of the data and the Normal distribution is not suitable distribution of data.

Fig 3.15 The probability density function of normal distribution for the rainfall of the period 1954-1998



For the purpose of value analysis, the following procedure has been followed:

1. The annual rainfalls were determined.
2. The annual values were arranged in descending order over the recorded period and each value was given a rank, m.
3. For each value of annual rainfall, denoted by x, the probability of exceedance, P(x) was calculated using the formula

$$P(x)= m/(n+1)=1/Tr \quad (3.6)$$

where

x : annual rainfall

m : the rank of x

n : the total number of recorded years .

Tr : the return period

The probability of non-exceedence was calculated using

$$F(x) = 1 - \frac{1}{p(x)} \quad (3.7)$$

Where F(x) : the probability of non-exceedance

4. The return period was calculated.
5. The distribution function was plotted. The annual rainfall values are plotted on Probability paper and then compared with Gumble probability distribution function, the probability distribution that has well fits annual values which used in a design process to estimate rainfall for design return period. Gumble probability distribution can be defined as

$$F(x) = \exp(-\exp((x-x_o)/\alpha)) \quad (3.8)$$

where

$$\alpha = 0.7797 * \sigma \quad (3.9)$$

$$x = \mu - 0.5772\,\alpha \qquad (3.10)$$

The above estimated parameters was found using the method of moments.

The estimated Gumble value of rainfall is defined as follows

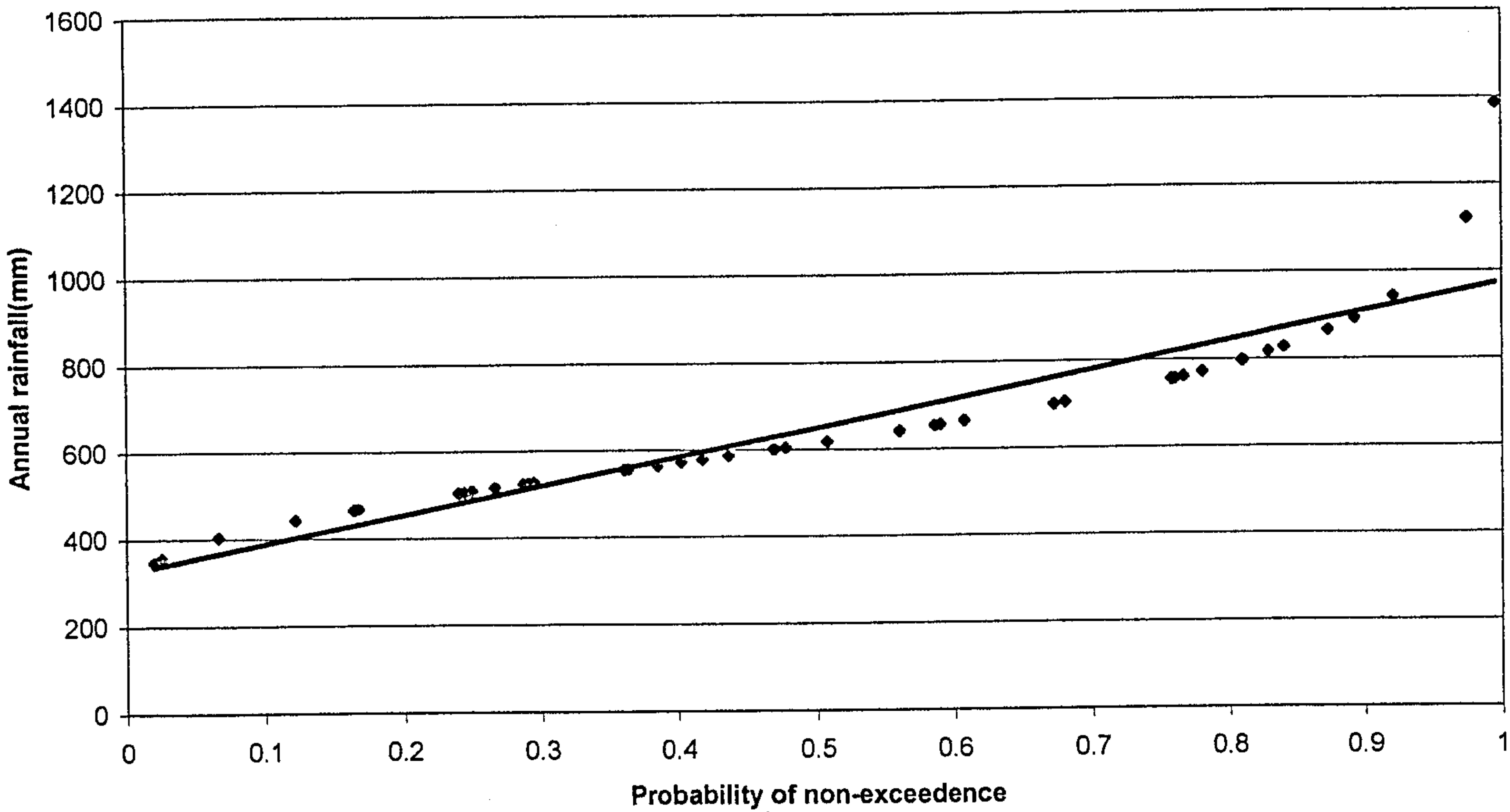
$$X = \alpha\{-\ln(-\ln(F(x))\} + x_o \qquad (3.11)$$

To check the best fitting of data, the square value of the correlation coefficient R^2, was determined between the actual and the estimated rainfall values and it was calculated at 0.97. All the results are shown in figure 3.16. From that figure and the magnitude of R^2, it is noted that the Gumble distribution represents the distribution of annual rainfall. The mean and the mode of the distribution equals 700 and 560 respectively.

3.3.4 Monthly Rainfall Analysis

The monthly rainfall for the years from 1954-1998 was calculated except for the years of 1961-1964 where there is no available data. The average monthly rainfall was found and the percent rainfall of each individual month have been calculated for every year. The monthly percent rainfall was found by dividing the rainfall in the month to the total rainfall in that year. The average and standard deviation for each month in the recorded years have been calculated. It is shown that the highest percent averages of rainfall in the wet season was found for January then for December and February. Figure 3.17 shows that the average percentage of monthly rainfall increases from October until it reaches the maximum percent of January and then the percent decreases gradually. The maximum percent of each year was found and plotted and it is shown that there is a deviation of maximum monthly percent from year and another year. It is found that in most of the years 30% of the annual rainfall falls in the most rainy month of the year as shown in figure 3.18. This figure shows that 33 year from

Fig 3.16 Gumble distribution of annual rainfall for Nablus district



the 41 year where the monthly percent is more than 30% of annual rainfall. Figure 3.18 also shows that in the last years there is a decrease in the maximum monthly percent in four following years but before that the decrease is year by year and in some cases two years. The 41 studied years were divided into four groups. The groups includes the rainfall of the years of 1954-65, 1965-75, 1975-86 and 1986-98 respectively. The monthly average percent of the rainy months of each group was found. Then the cumulative percent was estimated and plotted in figure 3.19. From the four lines which represent the four groups, it is found that there is no a big difference between the lines and they have nearly the same slopes and shapes. This means that the distribution of the rainfall on the months has nearly in the same style. In order to estimate the monthly percent rainfall of any year knowing its rainfall, the cumulative monthly percent rainfall was plotted with months beginning from September to August.

The question of the accuracy of the estimated values frequently arises. The central limit theorem in theoretical statistics states that the distribution of the means of a large number of samples of a population will approach a normal distribution as the sample size increases, regardless of the distribution of the population itself. However, in general, the samples size for hydrologic data is not large and in this case the distribution of means is not normal. Beard has applied the non- – central t - distribution to this problem and the results are given in Table 3.6. This table gives coefficients that are multiples of standard deviation of the sample. When the product of the standard deviation and the coefficient is added and subtracted from the variate for the exceedance probabilities, listed it will give values which a percent of the future variates should exceed or be less than respectively. These values are called confidence intervals.

Fig 3.17 Average monthly percent rainfall for Nblus district for the period of 1954-1998

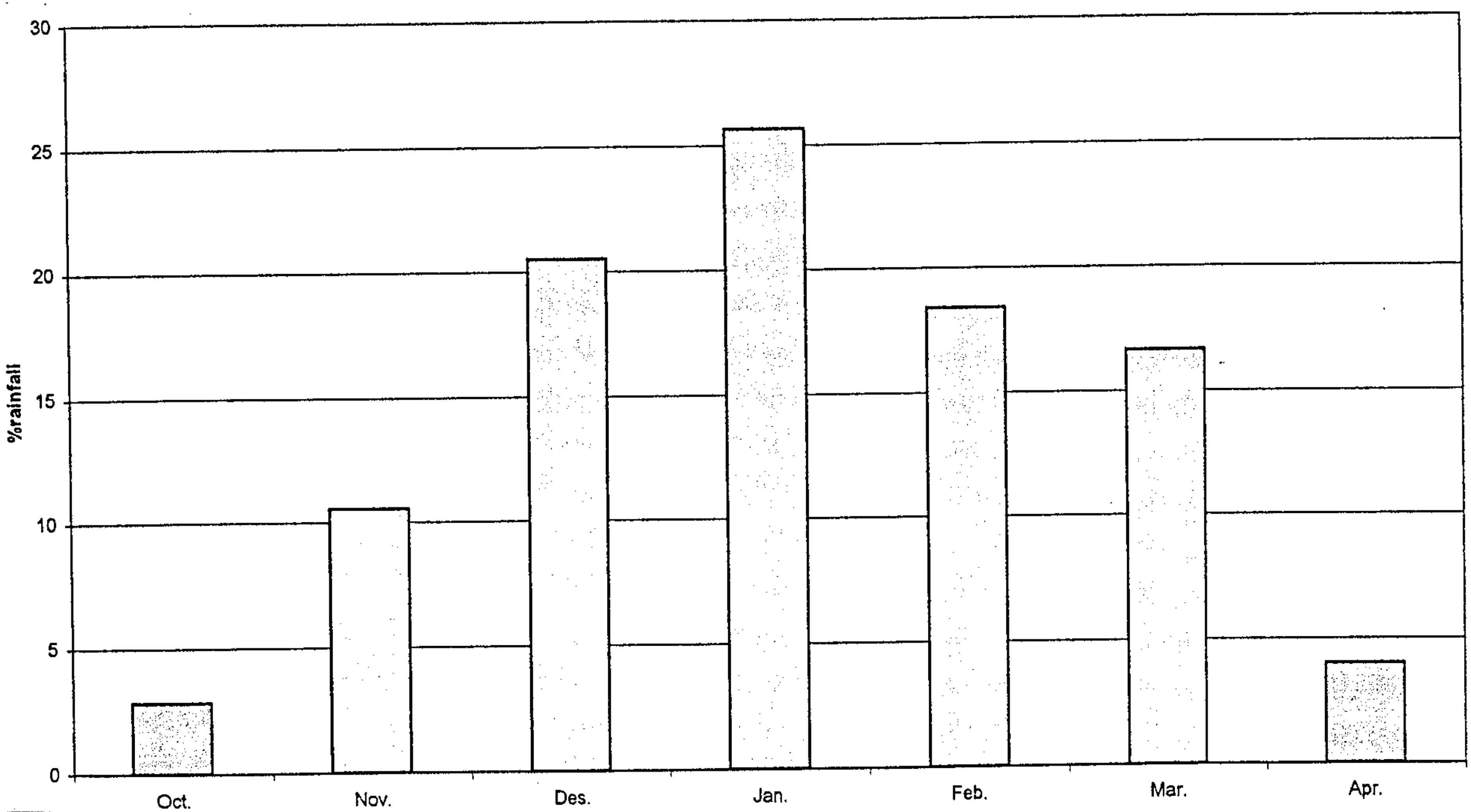


Fig 3.18 Maximum monthly percent rainfall for the period of 1954-1998

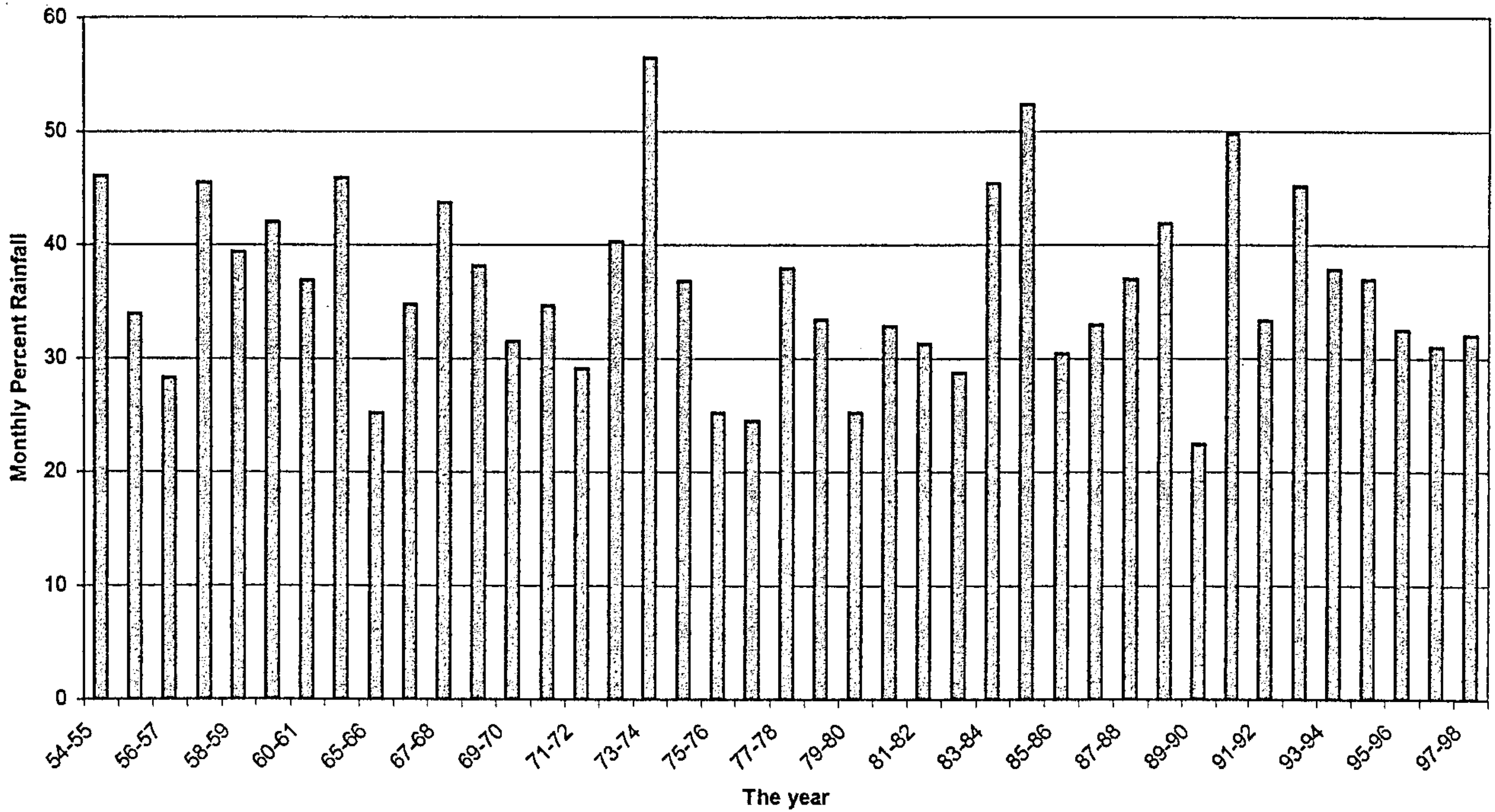
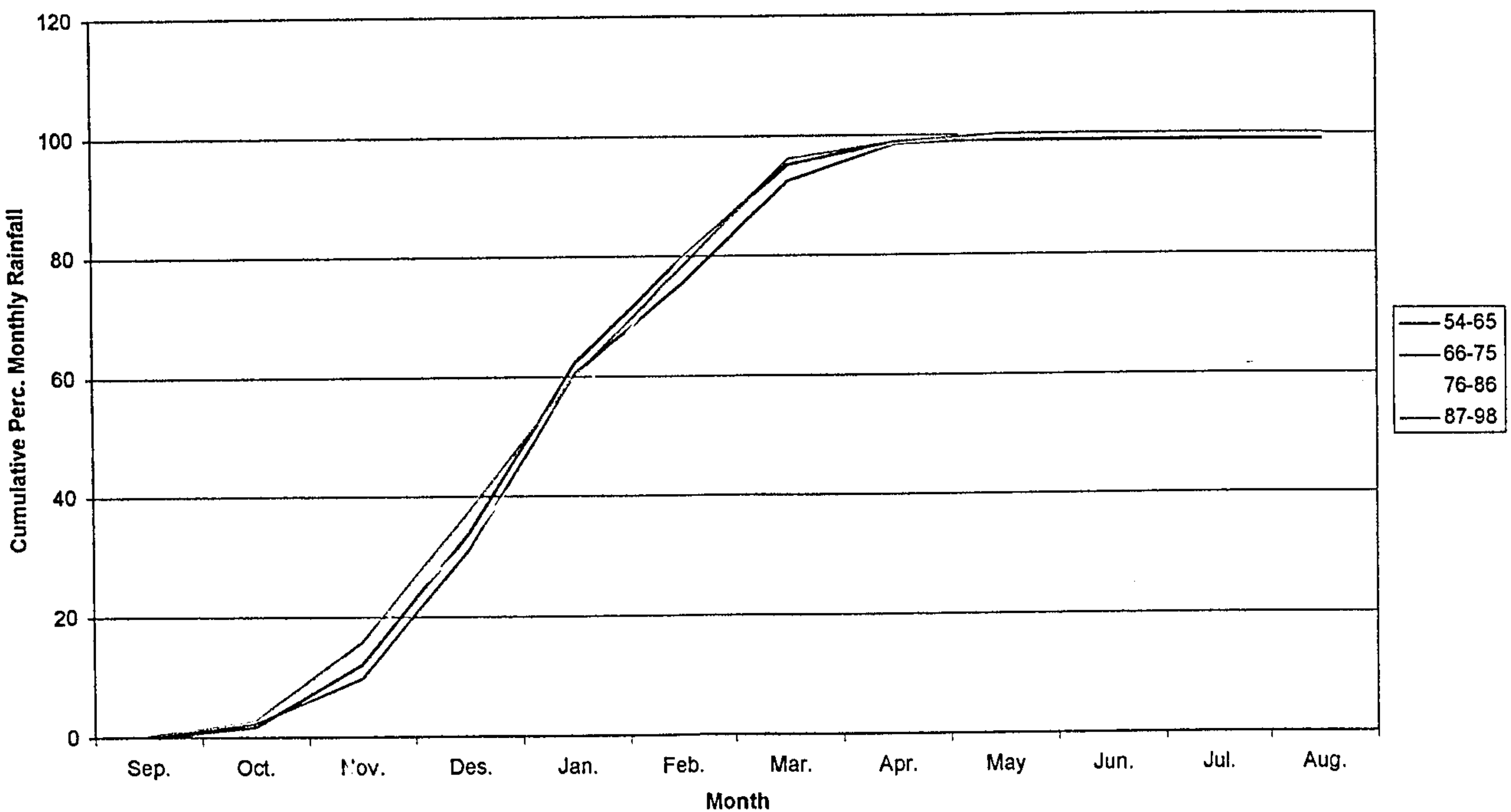


Fig 3.19 The cumulative rainfall for the rainfall of Nablus district for the period of 1954-1998



year return period, the exceedance probability = 1 / T = 0.01 and from Table 3.6, the 5% level coefficient is 0.61 and the 95% level coefficient is 0.43. Therefore there is a 5% chance that the values of the monthly percent will exceed x + 0.61 (S) and also 5% chance that it will be below x – 0.43 (S). The results are shown in figure 3.20. As For the 41 years analysis and the100 the rainfall of the rainy season of the year 1998-1999 was not included in this calculations, the rainfall of that year can be checked by these results. Figure 3.21 shows the application of the rainfall of 1998-1999 to figure 3.22. It is noted that rainfall of that year can be applicable to the figure.

Table 3.6 Confidence Limit Coefficient

Years of	Exceedance Probability, Percent, @ 5% Level						
Record	**.999**	**.99**	**.90**	**.50**	**.10**	**.01**	**.001**
5	1.22	1.00	0.76	0.95	2.12	3.41	4.41
10	0.94	0.76	0.57	0.58	1.07	1.65	2.11
15	0.80	0.65	0.48	0.46	0.79	1.19	1.52
20	0.71	0.58	0.42	0.39	0.64	0.97	1.23
30	0.60	0.49	0.35	0.31	0.50	0.74	0.93
40	0.53	0.43	0.31	0.27	0.42	0.61	0.77
50	0.49	0.39	0.28	0.24	0.36	0.54	0.67
70	0.42	0.34	0.24	0.20	0.30	0.44	0.55
100	0.37	0.29	0.21	0.17	0.25	0.36	0.45
	.001	.01	.10	.50	.90	.99	.999
	Exceedence Probability, Percent, @ 95% Level						

Source : Beard, L. R., " Statistical Methods in Hydrology, " U.S. Army Corps of Engineers, January 1962.

Fig 3.20 The confidence intervals of monthly rainfall (=0.05)

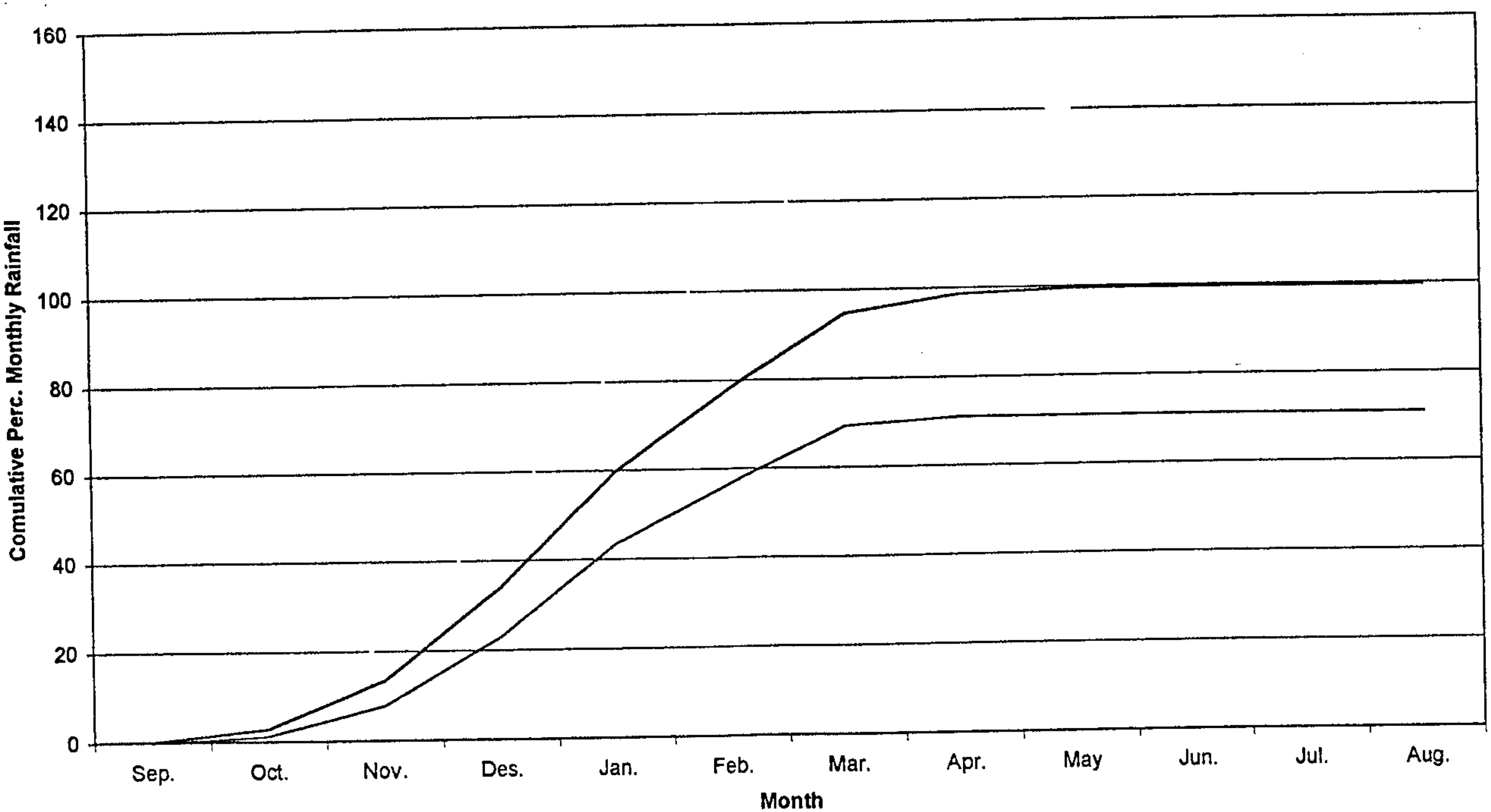
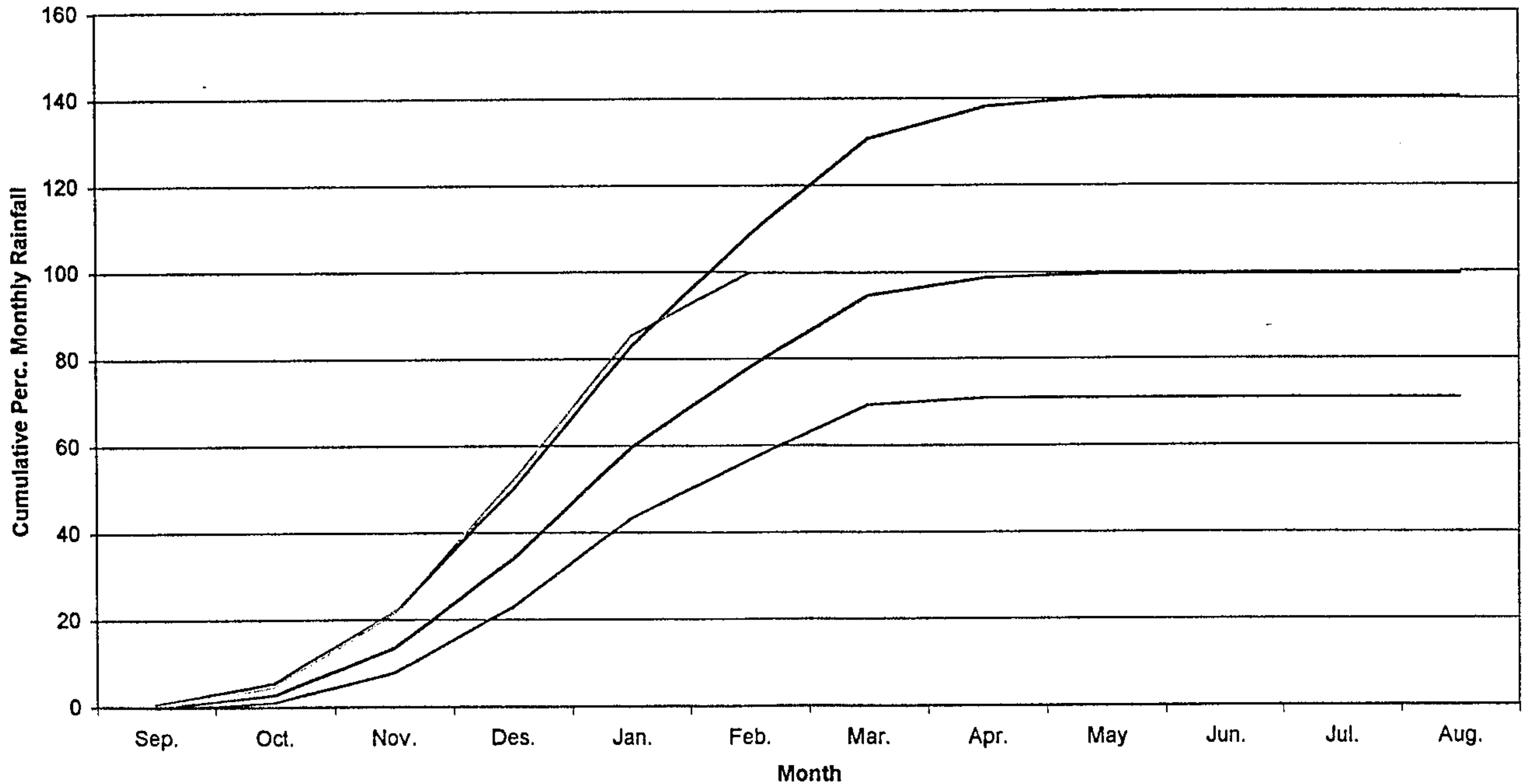


Fig 3.21 The application of rainfall of 1998-1999 to confidence intervals of monthly rainfall of Nablus district



3.4 Trend Analysis

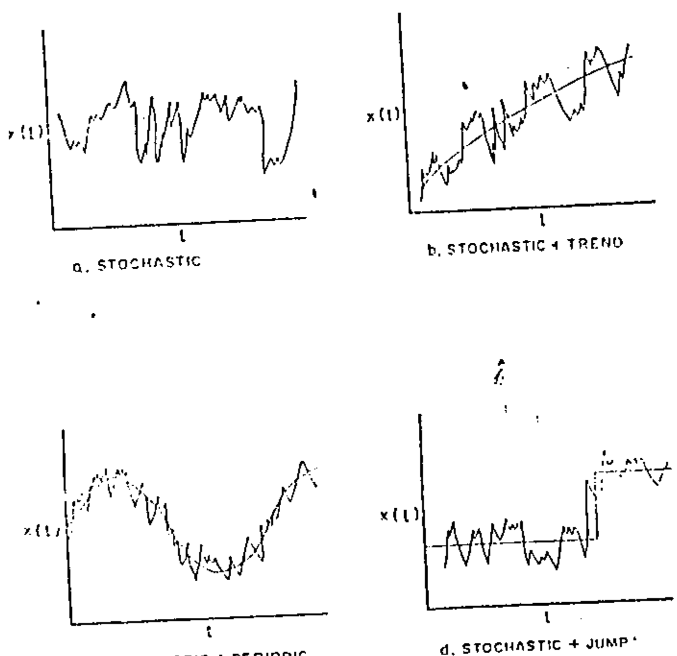
3.4.1 Introduction

A time series is a sequence of values arrayed in order of their occurrence which can be characterized by statistical properties. The sequence of values is represented by $x(t)$, $x(t2)$, $x(t3)$,..., where $t \quad 2 < t3$... . A time series can be composed of only deterministic events, only stochastic events or a combination of the two. Most generally a hydrologic time series will be composed of a stochastic component superimposed on a deterministic component. For example the series composed of average daily temperature at some point would contain seasonal variation, the deterministic component, plus random deviations from the seasonal values, the stochastic component. The deterministic component may be classified as a periodic component, a trend, a jump or a combination of these. Figure 3.22 a typical stochastic time series with various types of deterministic components. Trends in a hydrologic time series can result from gradual natural or man-induced changes in the hydrologic environment producing the time series. Changes in watershed conditions over a period of several years can result in corresponding changes in stream flow characteristics that show up as trends in time series of stream flow data. Urbanization on a large scale may result in changes in precipitation amounts that show up as trends in precipitation (Huff and Changnon 1973).

Jumps in time series may result from catastrophic natural events such as earthquakes or large forest fires that may quickly and significantly alter the hydrologic regime of an area. Man-Made changes such as the closure of a new dam or the egining or cessation of pumping of ground water may also cause jumps in certain hydrologic time series.

Atronomic cycles are generally responsible for periodicities in natural hydrologic time series. Annual cycles are many times apparent in streamflow, precipitation, evapotranspiration, groundwater level, soil moisture and other types of hydrologic data. Weekly cycles may be present in water use data such as industrial, domestic or irrigation demands. Generally, it is possible to classify time series as being either of two types: stationary or nonstationary. Assume that a time series is divided into several segments and that a statistical parameter such as the mean is used to characterize the data within each section. If the expected value of the statistical parameter is the same for each section, the time series is said to be stationary. If the expected values are not the same, the time series is nonstationary. In stationary time series, absolute time is not important, and the series may be assumed to have started somewhere in the infinite past. However, in nonstationary time series, it is necessary to consider absolute time since the series cannot be assumed to have begun prior to the time of the initial observation.

Figure 3.22 Typical stochastic time series with various types of deterministic components



3.4.2 Trend Analysis by using Moving Averages

Various methods of removing trend are available. All the methods, however, are not fully understood as to how they affect the time series The most general method involves the fitting of a pollynomial to the data. This method has two principal objections:

1. The coefficients of the polynomial must be defined by high –order moments which are unreliable because of their large sampling errors since N is small.
2. The coefficients of the polynomial must be recomputed each time a new value is added to the time series because they are based on the available data of the time series.

An alternative method of trend elimination is that of moving average, which consists of finding a polynomial which will fit part of the record and using different polynomials for different parts of the trend. This method permits the addition of newvalues without altering the previously fitted polynomials. In order to remove the trend, it is necessary to smooth out irregularities in the time series. Assume that the observations x1, x2,...xn are taken at equal intervals of time and in our case the time interval is a year. The method of moving averages consists of determining overlapping means. Generally, even a smooth trend obtained by the method of moving averages cannot be represented conveniently by a mathematical equation. If a mathematical trend is fitted to the data, a simple relation should be used unless logic indicates otherwise. The simplest mathematical expression is a straight line. However, a time series is apt to be such that a single linear trend cannot be used through the time of observation. In such cases, it is possible to use linear trends for portions of time series. After a trend has been established, it is possible to remove the trend from the data in one of several ways. One way is to take as a new variable the deviations about the trend line. It is necessary that these deviations about constitute a stationary time series. This procedure of trend removal is widely used in hydrologic studies. Using trend analysis on the annual rainfall, simple moving averages of 5-years and 10-years are applied to the annual rainfall data. For example, the moving average of 5- years was calculated by the first 5 records and then founding the average of them, and then founding the average of 5 records without the first one and so. The results are shown in figures 3.23.and 3.24. The slopes of the resulted lines are 5.21 and 5.36 respectively. Both moving averages indicate an apparent trend. This apparent trend may, however, be part of an oscillatory movement. With such a short series, it is difficult to prove that the apparent trend is significant, and not part of the oscillatory movement of the series.

To check the stationarity of data the moving average of 5-years and 10-years was calculated and plotted in fig.3.25. It is noted that the average is going to increase (i.e it is found that the average in the early years is less than the average and goes to increase and becomes more than the average.

Fig 3.23 Time series containing stochastic and several types of determinestic components.

Fig 3.23 The 5-year moving average for rainfall of Nablus district

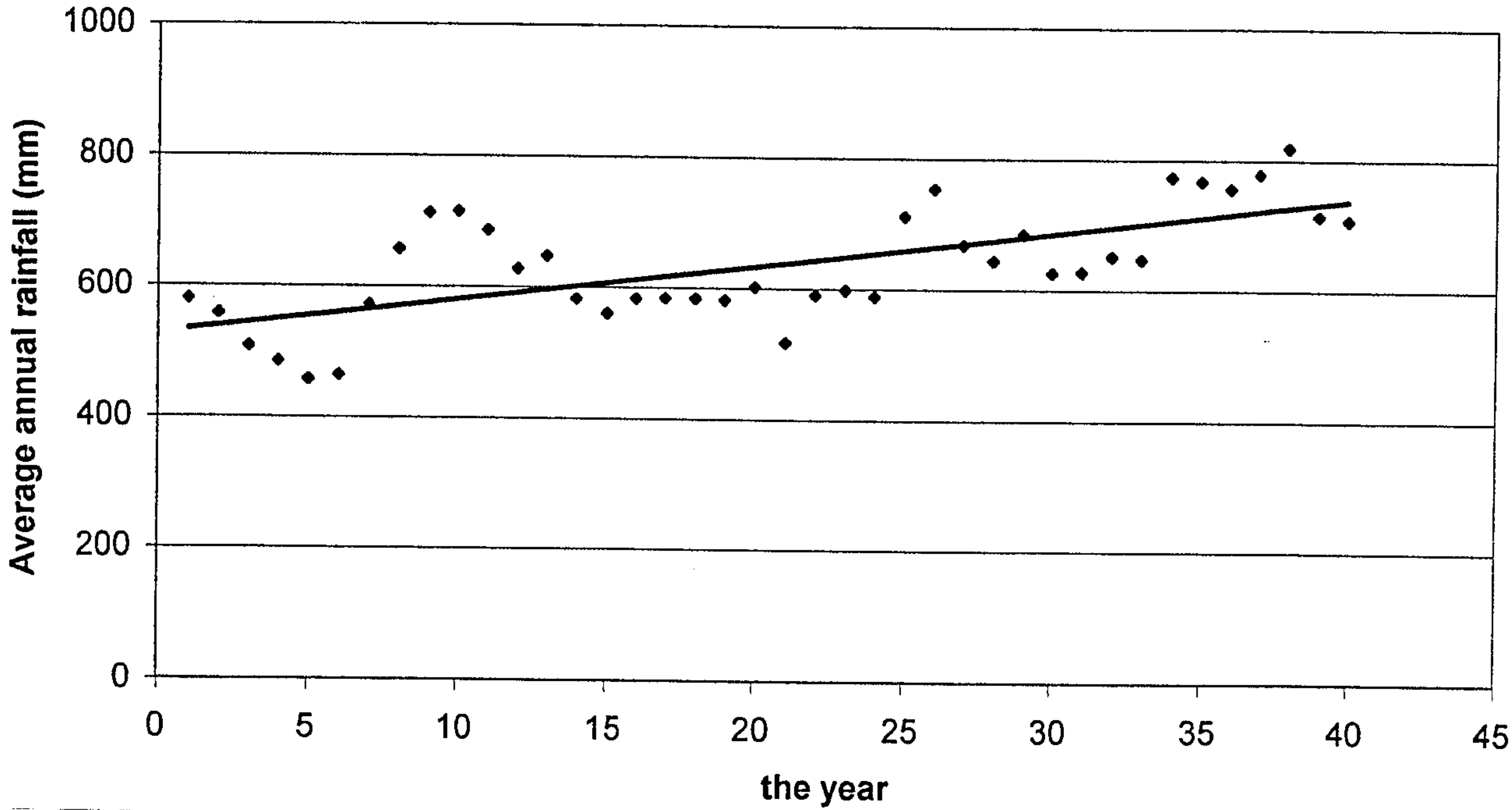


Fig 3.24 The 10-year moving average for rainfall of Nablus district

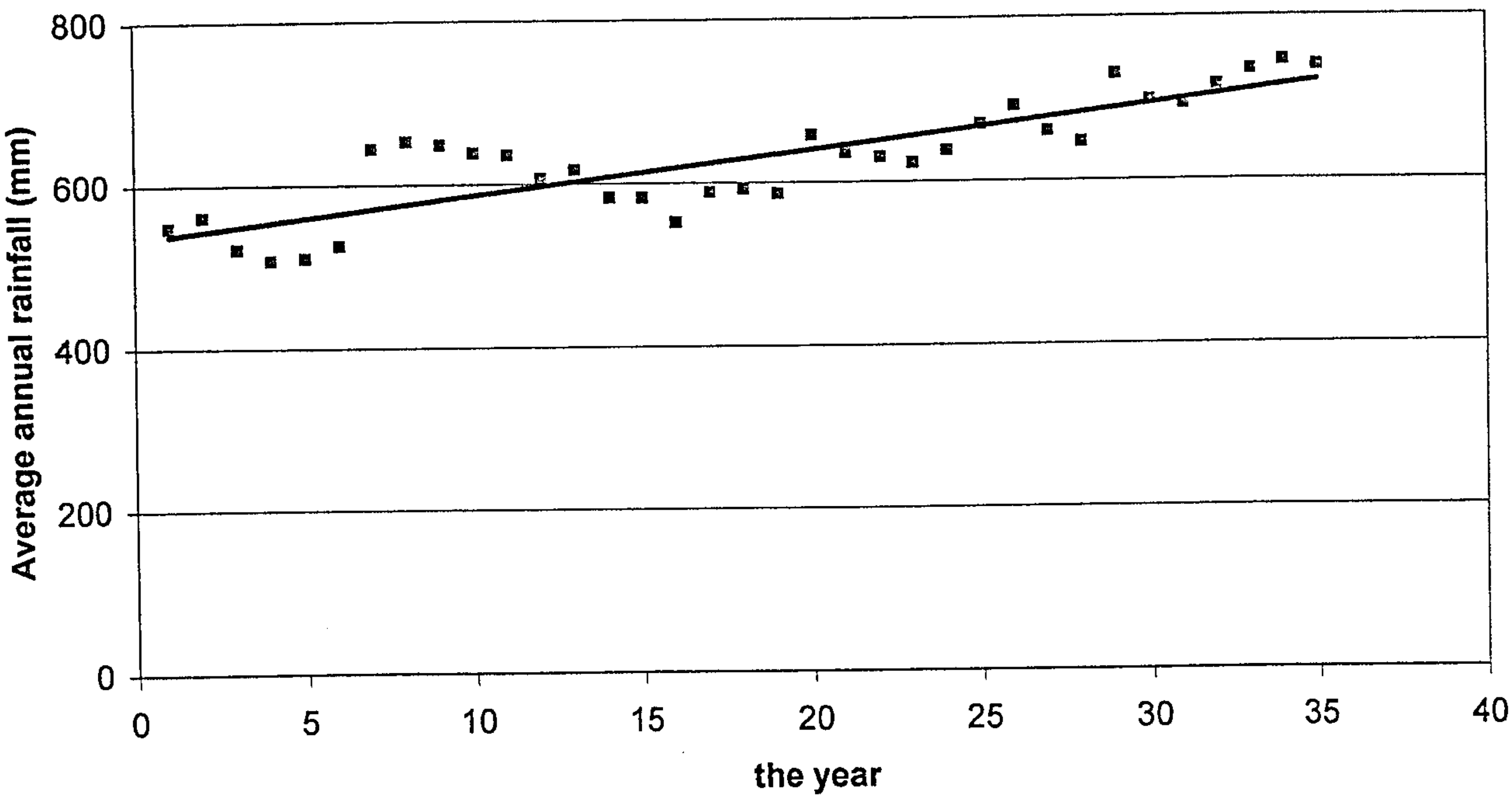
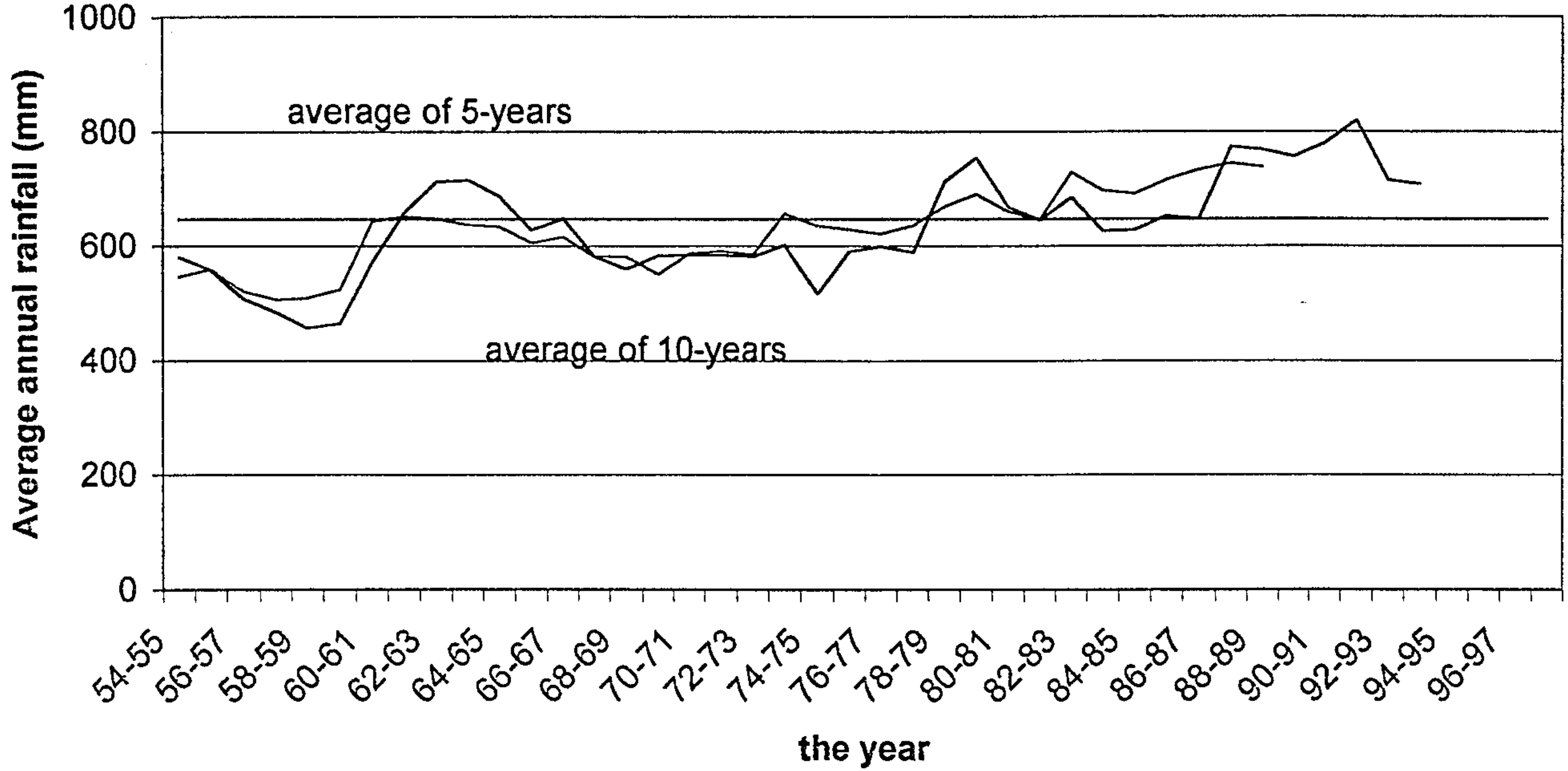


Fig 3.25 The 5-year and 10-year moving average for rainfall of Nablus district



4. Temporal Distribution of Rainfall Data in Nablus District

4.1 Monthly Distribution of Annual Rainfall

The monthly rainfall can be determined by the sum of the daily rainfalls. The monthly totals of rainfall show that the rainfall is concentrated in a few consective months of the year which are January, December, February and March. From these analysis, it is found that from the 41 years, there are 33 years having 30% of the annual rainfall falls in one month, which is the month that has the maximum rainfall of that year. Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 show the monthly rainfall distribution of the months October, November, December, January, February and March as percentage of the annual rainfall for the period of 1954 to 1998 respectively. From these figures, it is noted that there is a deviation for the monthly percentage for each individual month from year to another year but as mentioned in ch.3 the monthly distribution is in the same style. For the rainfall of the rainy months presented above, the average and standard deviation for each individual month were calculated over that period and this is shown in table 4.1. From the calculations, it is noted that the maximum average monthly rainfall was for January. For some months, the standard deviation exceeds the value of the average, which is due to the wide variation from the average of the rainfall from year to year.

Table 4.1 The average, standard deviation and the average number of rainy days for the monthly rainfall for the period of 1954-1998.

The month	Average (mm)	Standard deviation	Average no. of rainy days
October	17.6	19.3	
November	71.2	69.43	
December	139	105	10.55
January	161	79	12.53
February	120.5	87.97	10.73
March	104.5	61.24	9.43
April	24.6	35.15	
May	6	14.74	
September	1.84	5.27	

To investigate the relation between monthly rainfall and annual rainfall, the two values are plotted for the different rainy months. A linear correlation is assumed and applied. The figures 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, and 4.14 shows the plot for each individual month and Table 4.2 list the results of the linear correlation. From these results, it can be said that there is a relation between monthly and annual rainfall for the most rainy months which are November, December, January and February. The coefficient of correlation is very low for the months of September October, April and May.

Table 4.2 The parameters of the equation of Y=ax+b for the relation between monthly and annual rainfall.

The month	A	B	R^2
October	0.69	635.60	0.066
November	1.20	561.88	0.418
December	1.25	473.71	0.65
January	1.01	483.99	0.40
February	1.26	495.48	0.55
March	1.05	538.27	0.31
April	0.18	652.33	0.31
September	3.39	641	0.088

4.2 Daily Distribution of Monthly Rainfall

The available data for daily rainfall was for the years from 1954-98. Figure 4.15 shows the Gumble Distribution for the maximum daily rainfall for Nablus district. The daily distribution for each rainy month of December, January, February and March was found. For each month of specific year, the daily rainfall for each month was used to determine the monthly totals. The percent daily rainfall for that year was estimated by dividing the daily rainfall to the monthly rainfall. For each day of the month, the average percent of rainfall was estimated for the studied years. Figures 4.16, 4.17, 4.18 and 4.19 show the average and maximum daily distribution as percent of total monthly of the corresponding month. In each graph, the average rainy days for the corresponding month was found to give an indication about the number of days that this distribution represent. These figures show the pattern variation of daily rainfall for specific month relative to total rainfall of that month. It indicates the kind of variation that occurs. From those figures, it can be noted that the variation is very small and that the average daily rainfall can be used to represent the rain of a day. The curves for the different four rainy months are almost the same indicating fair distribution of the daily rainfall.

Fig 4.1 Monthly percent rainfall for October for the period of 1954 to 1998

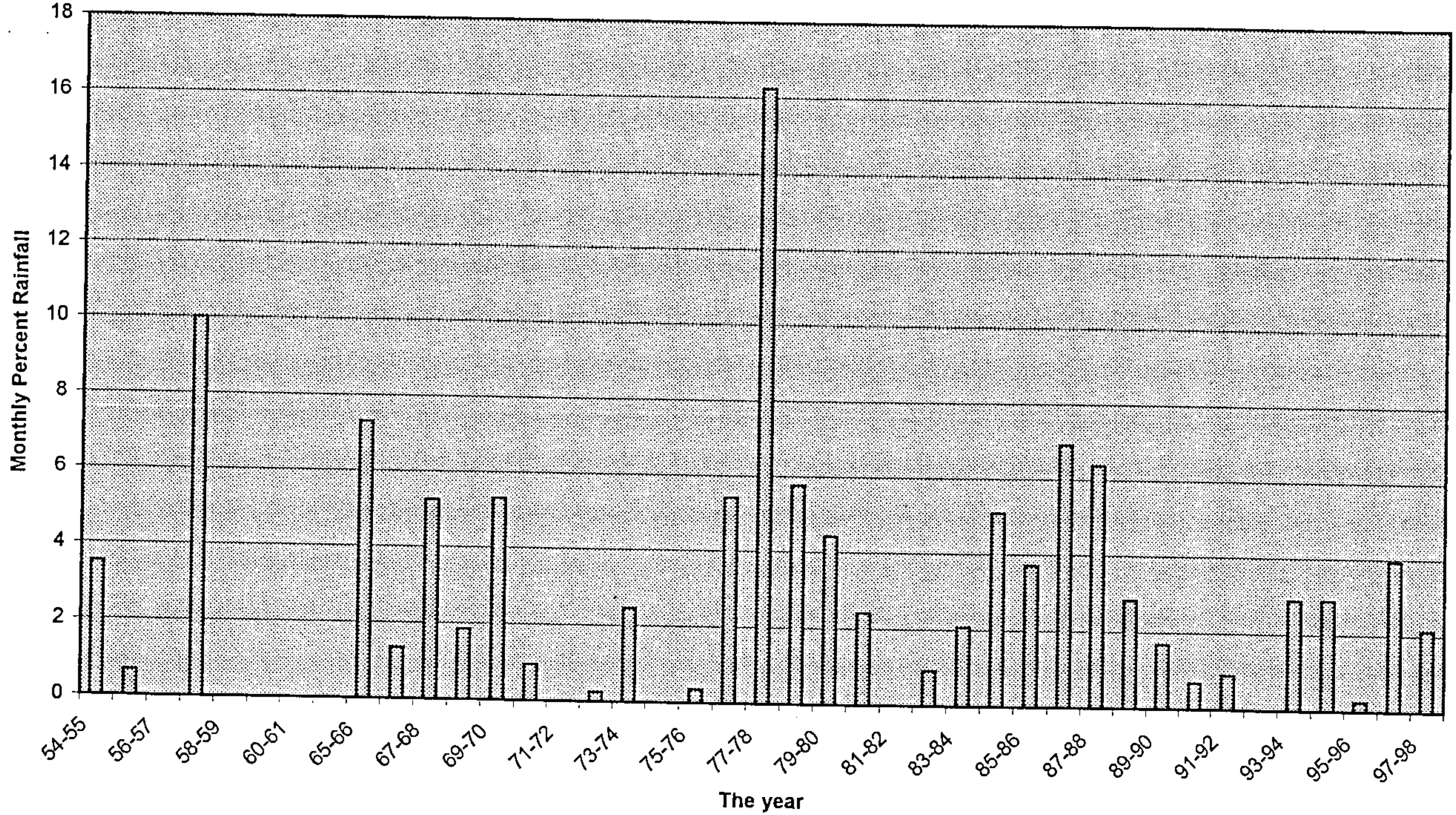


Fig 4.2 Monthly percent rainfall for November for the period of 1954 to 1998

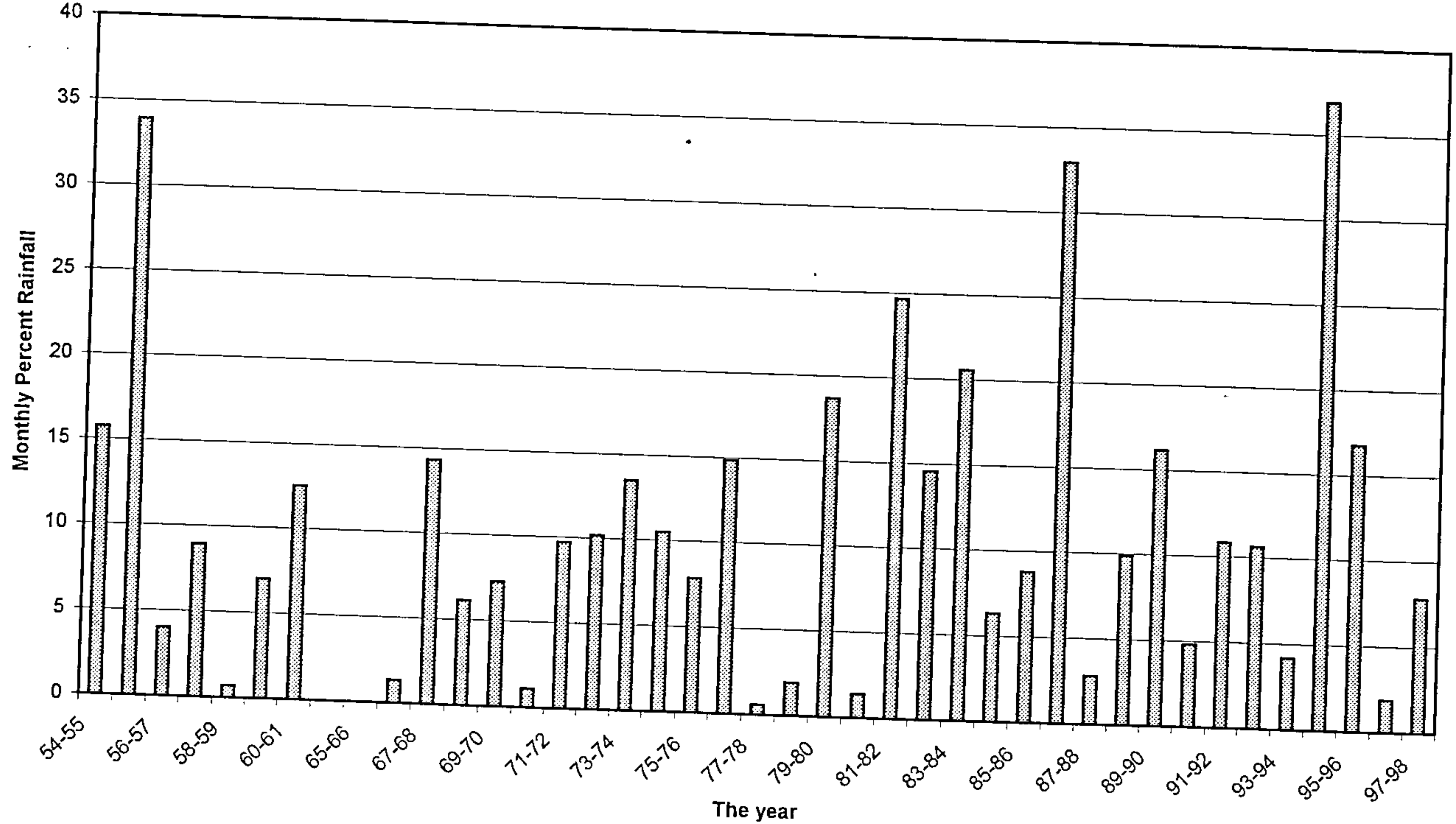


Fig 4.3 Monthly percent rainfall for December for the period of 1954 to 1998

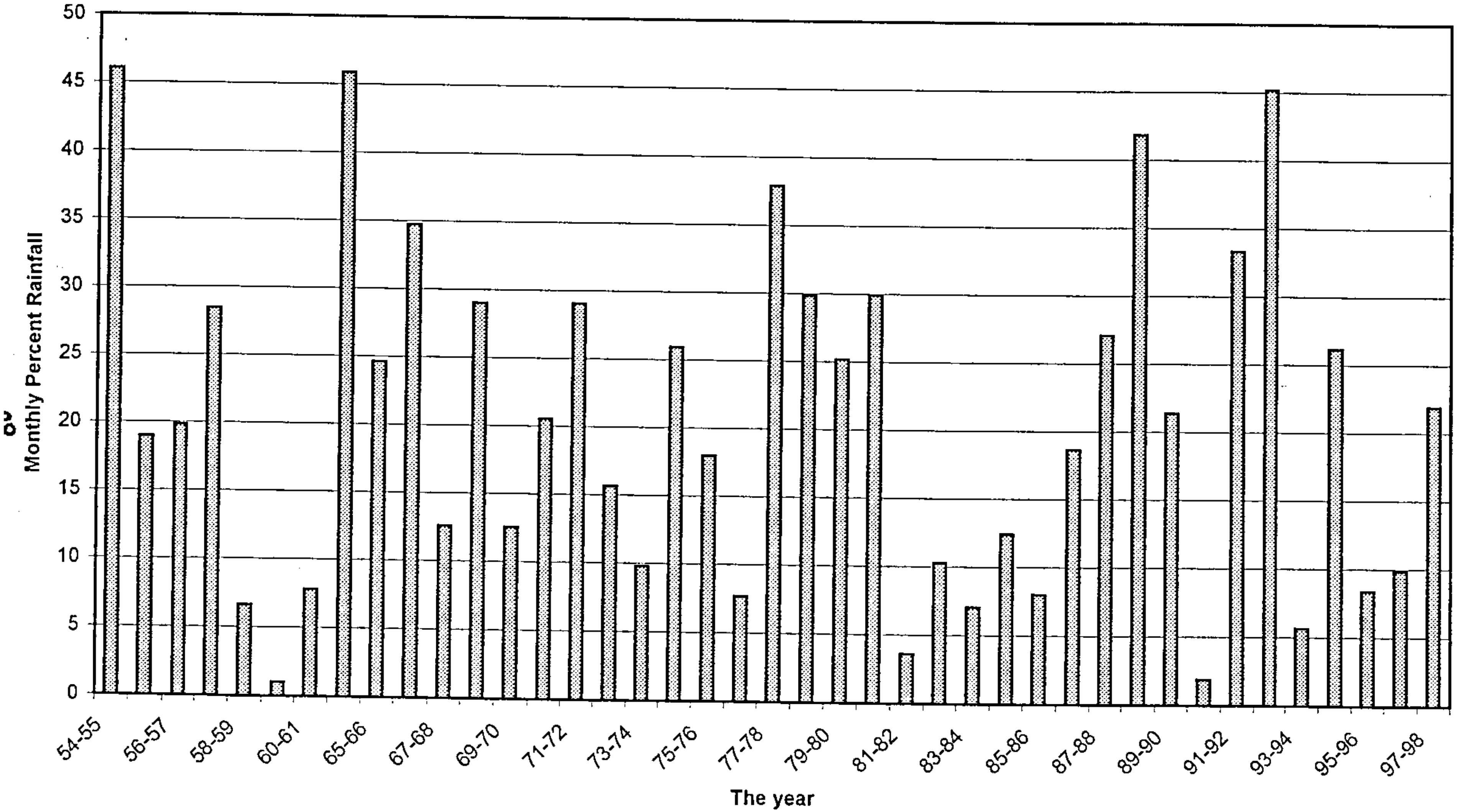


Fig 4.4 Monthly percent rainfall for January for the period of 1954 to 1998

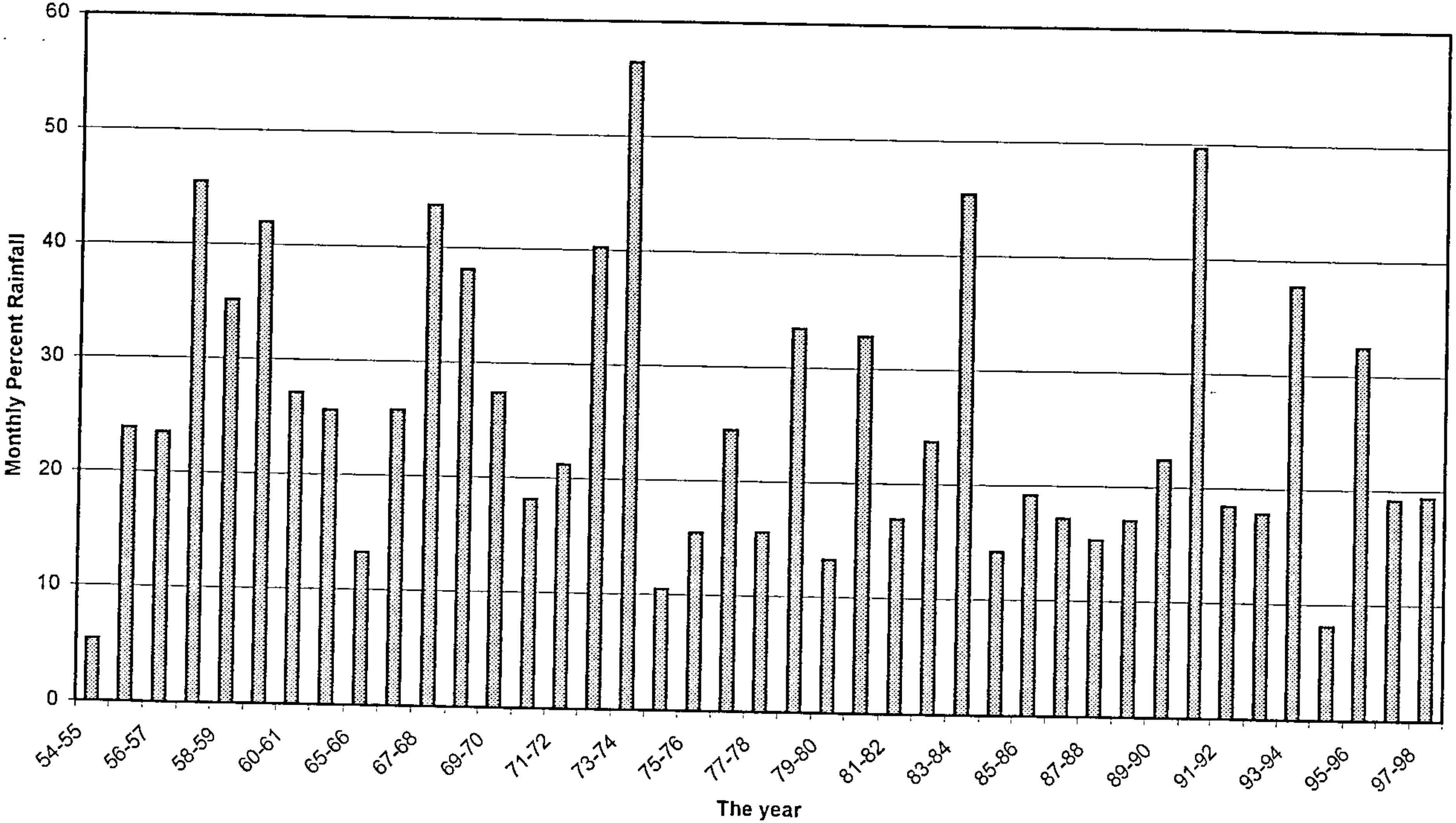
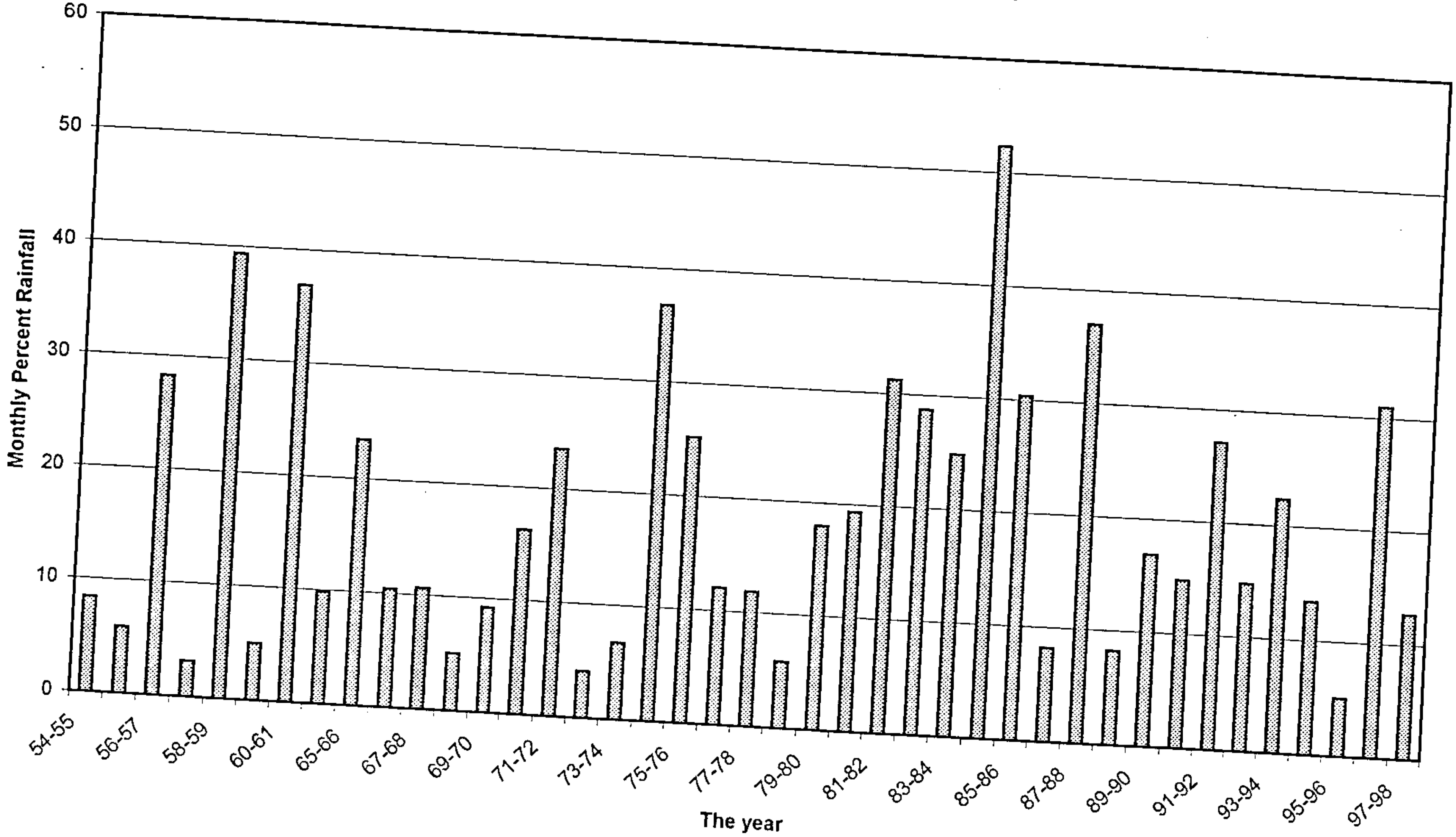


Fig 4.5 Monthly percent rainfall for February for the period of 1954 to 1998



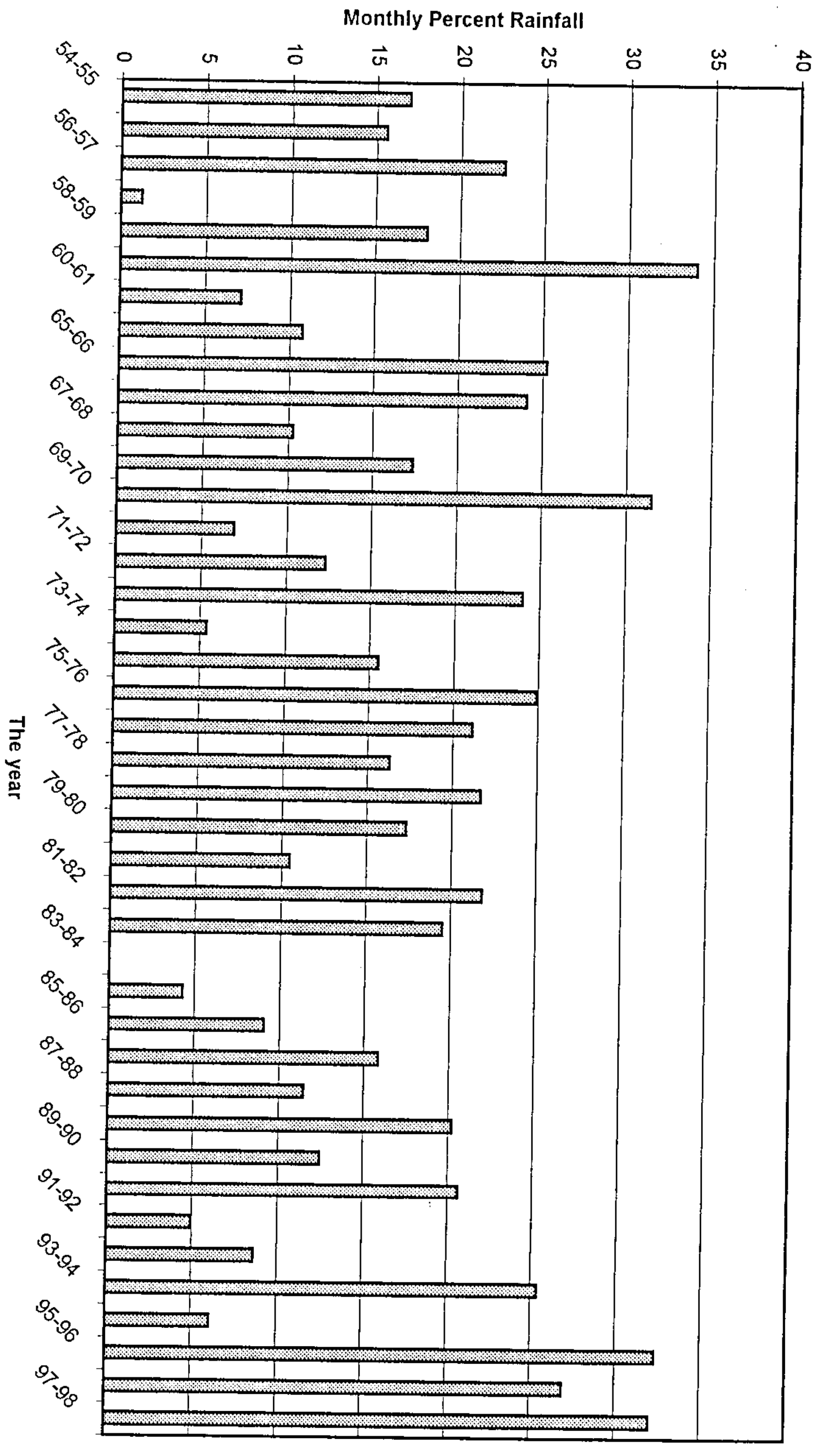


Fig 4.6 Monthly percent rainfall for March for the period of 1954 to 1998

Fig 4.7 Relation between monthly and annual rainfall for October for the period of 1954 to 1998

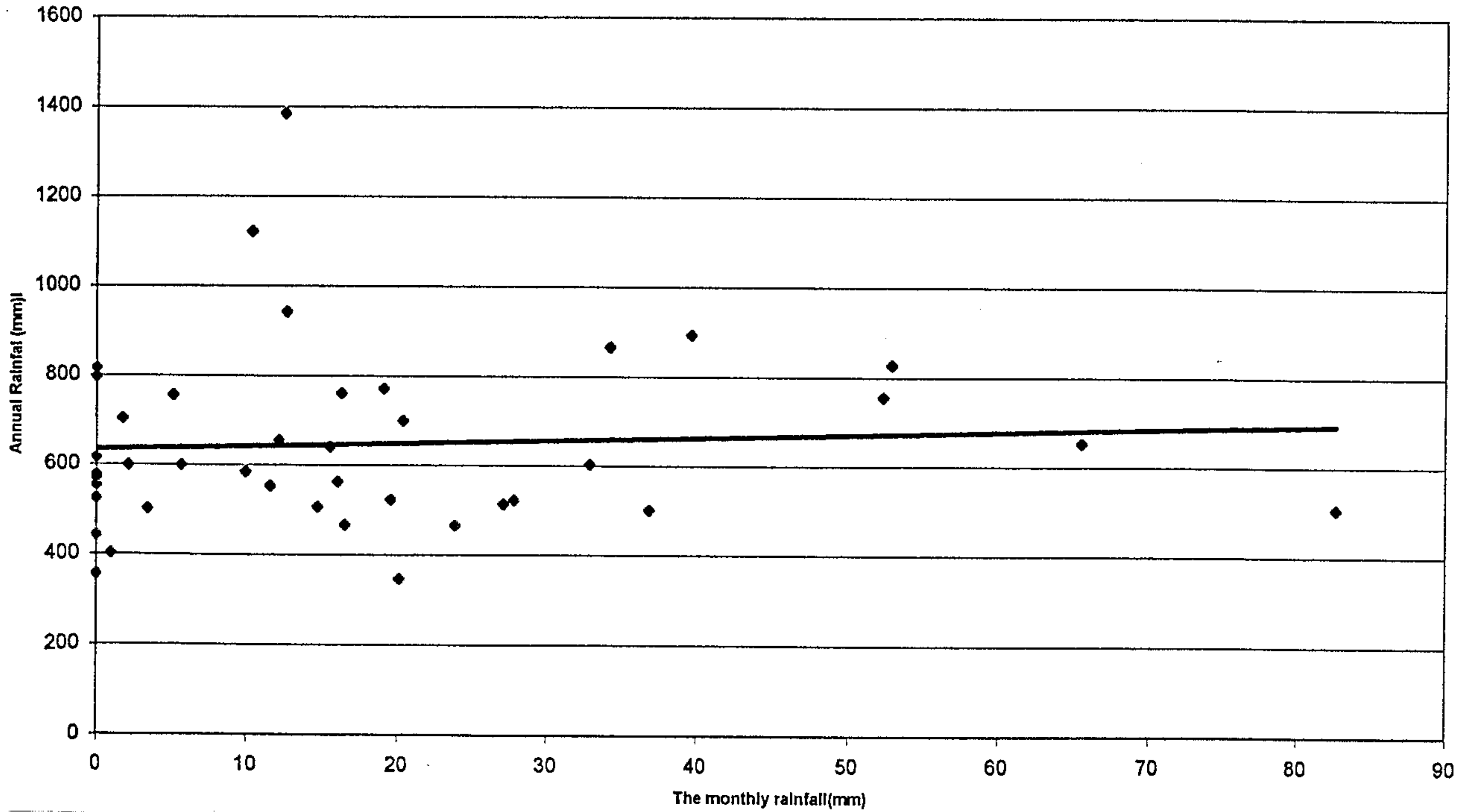


Fig 4.8 Relation between monthly and annual rainfall for November for the period of 1954 to 1998

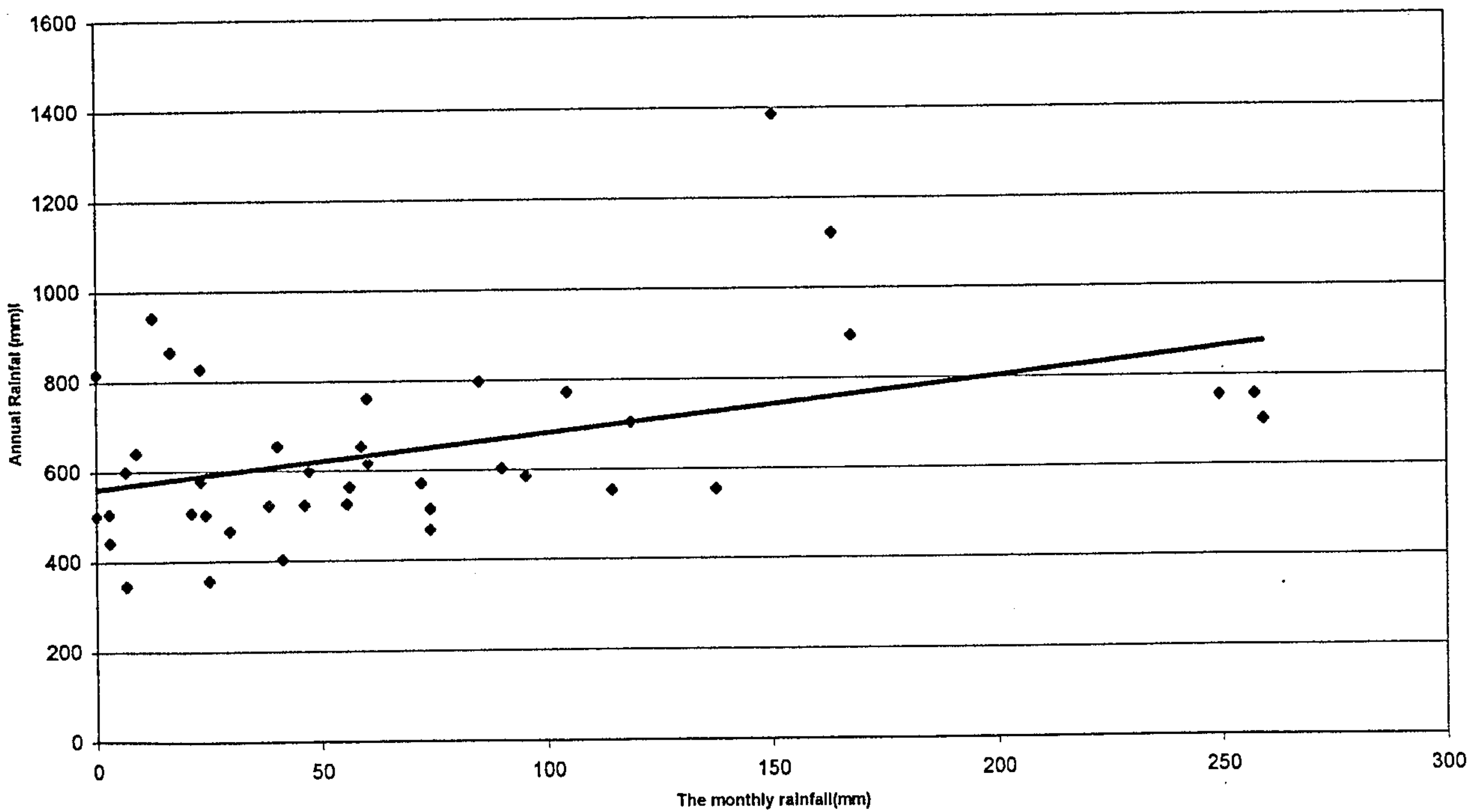


Fig 4.9 Relation between monthly and annual rainfall for December for the period of 1954 to 1998

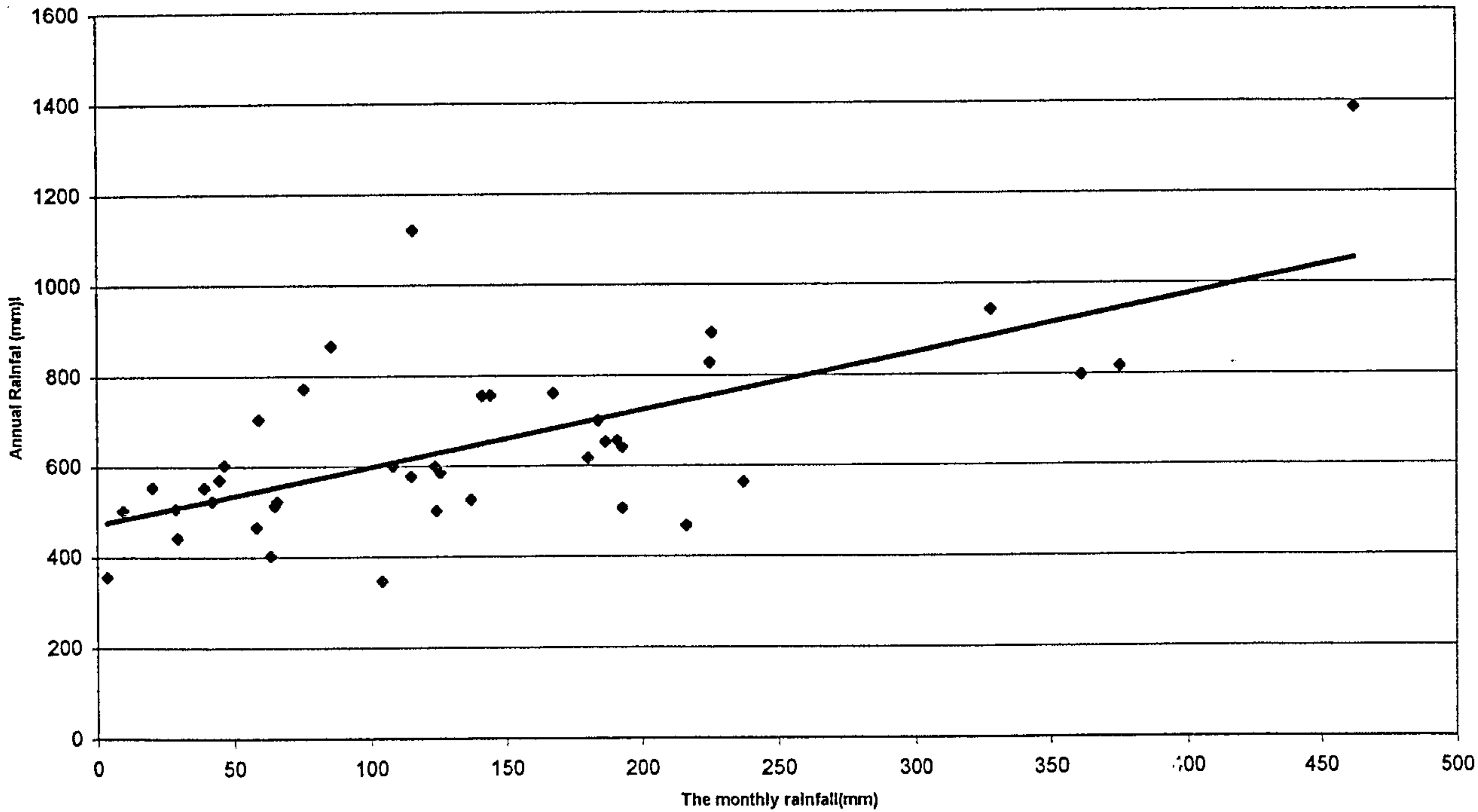


Fig 4.10 Relation between monthly and annual rainfall for January for the period of 1954 to 1998

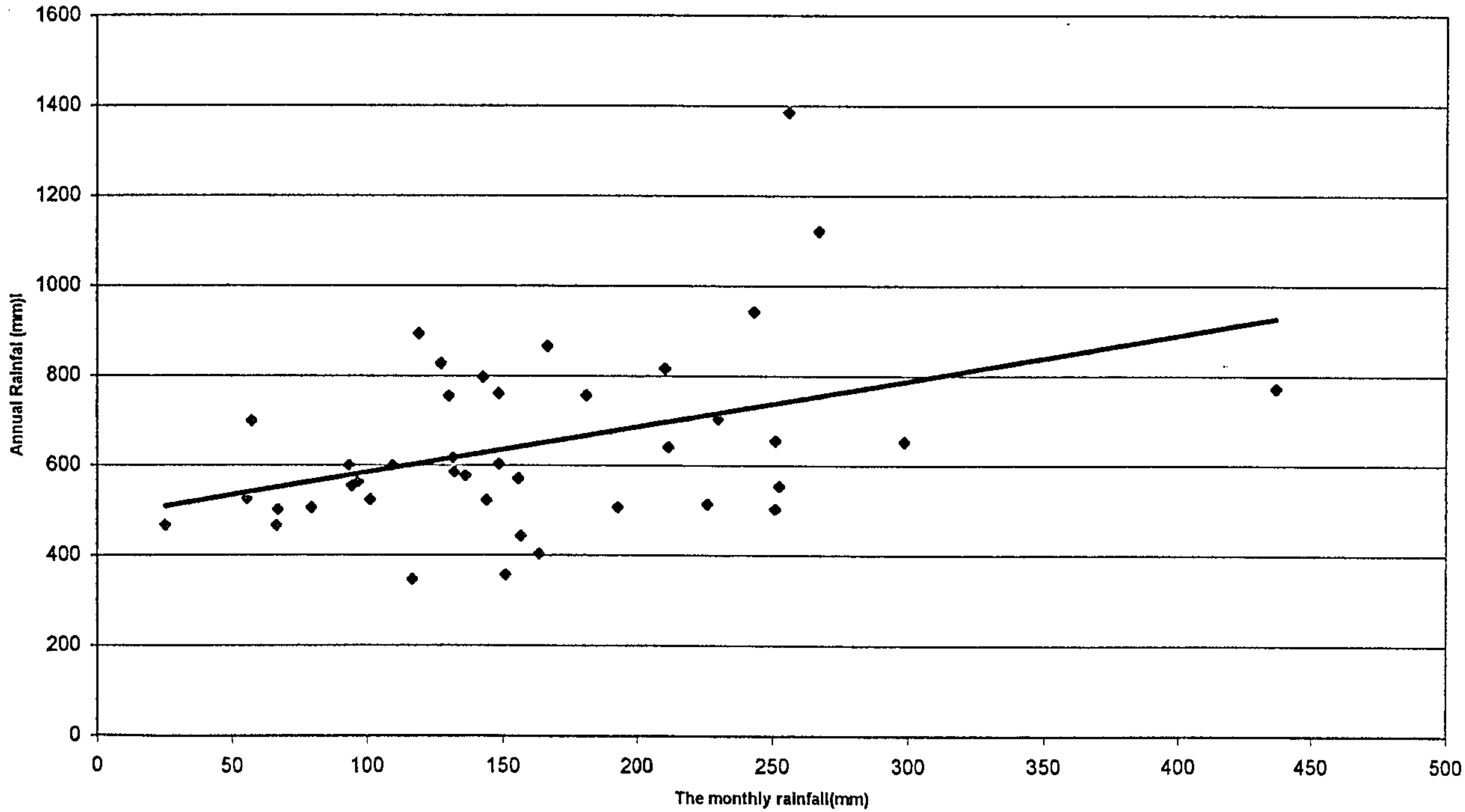


Fig 4.11 Relation between monthly and annual rainfall for February for the period of 1954 to 1998

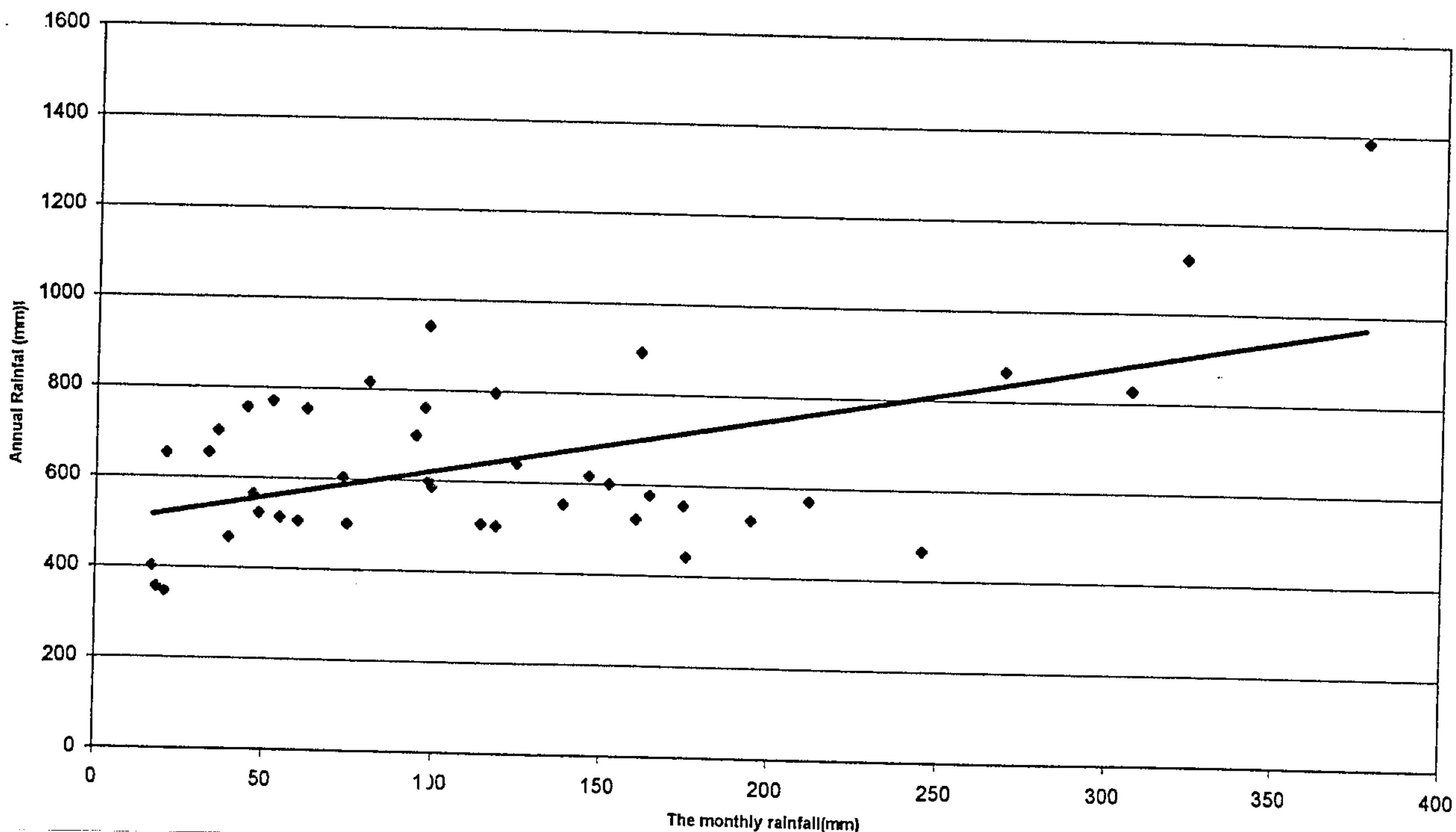


Fig 4.12 Relation between monthly and annual rainfall for March for the period of 1954 to 1998

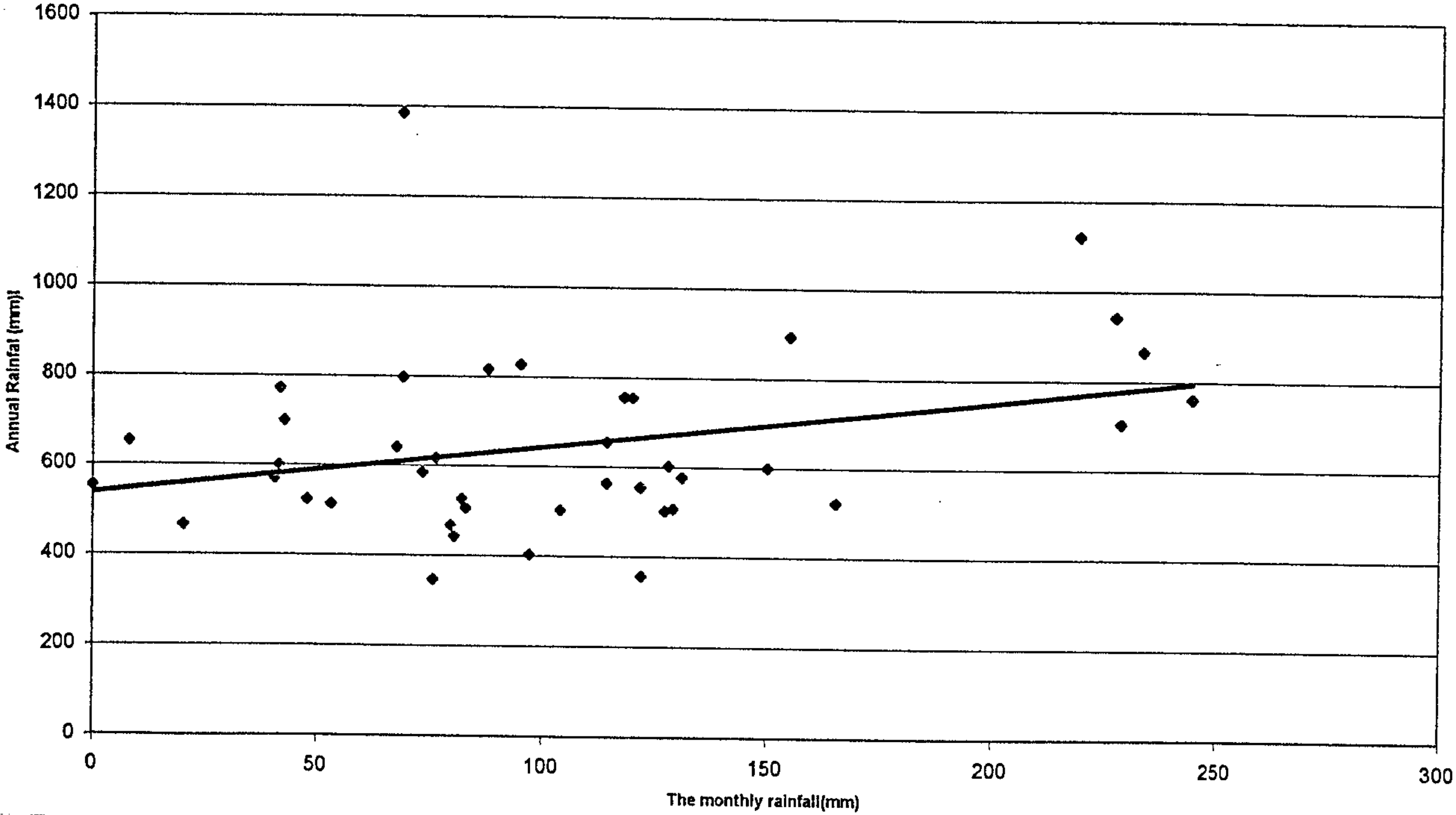


Fig 4.13 Relation between monthly and annual rainfall for April for the period of 1954 to 1998

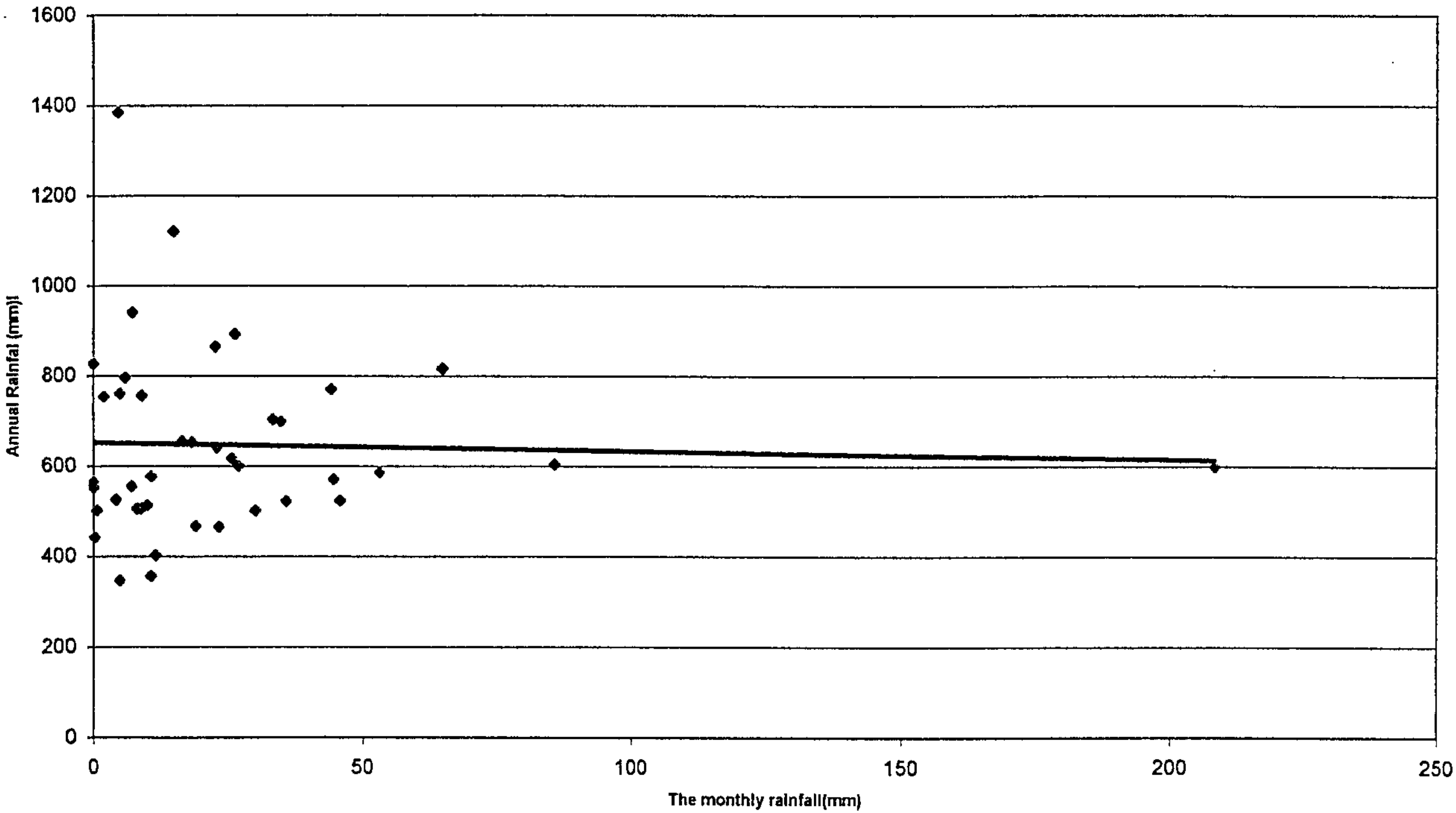


Fig 4.14 Relation between monthly and annual rainfall for September for the period of 1954 to 1998

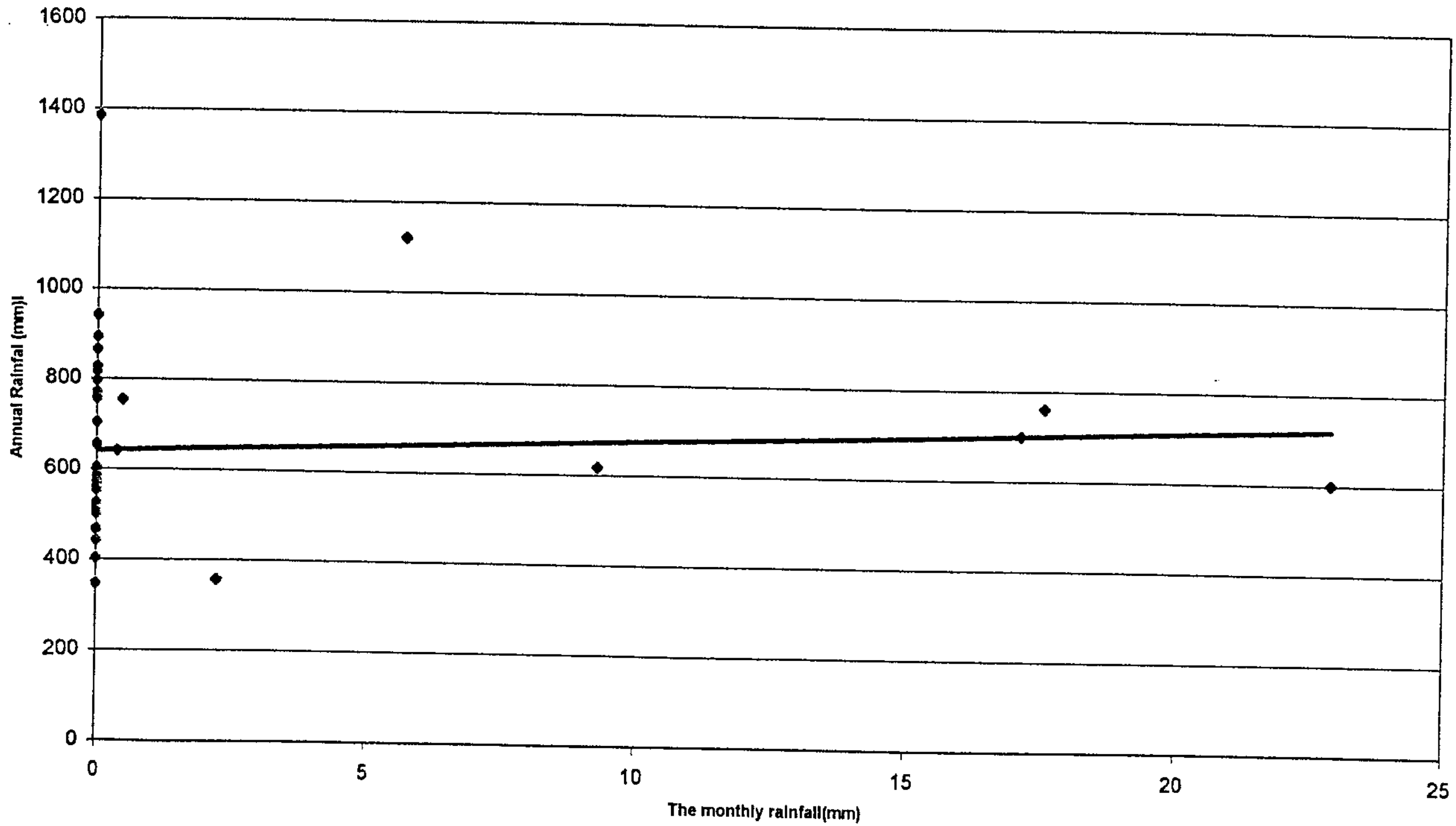


Fig 4.15 Gumble distribution for maximum daily rainfall for Nablus district

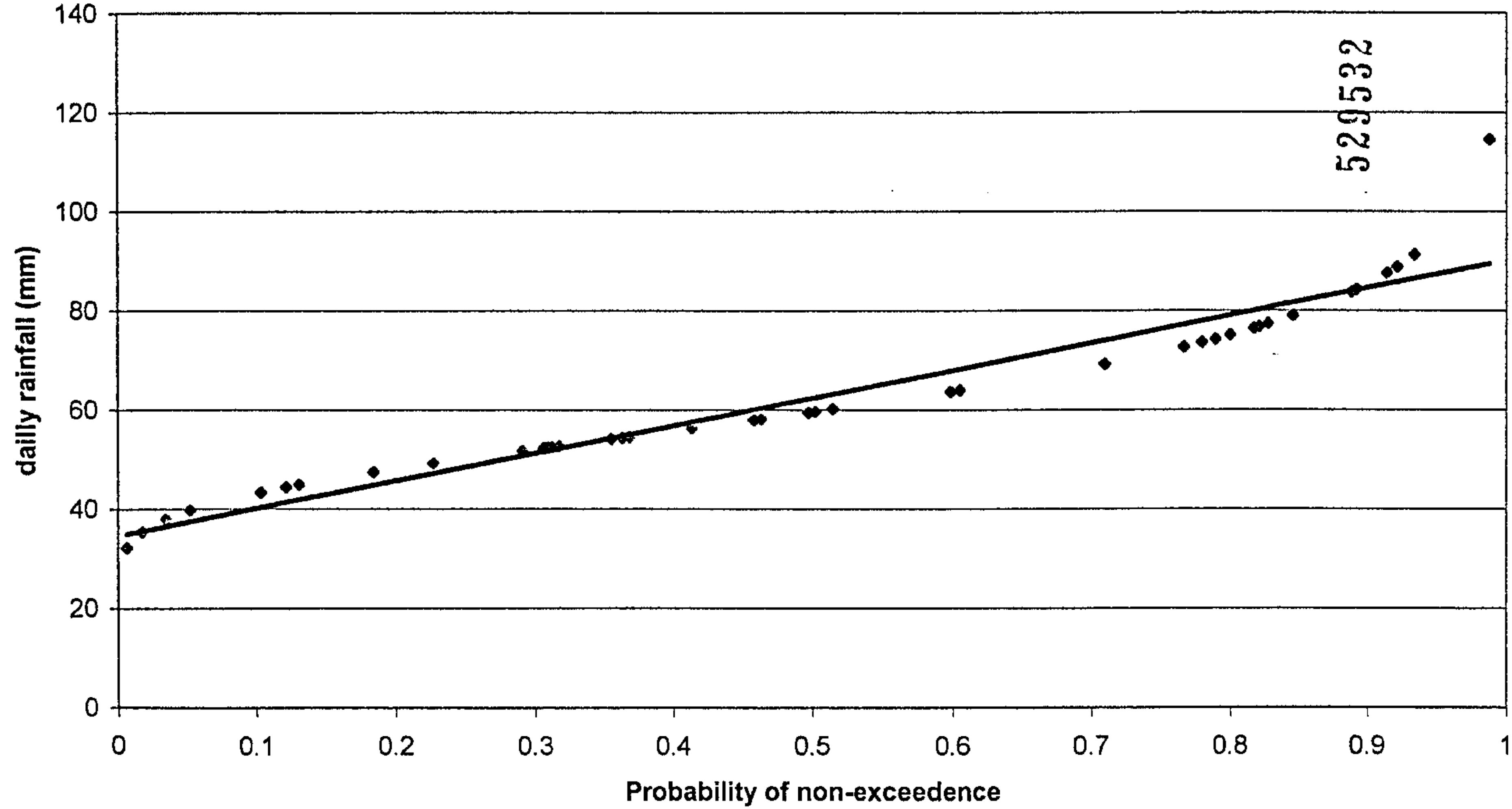


Fig 4.16 The variation of daily rainfall of December for Nablus district for the period of 1954-1998 (avg no. of rainy days = 10.5)

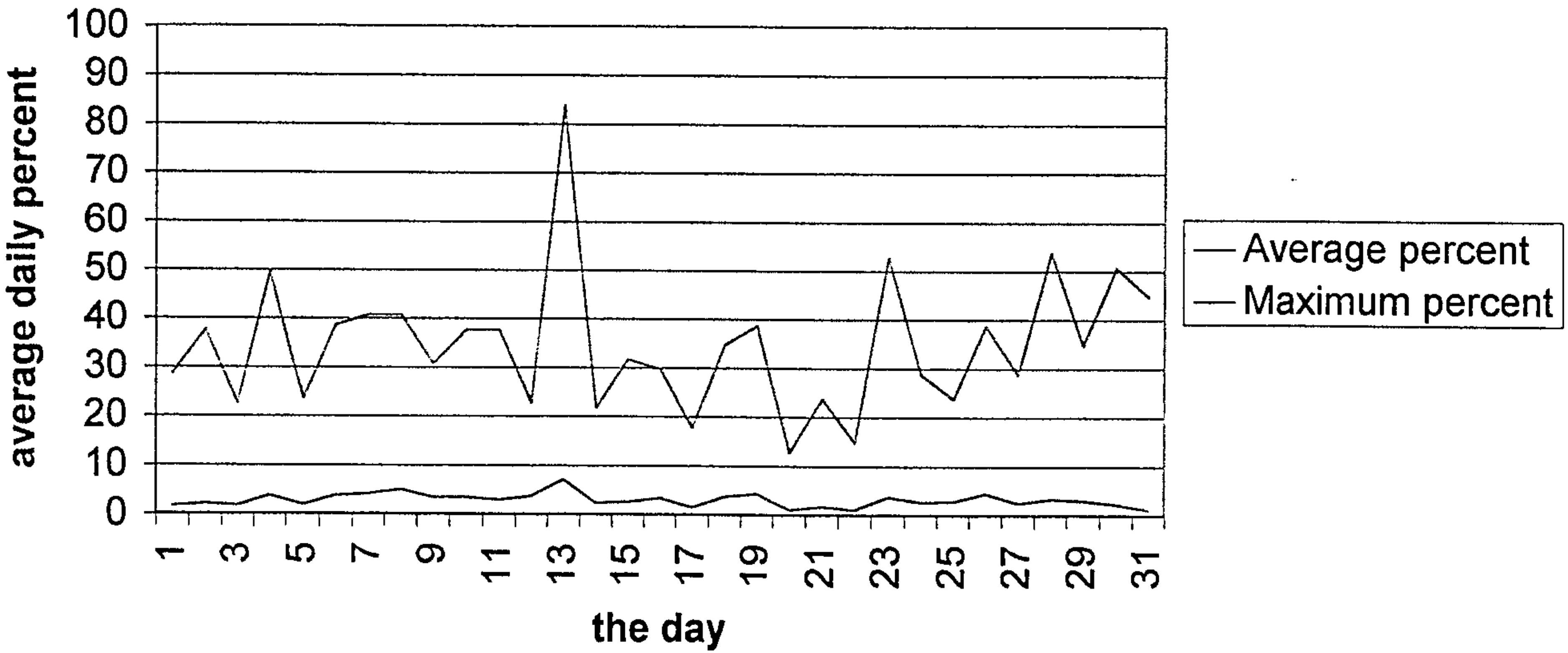


Fig 4.17 The variation of daily rainfall of January for Nablus district for the period of1954-1998(except1961-1964).
(the avg. no. of rainy days =12.5)

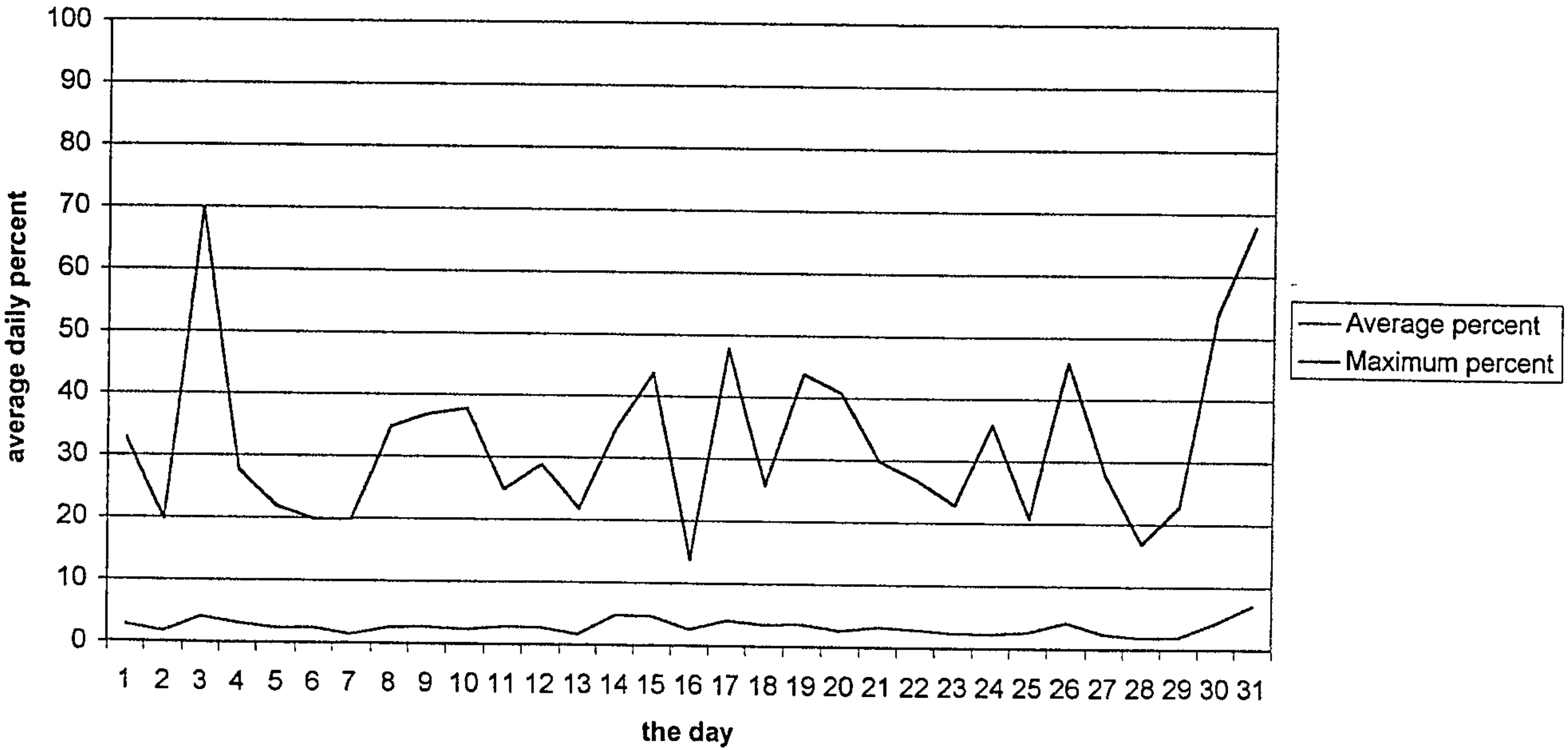


Fig 4.18 The variation of daily rainfall of February for Nablus district for the period of 1954-1998(except(1961-1994).
(the avg. no. of rainy days = 10.7)

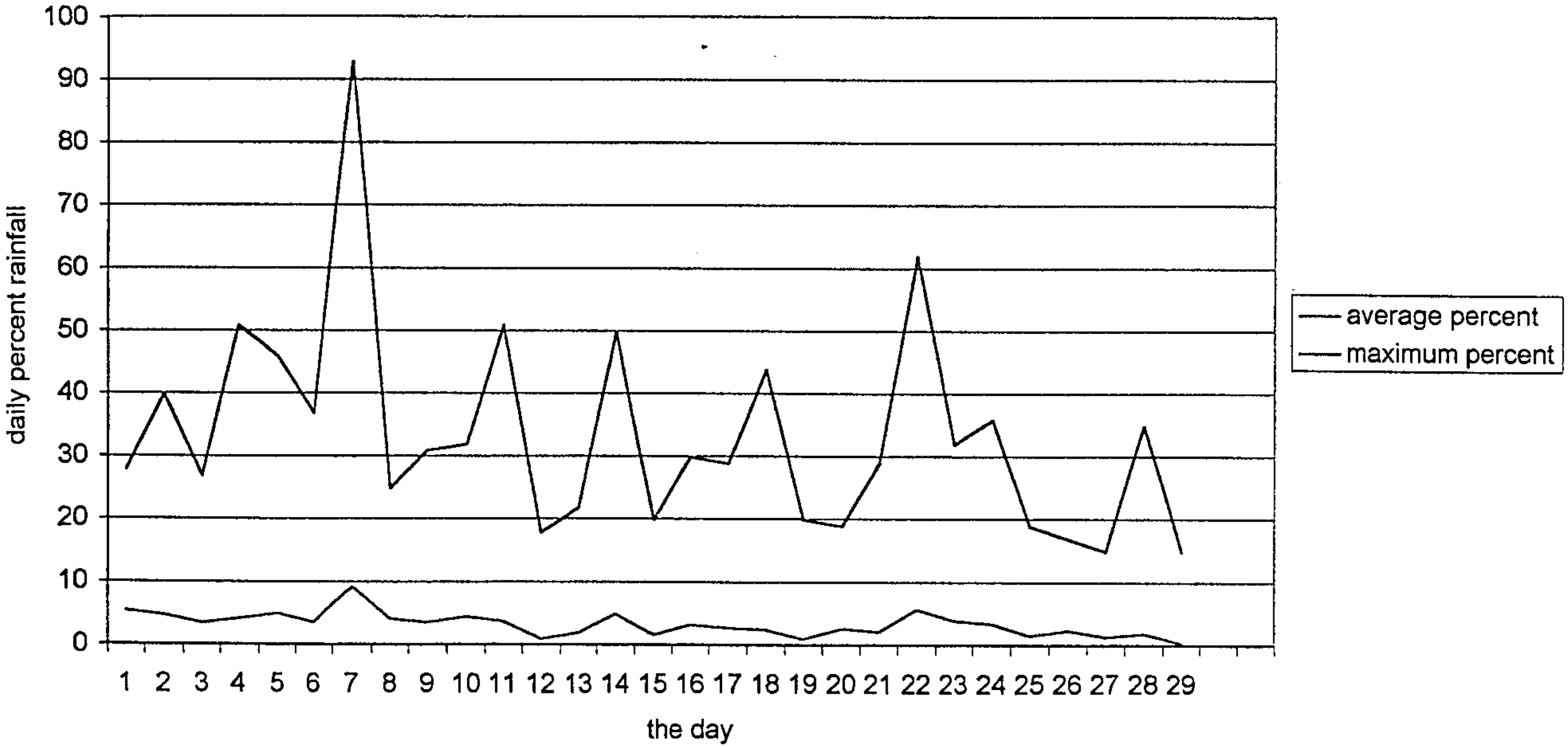
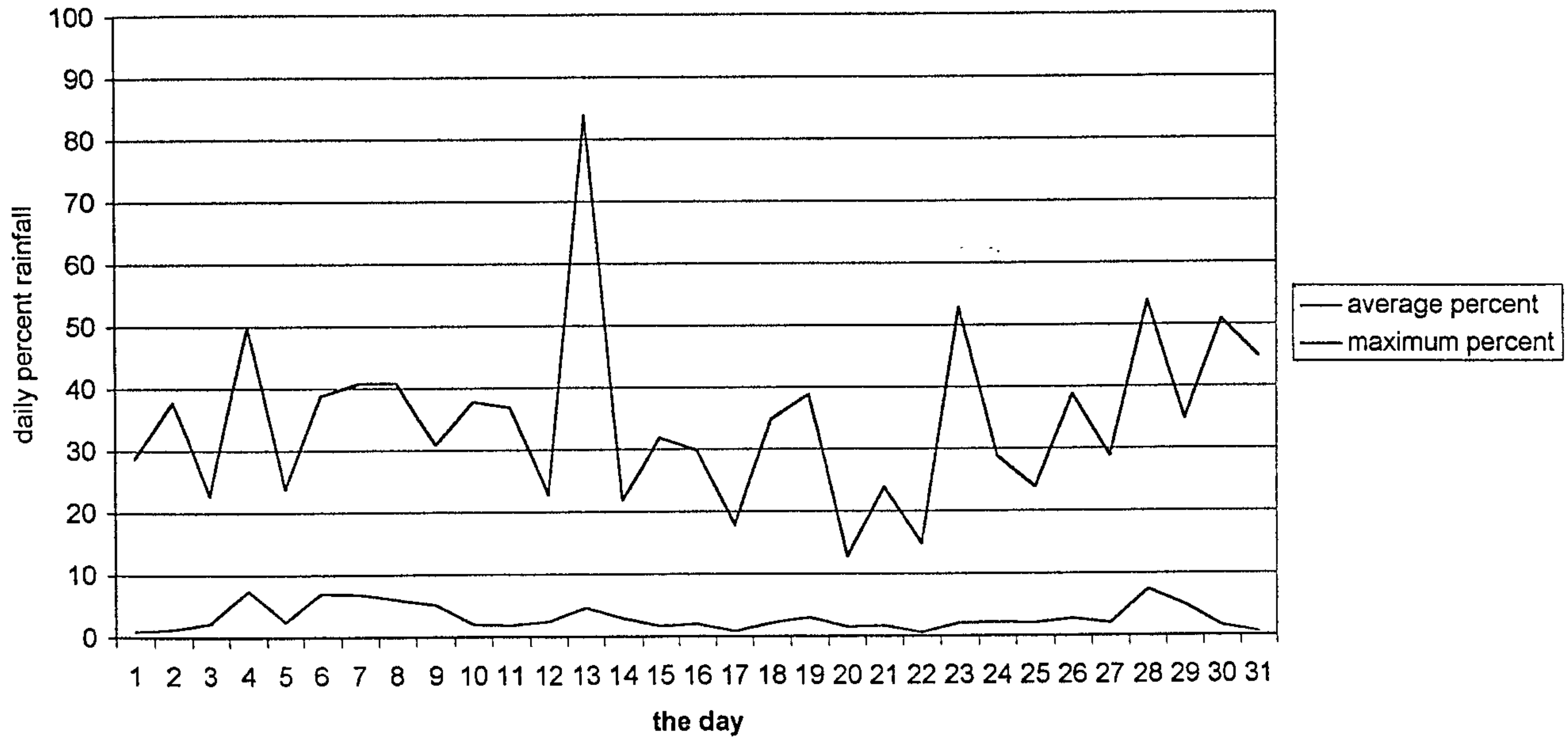


Fig 4.19 The variation of daily rainfall of March for Nablus district for the period of 1954-1998(except 1961-1964).
(the avg. no. of rainy days= 9.43)



5. Rainfall – Runoff relationship

5.1 Introduction

The relation between rainfall and runoff is useful in both the studies of surface and ground water and for the design of storm water runoff pipe system, culverts and small open channels. This relation also, can be used for hydrological planning and for the design of dams. In ground water it is useful for the estimation of the amount that percolates into the aquifers. The graph of excess rainfall vs. time, or excess rainfall hyetograph (ERH), is a key component of the study of rainfall- runoff relationship. The difference between observed and excess rainfall is termed abstractions, or losses. These losses are primarily water absorbed by infiltration with some allowance for interception and surface storage. The excess rainfall hetograph may be determined from hyetograph in one of two ways, depending the availability of stream flow data. In most hydrologic systems, the stream flow hydrograph is not available and the abstractions must be determined by calculating infiltration and accounting separately for other forms of abstraction, such as interception, and detention or depression storage.

5.2 Runoff measurement

Since there are no records of runoff for the studied area, measurements must be taken. Firstly the boundary of the catchment area was defined and its area was measured at 3.3 square kilometer. Figure 5.1 shows the boundary of catchment area and the path of Rujip wadi.. In order to measure the runoff, a rectangular sharp weir was designed as shown in figure 5.2. This weir was placed perpendicular to the sides and bottom of a straight channel at some point near the outlet of Rujeep catchment near the employee housing project. The sharp crested weir was used although the site has the problems of sediments. It was intended to use the weir for both flow

Fig 5.1 The boundary of the catchment area and the path of Rujib Wadi.

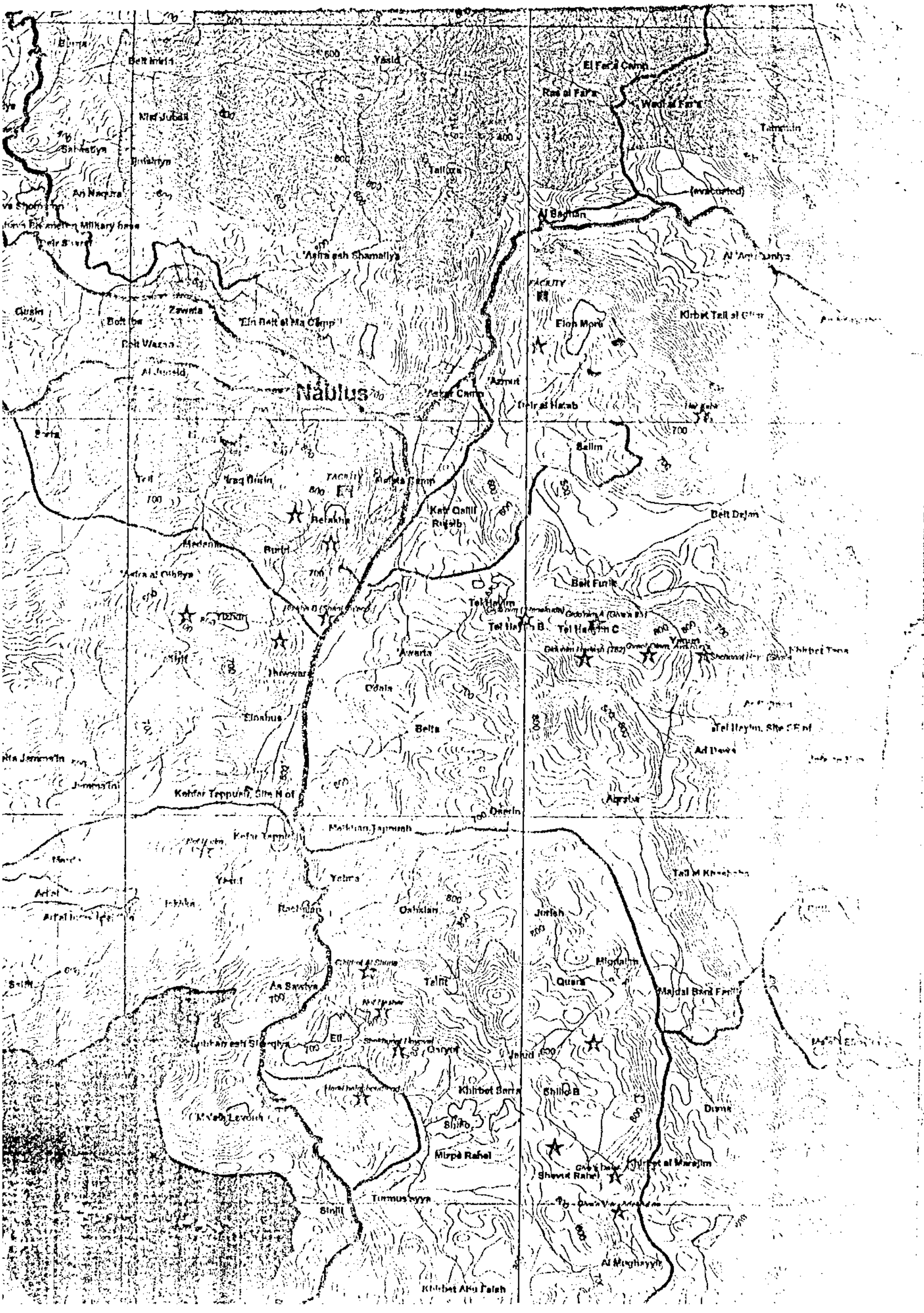
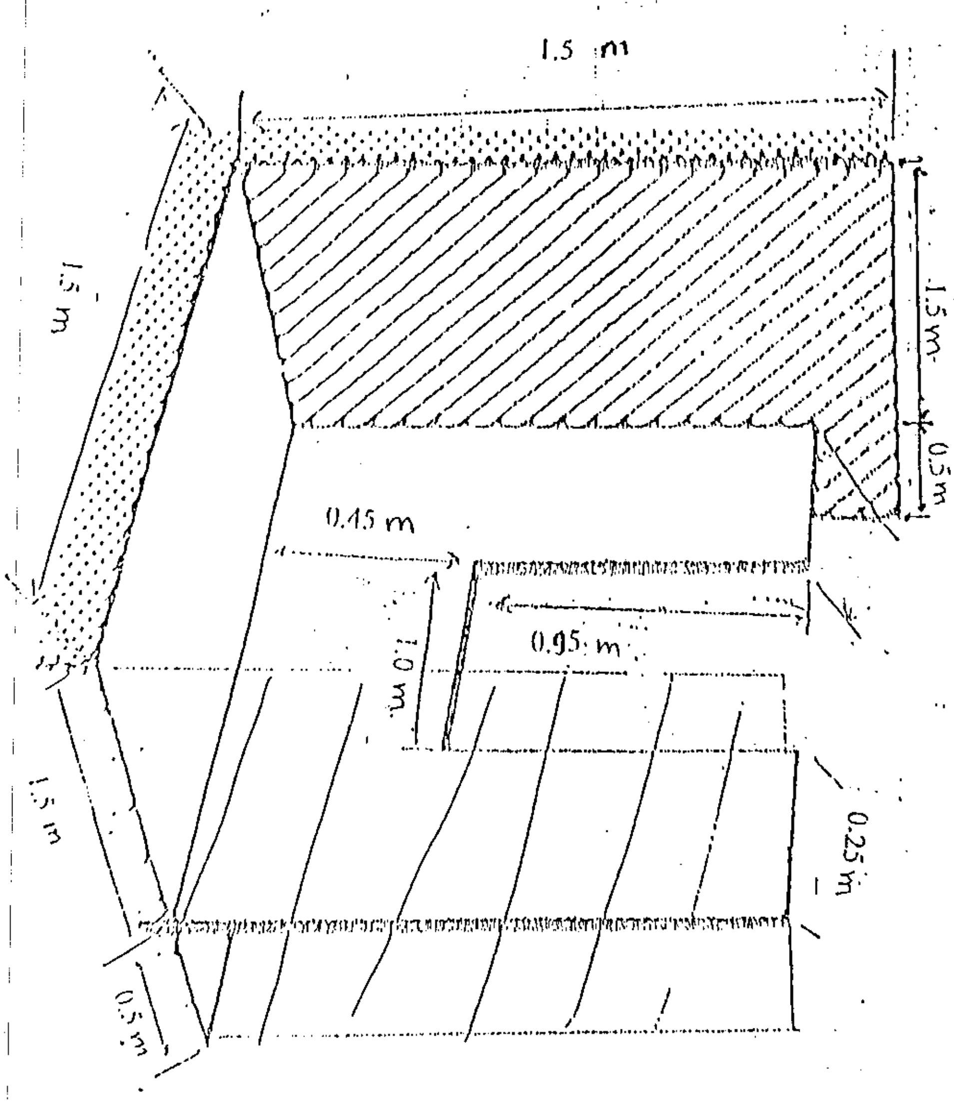


Fig 5.2 A rectangular sharp weir installed in Rujib Wadi



and sediment measurement. But unfortunately, and due to the reasons mentioned elsewhere, there was no possibility to record proper measurements from the weir during the study period. In the rainy season of the year 1997-98, there was only one rain event where there was a flow in the wadi in March, 19, 1998, but there were no records since there was an erosion near the weir that prevented the measurement.. The measurement was delayed to the rainy season 1998- 1999, but unfortunately, there was no rain event causing the flow.

5.3 Analysis of Runoff related to some rain events:

Since there is no measurement of flow, An attempt was done to study some rain events and to note when the flow was occurred. The chosen events have the rain have the most rainfall amounts from the rainy seasons of 1997 to 2000. For those seasons, five rain events were taken. Figures 5.3, 5.4, 5.5 and 5.6 shows these rain events and their occurrence. For the first event (December, 1997), there was no flow in the wadi and the maximum 24-hr rainfall of that event was 52.5 mm and the maximum 18-hr rainfall was 48.5 mm. For the second event (January, 1998), there was no flow and the maximum 19-hr rainfall 42-mm. The third rain event (March, 1998) has a runoff after 40-hr of 72.1 mm precipitation and the maximum 18-hr rainfall was 60 mm which causes the flow. According to the fourth event (January, 2000)there was runoff in the wadi, and the maximum 24-hr rainfall was 66 mm but the time of runoff beginning was not known. Finally, the fifth rain event (February, 2000) caused a runoff in the wadi and the maximum 18-hr rainfall was 56 mm but the runoff began after 15-hr from the beginning of rainfall with 48.5 mm from 56 mm (the total rainfall of that event). This value is approximate as that can be taken from the third event where is a flow (48.2 mm for 15-hr). Figure 5.7 shows the five events and the occurrence of runoff. From the fifth event and as the rainfall stopped completely after

Fig 5.3 Rainfall data for the rainstorm of December 18-19,1997

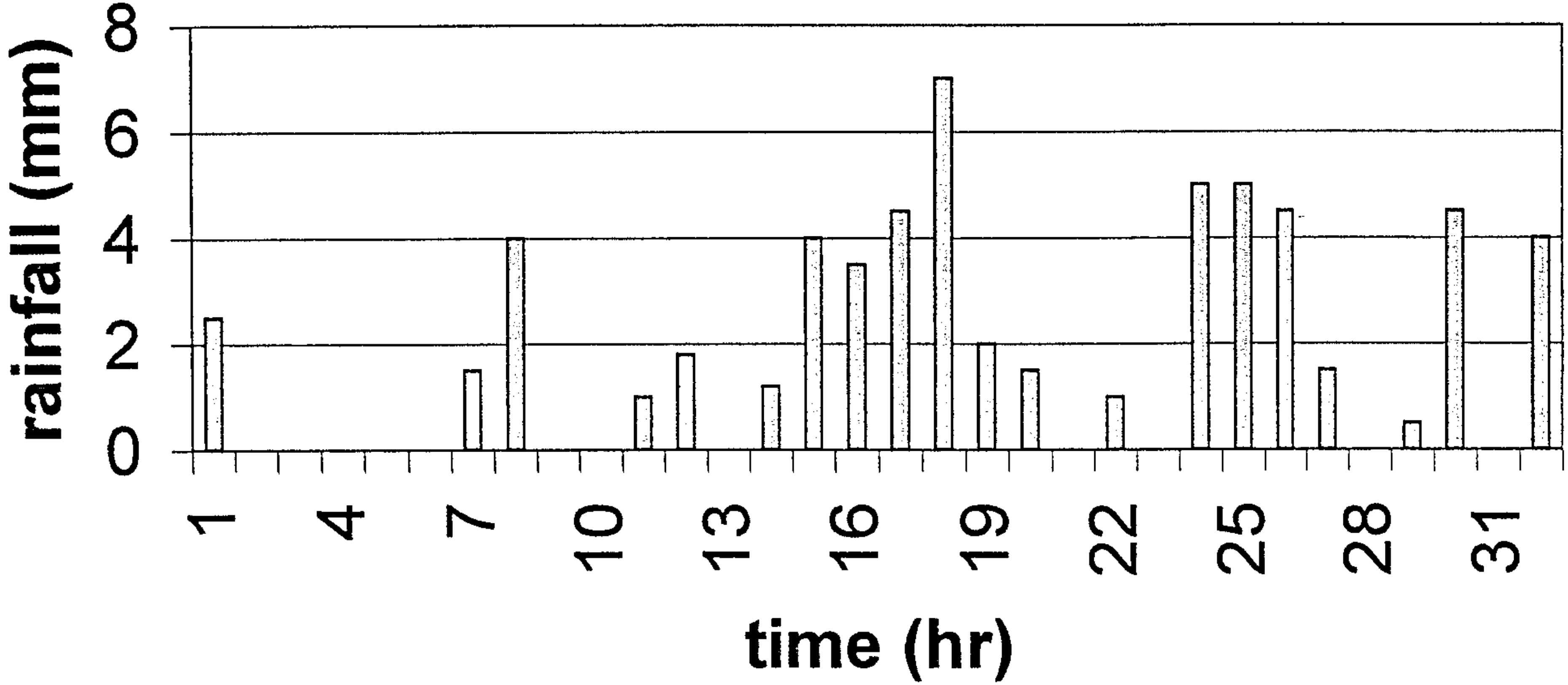


Fig 5.4 Rainfall data for the rainstorm of January 24-25,1998

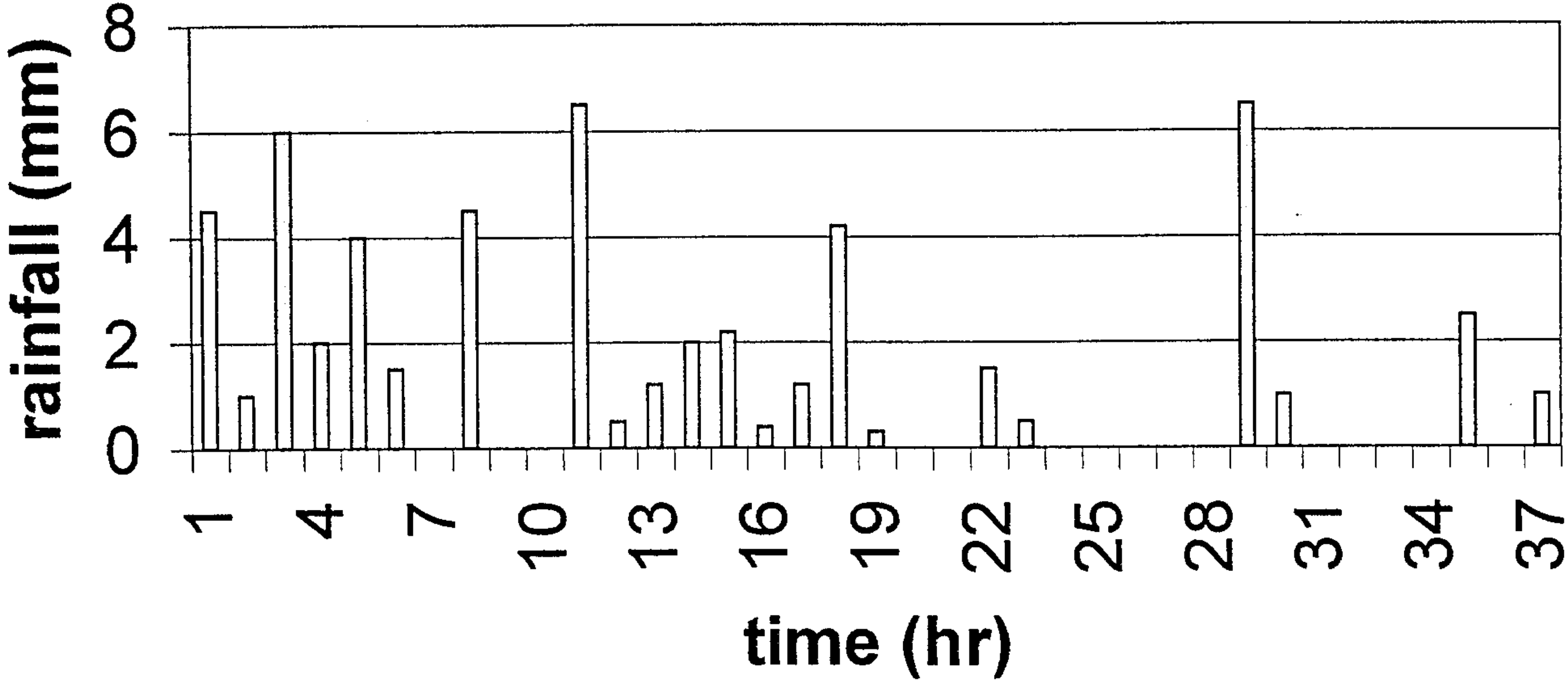


Fig 5.5 Rainfall data for the rainstorm of March 16-19,1998

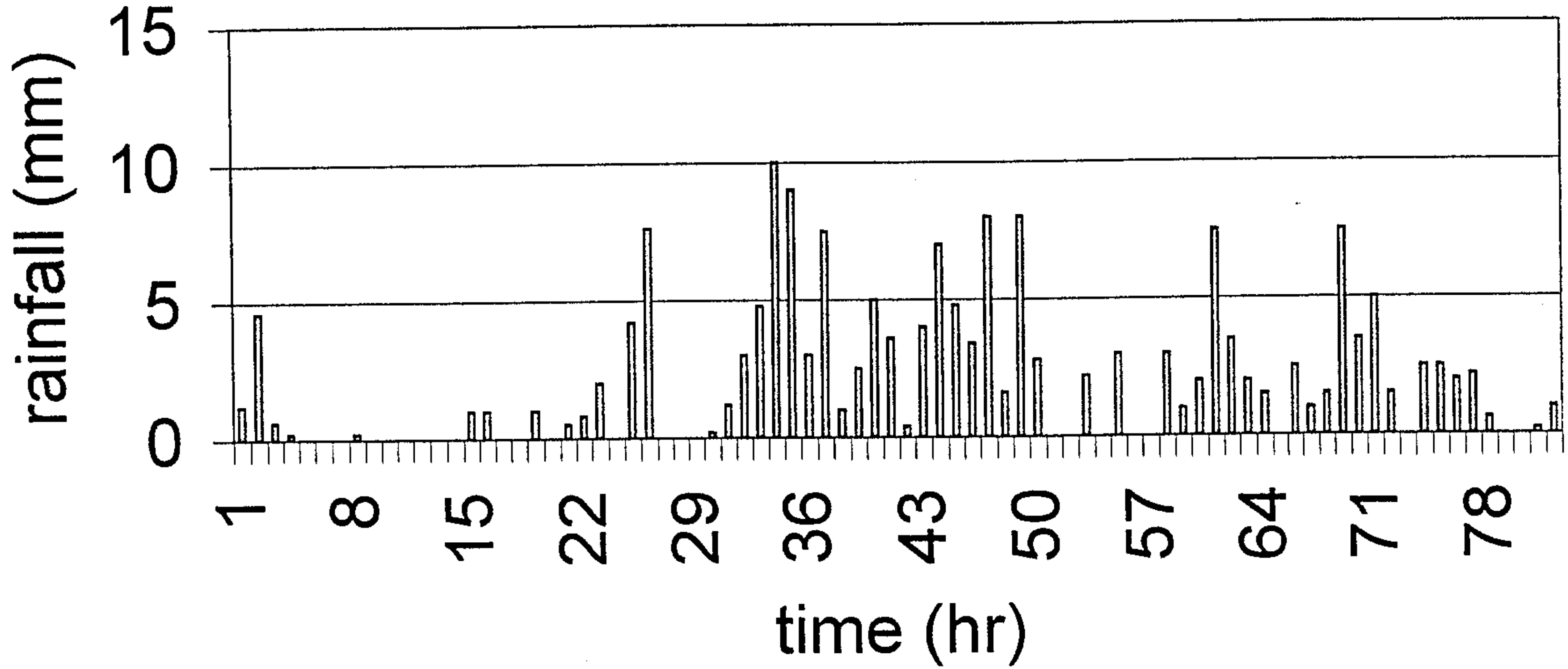
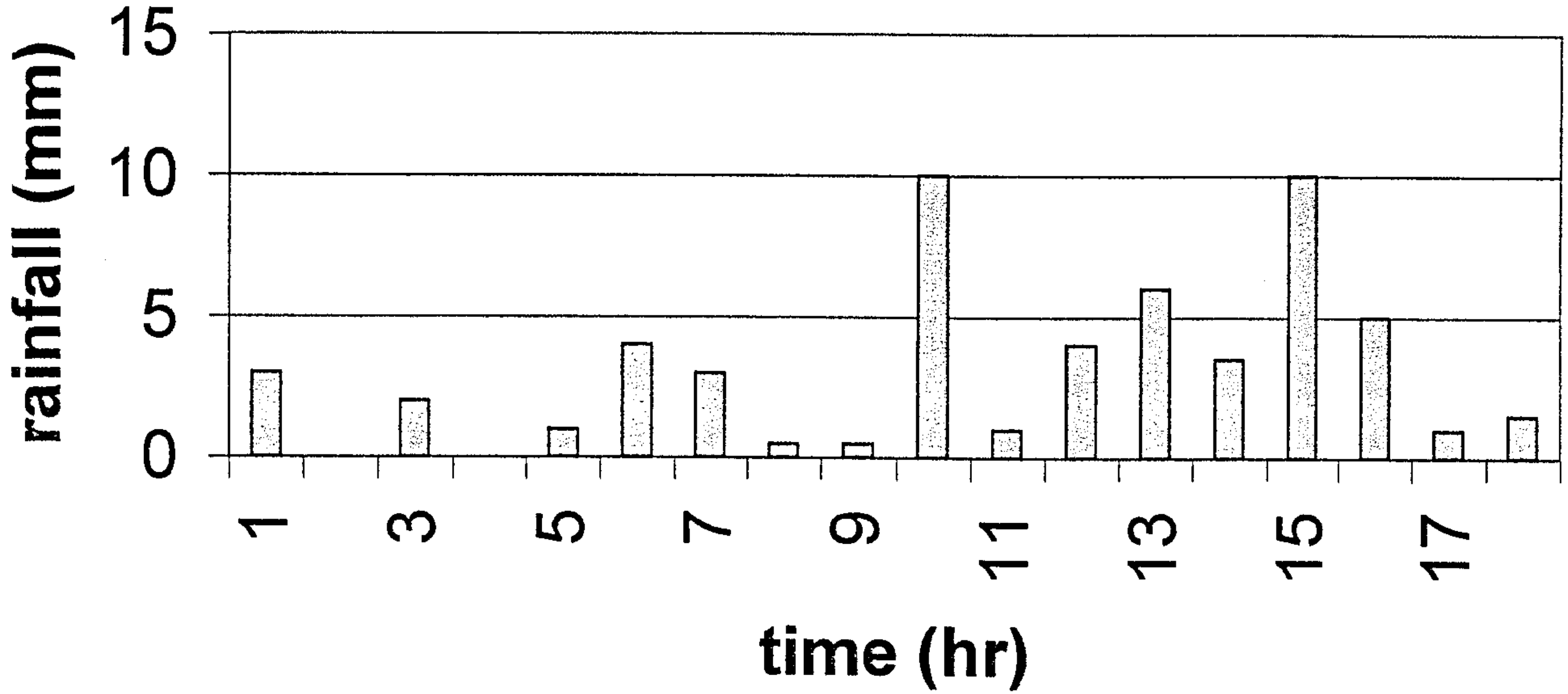
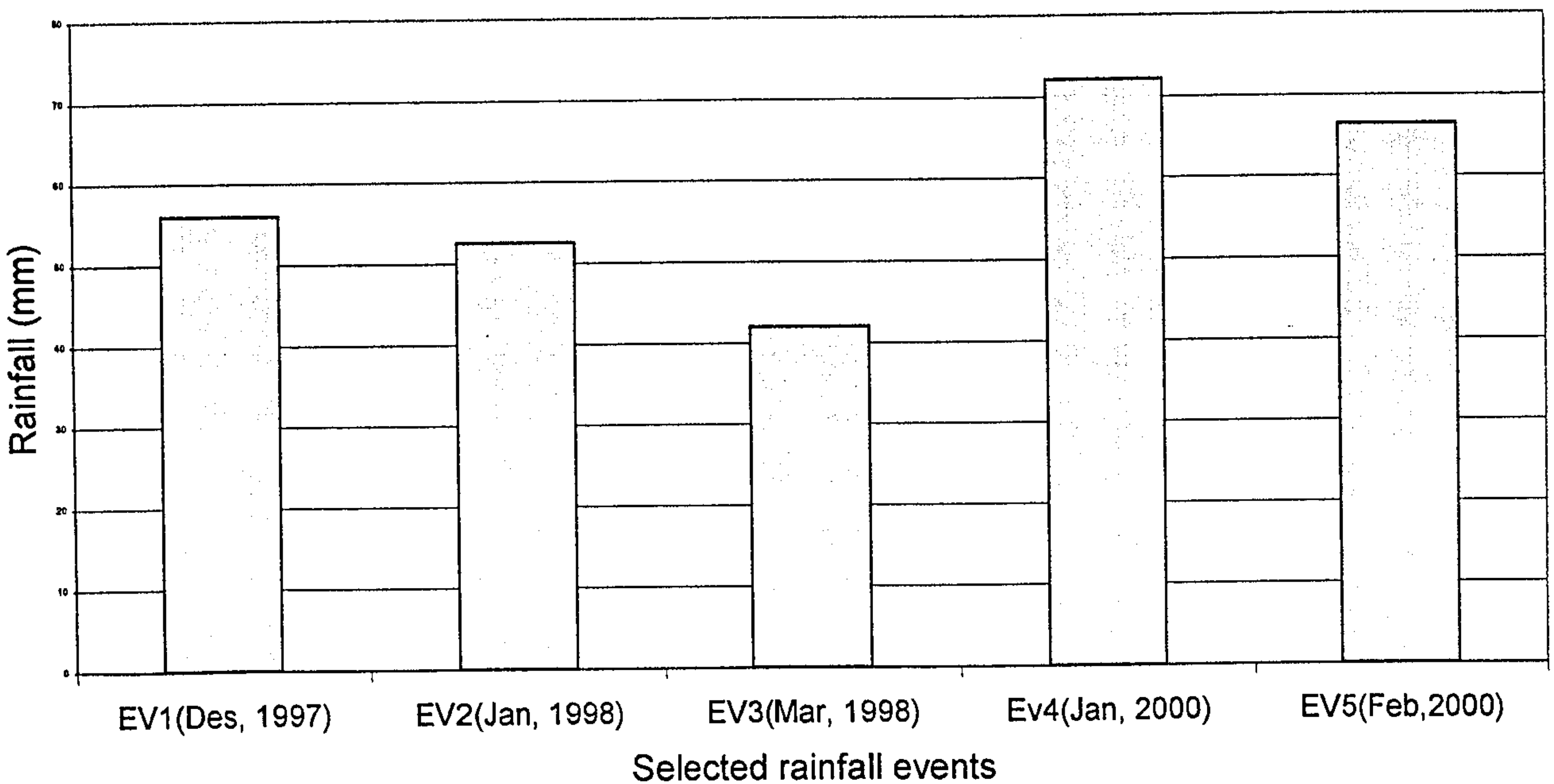


Fig 5.6 Rainfall data for the rainstorm of February 12-13, 2000



Flg 5.7 The chosen rain events for the study of rainfall - runoff relationship



This ratio is higher than the ratio found by Rofe and Raffety in 1965 but it is in the rang found in PHG,1995 (0.1- 16.5%). This ratio will be less tan 13.5% after releasing the infiltration and other losses. From the above figures it can be said that the runoff will be occur after 48.5 mm of duration of 15-hr.

5.4 Synthetic Unit Hydrograph

The majority of catchments are ungaged, and hence it is of great practical importance to have a procedure by which a unit hydrograph may be constructed for an ungaged catchment. In our case and as there was no data for runoff, a synthetic unit hydrograph is developed. There are three types of synthetic unit hydrograph (Chow, 1988): (1) those relating hydrograph characteristics (peak flow rate, base time, etc.) to watershed characteristics (Snyder, 1938; Gray, 1961), (2) those based on a dimensionless unit hydrograph (Soil Conservation Service, 1972), and (3) those based on models of watershed storage (Clark,1943).

In our case, SCS method will be applied.

SCS Method

A method developed by the Soil Conservation Service for constructing synthetic unit hydrographs is based on a dimensionless hydrograph Fig.5.8. This dimensionless graph is the result of an analysis of a large number of natural unit hydrographs from a wide range in size and geographic locations. The basic procedure of the SCS method for estimating runoff as reported in SCS (1972) can be summarized as follows:

(a) Determine the watershed area A (in mi^2) and slope (in percent).

(b) From table 5.1, the flow velocity V would be estimated. Then time of concentration in hours computed using

$$Tc = 1/60 * \sum_{i=1} \frac{lj}{vj} \qquad (5.1)$$

(c) The time of peak discharge, Tp in hr, from the beginning of the rise of the hydrograph, would be estimated by

$$Tp = tr/2 + 0.6\ tc \qquad (5.2)$$

where tr is the duration of the effective rainfall. If tr is equal .133 tc as suggested by SCS, then

$$Tp = 0.67\ tc \qquad (5.3)$$

(d) The peak discharge, $q_p = 2.08 \frac{A}{T_p}$ (5.4)

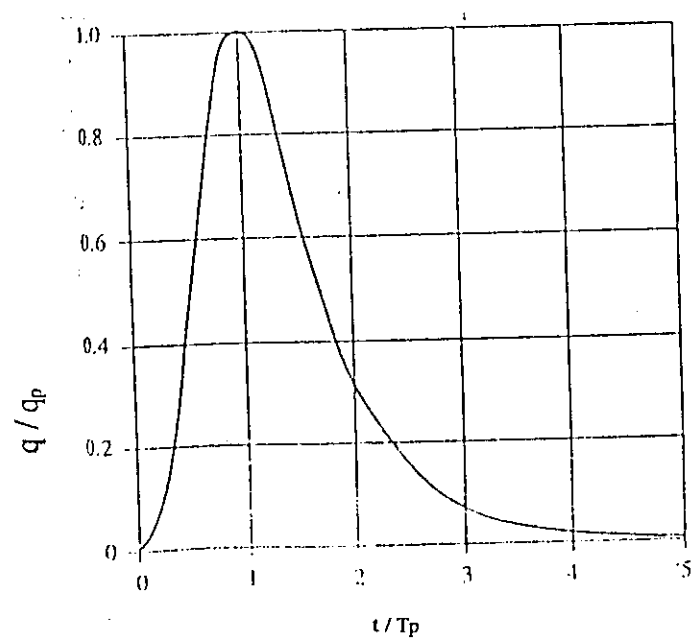
Where A is in km², q_p in m/ s.cm, and Tp in hr.

(g) The direct runoff hydrograph can then be established by using the nondimensional hydrograph shown in figure

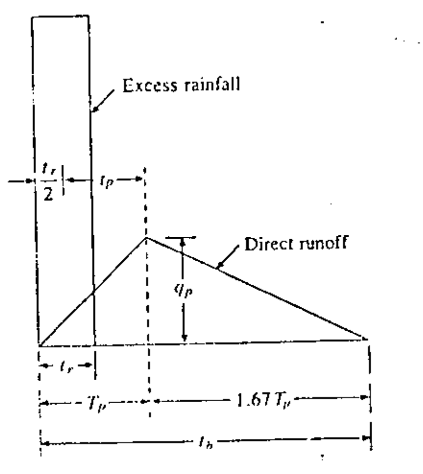
Table 5.1 Approximate average velocities in ft/s of runoff flow for calculating time of concentration (Chow, Applied hydrology,1988)

Description of water course	Slope in percent			
	0-3	4-7	8-11	12-
Unconcentrated				
Woodlands	0- 1.5	1.5- 2.5	2.5-3.25	3.25-
Pastures	0- 2.5	2.5- 3.5	3.5- 4.25	4.25-
Cultivated	0- 3.0	3.0- 4.5	4.5- 5.5	5.5-
Pavements	0- 8.5	8.5- 13.5	13.5-17	17-
Concentrated				
Outlet channel-determine velocity by Manning"s formula				
Natural channel				
Not well defined	0- 2	2- 4	4- 7	7-

Fig 5.8 Soil Conservation Service synthetic unit hydrograph (a) dimensionless hydrograph and (b) triangular unit hydrograph. (Chow, Ven, Te. Applied Hydrology, 1988)



(a)



(b)

In order to develop a synthetic unit hydrograph for Rujib catchment, the following calculations were found:

The mountains area a = 3 km^2 and the flat area a = 0.3 km^2, thus the total area = 3.3 km^2.

tr = 1 hr.

$tc = 1/60 * \sum \frac{L}{V}$

The rainfall path was divided into segments and the length and slope for each segment was found

From Table 5.1 the velocity for each segment was found. Table 5.2 shows the length of segments of the area and the slope and the velocity.

Table 5.2 The length of segments of the runoff bath and their slope and velocity.

The length L, ft	Slope s, %	Velocity V, (ft/sec)
700	10	3.8
300	10	3.8
1000	0.4	1
900	0.2	1

From the above table the time of concentration was computed at 1.971 hr.

Lag time = 0.6 * tc = 0.6 * 1.971 = 1.182 hr.

The rise time Tp = tr/2 + tp = 1.682 hr.

qp = 2.08 * 3.3 /1.682 = 4.08 m^3/ s.cm

The triangular unit hydrograph can be drawn with tb = 2.67 Tp = 4.49 hr. To check the unit hydrograph

The area of the triangle = ½ * 4.08 * 4.49 = 32974.56 m^3/cm

To check the depth of direct runoff, the catchment area * 1 cm = 33000 m^3

32974.56/33000 = 1

The dimensionless hydrograph in fig 5.8 may be converted to the required dimensions by multiplying the values on the horizontal axis by Tp and those on the vertical axis by qp.

areas

(a) The peak flow occurs at t/tp = 1 or t = 1.682

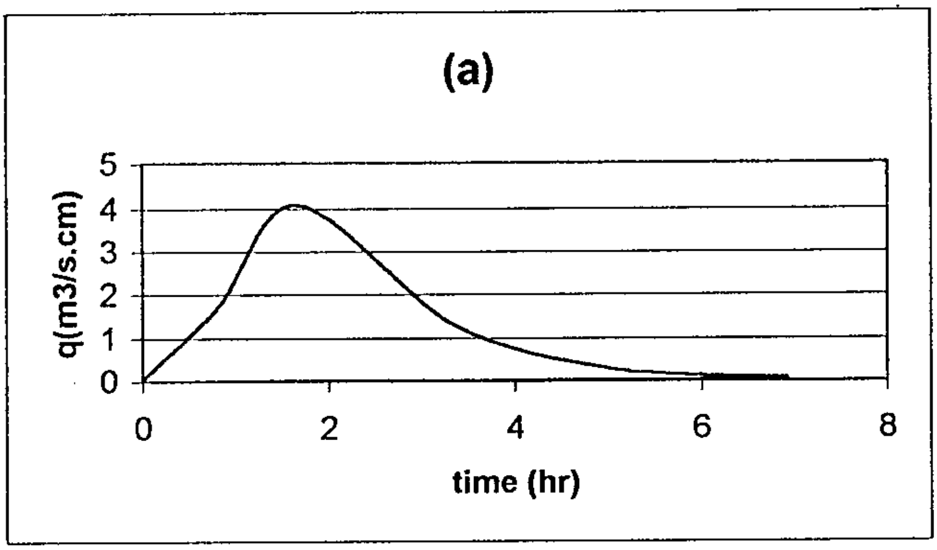
(b) The hydrograph ordinates are

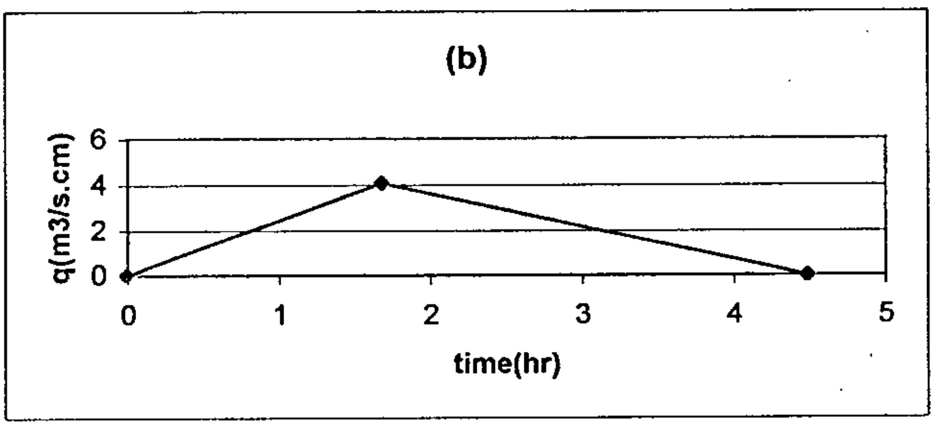
At t / tp = 0.5 , q / qp = 0.43 thus t = 0.84 and q = 1.75

t / tp = 2 , q / qp = 0.32 thus t = 3.364 and q = 1.31

t / tp = 3 , q / qp = .07 thus t = 5.046 and q = 0.28

Fig 5.9 Soil Conservation Service synthatic unit hydrograph for Rujib
Rujib catchment (a) the estimated hydrograph
(b) the triangular unit hydrograph





6. Results and conclusions

The analysis of the rainfall data of Nablus district was done in this study in two different dimensions. The first dimension includes the rainfall analysis where the annual, monthly and daily rainfall data were collected and analyzed. The second includes the analysis for some selected rainstorms to develop an ideas of the relationship between rainfall and runoff.

From the analysis of rainfall for the years of 1996-1997 and 1997-1998, the IDF curves were estimated. Initially the available rainfall plots of the two years were used to estimate the IDF curves depending on the rainfall of different duration's and on the estimated return periods. Lately the IDF were further developed. The IDF curves developed using the storms of the available two years data were compared with the only curves that was made available from Israeli sources. The comparison has proved that for short return periods the produced IDF curves using the above method gives correct figures. For Large return periods the difference between the produced curves and that published by the Israelis is found high. Nevertheless, producing IDF curves from limited available data (two year for our case) can be accepted for designing water system of shorter return periods. For large return period, these curves can be used as an approximate.

The annual rainfalls for the period of 1954-1998 were analyzed. From the annual rainfall analysis, it is found that the average annual rainfall for Nablus district has been calculated at 648 mm and the maximum annual rainfall for the last 44 years was 1387 mm. The deviation of the annual rainfall from the average is larger for the rainfall of wet years than those of dry years. It is found that the number of wet years in the second half of the years is more than the number of the first half as can be seen in fig 3.10. The number of successive dry years is larger than the number of successive wet years as shown in figures 3.11 and 3.12. The Poisson process and exponential distribution were used to describe the time between the wet and dry years. Gumble distribution shows the best fit for the annual rainfall for Nablus district.

For the monthly rainfall analysis , it is found that:

-The maximum monthly percent rainfall has been found for January and December and this is shown in figure 3.17.

-The analysis of monthly rainfall reveals that 30 percent of rainfall of the wet season was in the maximum rainy month of that season. Also it is found that the monthly rainfall was in the same style and there is no big shift in the distribution of monthly rainfall as shown in figure 3.19.

-The confidence limits of monthly rainfall were determined. This enables to except the monthly distribution when the annual rainfall was known as shown in figure 3.20. This result was checked by the rainfall of 1998-1999 and it was applicable as shown in figure 3.21.

It is found that there is a trend in the annual rainfall as shown in figures 3.23 and 3.24 which represents the 5-year and 10-year moving averages.

For the runoff analysis, it was found that:

-Runoff of Rujib Wadi when the rainfall exceeds 48.5mm for successive 15-hr.

-The ratio of runoff to rainfall will be 13.5 percent and this is in the range of 0.1-16.5 percent found in PHG, 1995.

Recommendations:

1. Develop a model that can be used to for producing IDF curves using the limited available data in the Palestinian areas.
2. Develop a runoff – rainfall model depending on the IDF curves which could be then used to verify these curves.
3. The stochastic models can be applied to the annual rainfall data to classify the time independent or time correlation.
4. To conduct field runoff measurement to find the exact runoff – rainfall ratio and to develop unit hydrograph for the catchment.

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Appendix

(Table 1… continued)

890	11	23	42.5	40.5	51.5	10	31.5	49	
900	11	23	43.5	40.5	51.5	10	32	49	
910	11	23	45	40.5	52	10	32.2	49	
920	12	23	45.2	40.5	53	10	32.2	49	
930	15	23	46.5	42	54.5	10	32.2	49	
940	16	23	46.5	42.5	55	10	32.2	49	
950	16	23	47	43	55	10	32.2	49.5	
960	16	23	47	45	55	10	32.2	50	
970	16	24	47	46	55	10	32.2	50.5	
980	16	24	48	46.5	56	10	32.2	51	
990	16	24	48.5	47	57	10	32.2	52	
1000	18	24	48.5	48	59	10.8	32.5	53	
1010	19	24	52	49	59	10.8	33	53	
1020	20	24	52.2	50	59	10.8	33.5	53	
1030	21	24	52.2	51	59	10.8	33.8	53	
1040	21.5	24.5	52.5	52	59	10.8	34	53	
1050	23	24.5	52.5	52.5	59	10.8	34.7	53	
1060	23.5	25	52.8	53	59	10.8	35	53	
1070	24	25	52.8	53	59	10.8	35	53	
1080	24	25	53	54	59	10.8	35	53	
1090	24		53.5	55	59	10.8	35.2	53	
1100	24		55	55	60.5	10.8	35.2	55	
1110	24.5		56	55	60.5	10.8	35.3	56	
1120	25		57	56	60.5	10.8	35.5	57	
1130	31		57	56	60.5	10.8	36.5	57.5	
1140	31.5		57	56	60.5	11.2	36.5	58	
1150	32		57	56	60.5	11.2	36.5	58.5	
1160	33		57	56	60.5	11.2	36.5	59	
1170	33		57	56	60.5	11.2	36.5	59.5	
1180	33		57.2	56	60.5	11.2	37.5	60	
1190	33		57.2	56	60.5	12	37.5	61	
1200	33		58	57	62	12	39	62	
1210	33		59	58	62	12	40	63	
1220	34		59	60	62	12	44.2	64	
1230	34.5		59	61	62	12	44.5	64	
1240	34.5		59	63	62.5	12	44.8	64	
1250	34.5		59	64	62.5	12	45	64.5	
1260	34.5		60	65	62.5	12	45.5	65.5	
1270	34.5		60.5	67	65	12	45.8	66.5	
1280	34.5		61	69	65.2	12	46.2	66.5	
1290	34.5		61	71	65.5	14	47.7	66.5	
1300	34.5		61	72	66	14	48.5		
1310	34.5		61	73	66.5	14	49		
1320	34.5		61	74	67	14	50		

(Table 1 … continued)

1330	34.5		61	75	68	14	50.5		
1340	35		61	76	68	14	51.5		
1350	35.5		61	77	69	14	52.5		
1360	35.5		61		69	14	53.2		
1370	36		61		69	14	54		
1380	36		61		69	14	54.5		
1390	36		61		69	14	54.8		
1400	36		61		69	14	55		
1410	36		61		69	18	55		
1420	36		61		69	18.5	55		
1430	36		61		69	19	55		
1440	36		61		69	19	55		
1450	37		61		71.5	23	55		
1460	39.5		61		71.5	25.8	55		
1470	39.5		61.5		71.5	25.8	55		
1480	40		62		73	25.8	55.2		
1490	40.5		62.5		73.5	25.8	55.2		
1500	40.5		62.5		74	25.8	55.3		
1510	42		63		75	25.8	55.5		
1520	43		65			25.8	56.5		
1530	45.5		65.5			25.8	57		
1540	45.5		65.8			25.8	57.5		
1550	45.5		66			25.8	57.5		
1560	45.5		67			25.8	57.5		
1570	46		67			25.8	58		
1580	47		67			25.8	59		
1590	47		67			25.8	59.8		
1600	49		67			25.8	60		
1610	50		67			25.8	60		
1620	51		67			25.8	61		
1630	51.5		68			25.8	62		
1640	51.5		68.5			25.8	62		
1650	51.5					25.8	62		
1660	51.5					25.8	62		
1670	51.5					25.8	62		
1680	51.5					25.8	62		
1690	51.5					25.8	63		
1700	51.5					26	64		
1710	51.5					26	64.2		
1720	51.5					26	64.2		
1730	51.5					26	64.2		
1740	51.5					26	64.2		
1750	51.5					26	64.2		
1760	51.5					26	64.8		

(Table 1 ... continued)

1770	51.5					27	64.8		
1780	51.5					27.8	64.8		
1790	51.5					28	64.8		
1800	51.5					28	64.8		
1810	53					29	64.8		
1820	53					29.5	64.8		
1830	55					30	64.8		
1840	57					30.2	65		
1850	57					30.5	65		
1860	57					31	65		
1870	57					32.5	65		
1880	57					33.5	65		
1890	57					34	65		
1900	57					35	65		
1910	57					36	65		
1920	57					38	65.2		
1930	57					40	65.2		
1940	57					41	65.2		
1950	57					42	65.2		
1960	60.5					45	65.2		
1970	61					46	66.1		
1980	61					48	66.2		
1990						49	66.2		
2000						50	66.2		
2010						52	66.2		
2020						54			
2030						55			
2040						55.7			
2050						56			
2060						57			
2070						58			
2080						59			
2090						61			
2100						62			
2110						64			
2120						64.5			
2130						64.8			
2140						64.8			
2150						65			
2160						65.1			
2170						65.2			
2180						65.2			
2190						65.5			
2200						65.7			
2210						66			

(Table 1 … continued)

2220						66.5			
2230						67			
2240						68			
2250						69			
2260						69.5			
2270						70.8			
2280						71.5			
2290						72.7			
2300						73.2			
2310						74			
2320						74.5			
2330						75			
2340						75.5			
2350						76.5			
2360						76.5			
2370						76.5			
2380						76.5			
2390						76.5			
2400						76.5			
2410						76.7			
2420						76.7			
2430						76.7			
2440						76.7			
2450						76.7			
2460						77.2			
2470						77.2			
2480						77.2			
2490						77.2			
2500						79			
2510						79			
2520						80			
2530						81.5			
2540						82			
2550						83			
2560						84			
2570						86			
2580						87			
2590						89			
2600						90			
2610						91			
2620						92.8			
2630						92.9			
2640						92.9			
2650						92.9			

(Table 1 ... continued)

2660						92.9			
2670						93			
2680						93			
2690						93			
2700						93			
2710						96			
2720						97.2			
2730						98.5			
2740						100			
2750						103			
2760						104			
2770						104			
2780						104.2			
2790						104.2			
2800						104.2			
2810						104.5			
2820						105			
2830						105.8			
2840						106.2			
2850						107			
2860						108.5			
2870						109.5			
2880						111			

Table 2: Monthly rainfall (mm) for the period of 1954-1998

The year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
54-55	0	16.5	74	216.4	25.2	39.3	79.6	18.9	0	0	0	0
55-56	0	5.1	257.3	144.1	180.7	44.5	118.2	9.1	0	0	0	0
56-57	0	0	23.2	115	136.2	164.2	131	10.9	0	0	0	0
57-58	0	65.6	58.6	186.5	298.5	20.5	8	18.2	0	0	0	0
58-59	0	0	3.1	29.6	156.5	175.4	80.3	0.3	0	0	0	0
59-60	2.3	0	25.1	3.6	150.9	18	122.1	10.8	2.3	0	0	0
60-61	0	0	71.9	44.7	155.6	211.6	40.5	44.8	0	0	0	0
64-65	0	0	0	375.3	210	80.3	87.7	64.9	0	0	0	0
65-66	0	36.8	0	124.3	66.9	118.4	127.3	0.6	0	0	0	0
66-67	0	12.7	12.6	328	243	97.9	227.3	7.3	0	0	0	0
67-68	0	27.1	74	64.9	225.7	54.7	53	10.1	0	0	0	0
68-69	0	12.2	40.2	190.9	250.9	33.1	114.3	16.4	0	0	0	0
69-70	0	27.8	38.2	65.8	143.8	48.4	165.4	35.9	0	0	0	0
70-71	0	5.7	6.6	123.8	109.4	98.1	41.3	208.7	0	0	0	0
71-72	9.3	0	60.1	180.1	131.5	146	76.2	25.8	9.3	0	0	0
72-73	0	1	41.2	63.5	163.3	16.5	97.2	11.7	0	0	0	0
73-74	0	19	104.4	75.8	436.8	52.2	41.6	44.3	0	0	0	0
74-75	0	0	55.4	137.1	55.5	194.6	82	4.2	0	0	0	0
75-76	22.9	2.2	47.2	108.3	93.1	152	150.1	27	22.9	0	0	0
76-77	0	32.9	90	46.6	148.4	73	128.1	85.7	0	0	0	0

(Table 2 … continued)

77-78	0	82.7	2.9	192.8	79.3	60.1	82.9	8.2	0	0	0	0
78-79	0	20.1	6.7	104.2	116.7	20.4	75.7	5	0	0	0	0
79-80	0	39.6	167.5	225.6	118.9	161	154.9	26.4	0	0	0	0
80-81	0.4	15.5	8.9	192.7	211.3	124.5	67.3	23.1	0.4	0	0	0
81-82	0	0	137.6	20.2	94.3	174.3	121.8	7.1	0	0	0	0
82-83	5.7	10.3	163.4	115.7	266.8	322.8	219.2	14.8	5.7	0	0	0
83-84	0	11.6	114.5	39.3	252.4	138.5	0	0	0	0	0	0
84-85	0	23.9	29.6	58.3	66.5	245.2	20.1	23.5	0	0	0	0
85-86	0	19.5	46.3	42.1	101.1	160.2	47.8	45.9	0	0	0	0
86-87	0.5	52.4	249.5	141.3	129.9	62.2	119.9	1.9	0.5	0	0	0
87-88	0	52.9	23.2	225	126.9	306.9	94.9	0	0	0	0	0
88-89	0	16	55.9	237.1	96.5	46.7	114.4	0	0	0	0	0
89-90	0	9.9	95.3	125.7	132.1	99.3	73.2	53.2	0	0	0	0
90-91	0	3.5	24.3	9.5	250.9	74.4	104	30.1	0	0	0	0
91-92	0	12.5	150.3	462.3	255.6	376.7	68.3	4.6	0	0	0	0
92-93	0	0	84.9	360.9	142.3	117.7	68.7	5.8	0	0	0	0
93-94	0	14.7	21.2	28.7	192.5	114	129.1	9	0	0	0	0
94-95	17.1	20.4	259.2	183.7	57.2	94.2	42.6	34.8	17.1	0	0	0
95-96	0	1.8	118.7	59.2	229.6	35.8	228.5	33.4	0	0	0	0
96-97	0	34.2	16.4	85.6	166.3	269	233.4	22.7	0	0	0	0
97-98	17.6	16.3	59.9	167.4	148.2	96.9	244.5	5	17.6	0	0	0

Table 3 The daily rainfall for December for Nablus district

Day year	1	2	3	4	5	6	7	8	9	10	11
54-55	0	0	0	0	52.5	12.6	0	0	0	0	0
55-56	0	0	0	0.6	1	0	59	10.3	0	0	3.2
65-57	0	0	0	7.1	0.3	4.2	10	38.2	27.2	0	0
57-58	1.4	2.9	0.6	0	0	73	50.8	24.4	0	0	0
58-59	0	0	7	9.9	0	0	0	0	9.4	0	0
59-60	0	0	0	4	0	0	0	0	0	0	0
60-61	0	0	0	0.7	0	15.7	0	0	0	0	0
65-66	0	0	0	0	0	0	0	0	0	0	0
66-67	16.5	0	0	0	0	0	9.8	0	0	5.8	40.9
67-68	0	0	0	0	0	0	0	0	0	0	0
68-69	0	0	0	3.6	9	14.7	37.5	14.7	1.2	0	1.6
69-70	0	0	0	2.3	0	0	0	0	0	0	0
70-71	3.4	0	0	0	10.9	6.4	31.2	0.4	5.4	11	11.9
71-72	0	0	0	0	5.7	30.2	11.5	26.3	0	0	0.2
72-73	0	0	5.8	3.6	0	0	0	0	1.7	0	0
73-74	0	0	0	0	0	0	19	19	0	0	0
74-75	0	0	0.2	1.3	8.2	22.1	0	19.2	0	54.8	14.5
75-76	0	0	0	0.1	0	0	0	9.1	31.2	2.7	0
76-77	10.1	2.6	0	0	0	0	0	0	3.3	0	0
77-78	0	0.7	0	5.1	25.8	2.1	0	12.9	0.4	0	0
78-79	3.8	41	20.1	0.6	0	0	0	6.1	3.6	0	0
79-80	0	0	0	0	14.7	24.2	0	0	0	0	0
80-81	0	0	0	0	0	0.4	0	0	0	74.5	16
81-82	0	0.3	0	0	0	0	0	0	0	0	0
82-83	0	0	0.5	22.3	0	13	0.4	0	0	0	0
83-84	9.93	0	0	0	0	0	0	0	0	9.1	7.7
84-85	0	0	0	6.7	0	0	0	0	7.2	0	0
85-86	0.3	0.7	0.5	0	0	0	0	0	0	0	0
86-87	1.5	0	0	0	0	0	0	8.7	12.9	4.7	0
87-88	0	0	0	0	0	0	0	0	0	0	0
88-89	0	0	0	0	0	11.1	0	0	0	0	0
89-90	1.2	0	0	0	0	6.4	5.2	52.6	0	0	48.3
90-91	0	0	0	0	0	0	0	0	0	0	0
91-92	7	58.2	57.8	11	0	0	0	3.9	6	1	24
92-93	17.8	17.5	0.8	3.2	0	0	6.4	0	0	0	0
93-94	0	0	0	0	0	0	0.1	0.3	0.2	0	0
94-95	5.2	46.2	18.7	8.4	8.4	0	0	0	0	0	0
95-96	0	0	0	12	12	0	0	0	3.9	11	10.4
96-97	0	0	1.2	0	0	0	6	0.7	1.6	0	0
97-98	0	0	0	0	0	0	0	28.8	21	19.5	0

(Table 3 … continued)

Day year	12	13	14	15	16	17	18	19	20	21	22
54-55	0	0	0	0	0	0	0	0	18.5	0	0.5
55-56	6	7	23	7	0	0.7	1	0	0	0	0
65-57	0	2	0	0	0	0	0	3.2	6.4	8.1	1.9
57-58	0	0	0	0	0	0	0	10.2	3.3	0	0
58-59	0	0	3.5	0	0	0	0	0	0	0	0
59-60	0	0	0	0	0	0	0	0	0	0	0
60-61	0	0	0	0	0	0	0	0	0.5	2.5	0
65-66	0	0	0	5.2	28.7	0	0	2.4	0	0	0
66-67	37.8	0	0	0	30	54.9	28.8	48.5	8.9	0	0
67-68	0	0	0	0	0	0	0.6	2.1	0	11	8
68-69	0	0	32	7.8	6.2	8.1	0	0	0	0	0
69-70	1.5	0	0	5	3.9	1.1	4	0	0	0	0
70-71	21.6	4.8	0	0	0	0	5.5	2.7	0	0	0
71-72	11.4	10	5.3	5.2	0	15.5	8.1	0	1.7	1.4	12.1
72-73	0	0	0	0	0	0	21.8	19.7	8	1.9	0
73-74	0	0	0	0	20.5	9	0	0	0	0	0
74-75	0	5.3	0	0	0	0	4.8	0	9.6	0.3	0
75-76	0	0	0	0.3	3.2	4.9	0	0	0	26.1	1.6
76-77	0	0	0	0	0	0	0	5.1	2.2	0	0
77-78	4.4	10.9	12.2	51.9	7.2	0	0	0	0	15.5	30.2
78-79	18.2	0	0	0	1	0	0	0	0	0	0
79-80	0.6	19.1	50.3	0.2	0.7	0	2	16	0	0	0
80-81	29.9	18.8	0	1.2	0.2	0	0	0	0	0	0
81-82	0	0	0	0	2.2	0.3	0	0	0	0.3	0
82-83	0	11	0	0	0	0	0	0	1.6	2.6	1.4
83-84	0	3.1	0	0	0	0	0	0	0	2.2	0
84-85	4.7	38.9	0.6	0	0	0	0	0	0	0	0
85-86	0	0	0	10.5	0.2	3.7	2.9	2.8	0	0	1.2
86-87	0	3.9	1.1	0	0	0	5.3	53.2	2.5	1.8	0.2
87-88	0	0	0	0	0	0	0	0	0	0	0
88-89	0	2.7	8.5	0	4.2	0	55.8	51.7	6.2	0	0
89-90	1.9	3.4	3	1.1	0	1.4	0	0	0	0.2	0
90-91	0	1.2	0	0	0	0	0	0	0.1	0	0
91-92	84.5	14.7	0.5	0	0	0	1.9	0	2.2	0.2	0
92-93	5.5	12	54.6	115.5	76.7	5.7	0	5.8	0	0	0
93-94	0	25.5	1.3	0	0	0	0	0	0	0	1.3
94-95	5.6	0	0	0	11	8.6	54.9	16.9	2	0	0
95-96	15.5	1.5	0	0	3.3	0.1	0	0	0	0	0
96-97	14.4	54.6	0	0	0	0	0	0	0	0	1.6
97-98	6.2	0.2	0	1.1	14.3	0	33.4	27.2	0	0	0

(Table 3 ... continued)

Day year	23	24	25	26	27	28	29	30	31
54-55	0.9	0.3	0	0	23.5	61	43.5	2.8	0
55-56	0	2.5	13	4	0	0	0	1.5	1.5
65-57	0	0	0	0	0	0	2.3	2	0
57-58	0	19.6	0	0	0	0	0	0	0
58-59	0	0	0	0	0	0	0	0	0
59-60	0	0	0	0	0	1.1	2.8	0	0
60-61	0	0	0	0	0	24.4	0	0.9	0
65-66	41.4	14.1	1.4	0	31.3	0	0	0	0
66-67	0	0.3	22.6	0	0	0	0	0	0
67-68	29.5	0.6	0.3	3	0	0	0	0	0
68-69	0	0	5.1	49.4	0	0	0	0	0
69-70	11.2	0	0	22.5	0	0	0	4.1	2.3
70-71	0	0	0	0	0	0	0	0	0
71-72	0	5.6	2	16.4	3.8	6.8	0	0	0.6
72-73	0	0	0	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0	0.1	0
74-75	0	0	0	0	0	0	0.2	1.6	0
75-76	0	0	0	16.3	0.5	1	3.1	8.2	0
76-77	0	0	0.5	9.2	0.6	0.9	5.6	4.9	1.6
77-78	13	0	0	0	0	0.3	0	0	0
78-79	0	2.5	7.1	2.7	0	0	0	0	0
79-80	0	2.7	54.9	31.7	3.4	6.2	0	0	0
80-81	0	8.4	0	32.7	2.4	1.5	11.4	1	0
81-82	0	0	1.4	0	3.4	0	3.6	0	0
82-83	0	0	0	0	0	1.5	8.7	0	52.8
83-84	0	0	0.2	1.5	0.2	0	0	0	0
84-85	0.2	0	0	0	0	0	0	0	0
85-86	5.1	0	0	10.5	4	0	0	0.7	0
86-87	0	28.9	0	0	10.6	0.5	0	0.1	0
87-88	31.3	43	15.2	1.9	2	34.9	15.7	0	0
88-89	0	0	30.7	11.7	7.9	0	0	0	0
89-90	0	0	0	0	0	3.2	0	0	0
90-91	0	8.2	8	0	0	0	0	18.2	0
91-92	0	13.3	24.9	0	51.4	0	0	0	0
92-93	25.2	0	0.5	5.8	0	4.2	0	0	0
93-94	0	0	0	0	0	0	0	1.5	0
94-95	0	0	0	0	0	0	3.8	0	0.4
95-96	0	0	0	0	0	2.5	0	0	0
96-97	0	0.4	0	0	0	0	0	9.8	0
97-98	0	0	0	0	0	5.5	0	0	0

Table 4 The daily rainfall for January for Nablus district

Day year	1	2	3	4	5	6	7	8	9	10	11
54-55	0	0	0	0	0	0	0	0	0	0	0
55-56	0	0	3	9	31.9	10	0	3	9	0.3	0
65-57	0	0	0	0	3.5	0	0	0	0	0	13.1
57-58	9.1	0	5.6	35.1	19.5	14.5	0	0	24.6	5.9	0
58-59	0	0	0	0	0	10	0	25.7	8.5	0	0
59-60	0	0	0	0	0	10	0	25.7	8.5	0	0
60-61	6.6	22	0	0	3	0	0	0	0	22.8	20.6
64-65	0	8.5	0	2	0	1	22	0	0	0	32
65-66	4.4	0	0	0	0	0	5.9	0	9.2	0	0
66-67	0	0.6	1.1	0	0	0	0	8	0	0	0
67-68	0	0	0	0	0	16.7	0	0	21	1	0
68-69	0	0	0	8.5	2	28	27	6.1	0	0	0
69-70	0	0	0	0.5	1.6	0	0	0	0	0	0
70-71	0	0	0	0	0	0	0	0	2.2	14	0
71-72	0.6	0	0	0	0	0	0	0	0	0	0
72-73	0	0	0	0	0	0	0	0	0	0	0
73-74	0	0	0	0	0	14.8	3.8	12.1	27.8	3.7	0
74-75	0	0.4	0	5.2	0.6	0	0	4	0	21.3	11.8
75-76	0	0	0	0	8.1	0	0	0	0	0	6.7
76-77	4.2	17.4	3.2	3.5	2.9	1.6	0	0	0	0	0
77-78	0	1.7	46.2	5	0	0	0	0	0	0.3	0
78-79	0	0	3	3	0	0	0	0	45.1	13.1	0
79-80	0	0	0	0	23.4	3.8	0	0	0	1	2.5
80-81	51.4	0	32.4	11.4	0	0	1.4	0	0	1.7	20.5
81-82	0	0	0	1.7	5.5	0	0	6.4	0.9	0	0
82-83	59.1	7.9	3.2	26.7	0.7	0	0	0.5	0	0	0
83-84	9.9	0.8	0	0	0	0	0	0	6.9	0	0
84-85	0.9	1.6	0	0	0	0	0	0	0	0.5	0
85-86	11.6	0	19.6	0	0	0	0	2.4	0	0	23.6
86-87	2	21.7	5.6	0	20.3	21.1	0.3	0	5.9	0.3	0
87-88	0	0	3.4	27.5	16.7	2.3	0	0	0	0	0
88-89	0.5	21.9	4.5	0	0	0	9.6	4	9.2	6.5	0
89-90	1.4	0.9	31	35.7	0.4	0	0	0	0	0.2	0
90-91	0	0	25	0	0.1	0	0	7.8	0	0	0
91-92	80.5	4	0	0	0	0	0	0	0	0	0
92-93	0	1	1.1	0	0	27.9	28.5	39.5	0.2	0	0
93-94	3.5	2.6	27.3	41.2	0	0	0	0	0	0	0
94-95	0	0	0	0	0	0	0	0	0	0	0
95-96	0	0	2.2	1.6	9.4	28.7	0.2	0	0	1	0
96-97	0	0	0	0	0	0	0	0.5	0.3	0	0
97-98	0	0	0	0.3	2.2	5.9	2.5	0.5	0	16.1	15.3

(Table 4 … continued)

Day year	12	13	14	15	16	17	18	19	20	21	22
54-55	0	0	0	0	0	0	0	0	0	0	0
55-56	0	4.5	0.2	4.4	0.2	0	0	0	0	0	0
65-57	27.2	2	0	0	0	0	31.9	3.2	4	0	0
57-58	0	0	0	0.7	0.4	0	0	10.2	19.9	0	0
58-59	0	0	0	5.1	0	0	0	2.1	64.2	6	0
59-60	0	0	0	5.1	0	0	0	2.1	0	4.9	13.5
60-61	23.5	0	0	0	0	4.7	3.3	28.3	0	20	0
64-65	10.5	0	0	15	0	1.8	14.6	32	0	0	0
65-66	0	0	0	0	0	0	0	0	0	0	0
66-67	0	0	0	0.1	11.6	58.2	36.5	31.6	1.4	0	0
67-68	0	0	84	35.5	23	3.3	0	0	0	2.5	0.8
68-69	19.8	3.2	7.8	0	0	0	17	1	2.2	10.6	36.6
69-70	0	0	5.9	0	0	0	0	3	0.6	25.8	22.9
70-71	11.8	13.2	15.1	35.1	3.2	0	0	0	0	0.4	0
71-72	0	23.4	32.5	7.1	3.9	1.4	0	0	0.4	4	0
72-73	19.5	8.5	52.7	19	16.7	0	0	0	0	1.4	2
73-74	0	35.6	69.4	15.5	58	36.2	0	1.1	60.2	14.2	0.6
74-75	0	0	0	0	0	3.4	0.3	0	0	0	0
75-76	27.3	0	0	0	1.1	0	13.3	0.5	7.9	2.3	0
76-77	0	0	0	13.4	5.8	0	2.8	64.7	11.5	6.2	3.8
77-78	0	0	0	0	0	1	0	0	3.8	0	0
78-79	0	0	0	3	3	0	0	0.4	0.8	36.6	4.5
79-80	0	8.3	20.9	0.5	0	1.6	0	0	0	0	4.7
80-81	7.6	0.1	0	0	9.2	0.2	0	0	0	0	0
81-82	0	0	2.6	0	0	0	0	0	0	0	0
82-83	0	1	43.4	0.1	0	19.6	37.9	0	0	0	0.2
83-84	0	2.6	0	0	0.3	44.9	7.6	0.3	0	0	0
84-85	0.4	0	0	0	0	0.7	0.8	1	0.4	14.5	0
85-86	4.6	0	14.2	4.3	0.3	0	11.4	0	0	0	0
86-87	0	0	0	0	0	0	0	0	0	9.2	3.2
87-88	2	5.3	0	16.6	17.6	6.6	0.2	0	1.8	0	1
88-89	0	0	0	24.4	0	0	0	0	9.9	11.1	0
89-90	0	0	0.1	2.2	6.2	1	0	0	5	3.6	8
90-91	1.7	0.4	0	0	0	0	0	17.7	0.6	2	9.7
91-92	0	2.9	13.4	0.5	22.7	13.1	3.3	0	10.7	0	1.6
92-93	0	0	0	0	0	0	0	0	0	0.4	23.7
93-94	0	0	9.6	10	18.8	0	0	0	0	3.3	0.1
94-95	0	0	0	0	5.3	40	12.2	22.2	0	0.5	3
95-96	0	0	0	0	4	73.8	67	0	0	0	74.7
96-97	0	7.9	1	47.5	10.6	0	0	10.4	5.3	0	0
97-98	1.3	0.2	0	0	0	0.8	0.5	0	0	0	0

(Table 4 … continued)

Day year	23	24	25	26	27	28	29	30	31	
54-55	0	0	0	11.5	0	0	0	13.5	0	13
55-56	0	0	0	0	40.5	18.5	43	4	1.7	16
65-57	0	0	0	0	0	0.6	7.5	2.8	26	11
57-58	0	0	13.6	4.1	0.4	0	54	89	1.6	17
58-59	0	0	14.9	0	0	0	0	17.9	2.2	9
59-60	1.4	0	0	0	0	2.5	0	0	0	9
60-61	0	0	0	0	0	0	0	0	0.8	11
64-65	0	0	0	0	22.5	1.6	0	0	0	12
65-66	0	0	14.2	22.7	0	0.3	5.6	1.6	3.2	9
66-67	0	0	0	4.7	19.4	38.7	10.5	3.4	0	14
67-68	11.2	0	0	0	0	18.5	2.5	11.5	10.6	14
68-69	4	23.9	5	3.6	9.4	23	10.5	0	1.5	21
69-70	21.4	18.7	16.7	9.4	0	0	0	0	0	11
70-71	0	0	0	0	0	0	6.8	0	0	9
71-72	0	0	6.6	15.8	1.4	6.8	0	0	0	12
72-73	0	0	0	0	7	0.6	0	11.3	22	11
73-74	7.6	0	0	0	0	0	0	17.2	20.8	17
74-75	0	0	0	0.9	5.4	2.1	0	0	0	10
75-76	13.9	0	0	0	0	0.2	2.4	6.4	3	13
76-77	0	0	0	0	0	6.6	0.9	0	0	15
77-78	0	0.8	2.4	4.7	0	0	0	0	0	9
78-79	7.2	0	0	0	0	0	0	0	0	11
79-80	24.2	8.6	1.5	0	0	0.5	3.9	0	0	14
80-81	0	0	4.8	15.7	7.1	0	0	0	42.2	14
81-82	0	0	3	3.7	6.7	2.2	0	0	59.7	9
82-83	37.9	28.5	0.3	0	0	0	0	0	0	15
83-84	0	0	0	38.5	43.4	0	0	0	0	10
84-85	0	0	0	0	0	0	0	0	45.7	10
85-86	0	0	0	0	0	0	0	0	0	10
86-87	7.3	11.8	22.8	5.3	2.4	0	0	0	0	15
87-88	0	2	4.7	0	1.4	2	0	0	8.4	17
88-89	0	0	0	0	0	5.8	0	0	0	11
89-90	3.6	0	2	22.4	0.4	0	0	0	0	17
90-91	13.5	22.9	29.5	0.4	0	0.8	15.1	63.9	56.4	15
91-92	0	0	0	0	0	0	1.2	27.6	60.6	13
92-93	0	0	0	0	0	0	0	0	15.9	9
93-94	4.7	4.9	3.5	0.9	0	4.6	0	0.7	36.5	16
94-95	0	0	0	0	0	0	0	0	0	6
95-96	6.6	0.7	0	0	0	0	6.1	0	0	13
96-97	2.1	0	0	5.8	0	0	0	16.2	0	11
97-98	0	42.3	16.8	0	0	7.6	0	5	0	15

Table 5 The daily rainfall for February for Nablus district

Day year	1	2	3	4	5	6	7	8	9	10	11
54-55	0	0	0	8.8	0	5.5	21	0	0	1.5	0
55-56	0	0	0	0	31.9	6.5	16.5	1.7	0	0	0
65-57	38	9.5	0.5	1.1	0.8	0	0	0	8.6	27.8	9.2
57-58	0	0.5	0	1.1	4.9	2.6	0	0	0	0	0
58-59	27.1	0	0	5.7	4	0	0	0	0	0	0
59-60	0	6	0	8.6	2	0	0	0	0	0	0
60-61	3.9	1.8	0	0	23.5	0	3.4	28.8	0	11.2	0
64-65	0	0	1	17.8	8	4.5	2	18.8	0.2	0	0
65-66	4.6	47.6	9.9	0	0	0	0	0	0	0	0
66-67	0	0	10.1	0.3	0	0	0	2.8	0	0.2	0.3
67-68	5.7	0.6	0	0	0	0	7.2	0	0	0	0
68-69	1.4	0	0	0	0	0	26.4	4.4	0	0	0
69-70	0	0	0	0.3	0	4	0	0	0	0	0
70-71	0	0	4.1	6	0	12.5	2.8	6.7	0	0	4.6
71-72	0	9	24.3	6.1	28.6	29.4	16.2	0.4	0	0	0
72-73	0	0	0	0.2	0	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0	0	0	13.9	24.1
74-75	51.2	7.6	19.7	0	0	6.4	1	2.9	30	12	0
75-76	0	0.3	6.2	0.2	2.1	0	0	15.6	38.8	5.3	3.2
76-77	0	0	0	3.6	16.8	27.3	8.3	14.5	1.1	0	0
77-78	0	2.2	0	0	0	0	0	0	2.5	9.2	0
78-79	0.9	0	0	0	0	0	6.3	0.7	2	6.2	0
79-80	0	0	0	7.8	21.3	0	0	0	0	11.8	0
80-81	18.7	1.2	0	9.4	5.8	0	0	7.2	0.4	0	0
81-82	21.11	26.6	45.3	13.2	2.7	0	0	0	0	0	0
82-83	0	33.9	4.1	7	0	9.1	0.3	0	0	0	0
83-84	0	0	0	0	0	0	79.3	5.9	0	0	0
84-85	48.7	28.9	2.7	8.4	1.1	0.2	0	0	0	0	0
85-86	0	0	0.2	1.1	47.3	9.5	0	10.7	20.4	0	0
86-87	0	3.3	16.8	0.3	0	0	1.7	3.2	19.3	0	0
87-88	75.3	28.6	0	0	0	0.6	2.4	0	0	0	0
88-89	1.2	0	0	0	0	0	0	0	0	1.6	18.2
89-90	6.5	0	0	0	1.3	8.2	0.6	0	8.8	21.7	1.3
90-91	1.9	17.1	8.1	0	0	0	4	2.3	4.9	0	0
91-92	15	1.3	36	36.2	0	22.3	4.4	25.5	36	0.8	0.1
92-93	22	12.3	4.4	0	0	0	0	23.9	8.5	20.3	15.6
93-94	5.5	3.5	0	0	0	0	0.1	0	0	0	32.4
94-95	0	0	0.4	7.6	4.3	5.8	45.9	17.7	0	0	0
95-96	10.8	0	0.3	0.3	0	0	0	0	0	4.7	0
96-97	0	22.8	35.2	20.2	0	0	0	0	0	0	0
97-98	0	0	0	0	0	0	6.8	3.2	13.5	15.4	3.7

(Table 5 ... continued)

Day year	12	13	14	15	16	17	18	19	20	21	22
54-55	0	0	0	0	0	0	0	0	0	0	2.5
55-56	0	0	0	0.3	0	0	0	0	8.8	0.4	0.6
65-57	3.2	0	0	0	0	0	0	0	0	0	0
57-58	0	4.5	0	0	0	0	0	0	0	1.9	5
58-59	7.6	11.8	27	5.2	5.5	2.5	24	4.3	1.7	18	0
59-60	0	0	0	0	0	0	0	0	0	0	0
60-61	0.8	18.7	19.3	43.6	22.9	0.8	10.5	0.3	0	0	0
64-65	0	4.6	5.4	0	0	0	0	0	0	0	4.6
65-66	0	0.2	0	0	14	20.5	0	0	0	0	0
66-67	1	0.8	7	2.3	0	27.5	3	2.8	3.9	6.7	21.5
67-68	0	0	29	0	0	0	0	3.3	9	2.5	0
68-69	0.9	0	0	0	0	0	0	0	0	0	0
69-70	0	0	0	0	0	5	3	0	0	3.8	26
70-71	0.1	6.3	0	0	0	0	0	0	0	1	1.7
71-72	0.2	0	0	0	9.3	17.6	4.6	0	0	0	0
72-73	0	0	0	0	0	0	0.2	0	0	0.5	10.2
73-74	8.6	0	0	0	0	0	0	0	0	0	0
74-75	0	0	0	0	0	0	0	0.1	37.1	9.3	0
75-76	0.5	0	0	0	0	0	0	0	0	0	0
76-77	0	0	0	0	0	1.5	0	0	0	0	0
77-78	0	0	0	0.4	17.5	11.7	0.4	0.4	0	0.7	2.8
78-79	0	0	0	0	0	0	0	0	3.1	0.2	0
79-80	0	8.6	9.2	11.4	9.1	3.3	0	1.4	1.1	0	0
80-81	0	0	0	5.1	7.9	1.1	0.8	0.5	0	0	0
81-82	0	19.1	17.1	0	0	0.8	0	0	15.3	0	0.6
82-83	0	0	0	0.4	11.2	19.4	44.8	67.2	53	33	1.1
83-84	0	0	0	0	0	0	0	0	0	0	0
84-85	0	0	31.6	26.9	1.2	10.2	0	0	6.9	0.2	12.8
85-86	0	8.9	58.2	0	0	0	0	0	0	0	0
86-87	0	0	0	0	0	0	0	0.7	0	0	0
87-88	0.7	11.7	1.5	12.8	27.4	15.7	10.4	0	0	2	44.5
88-89	4.2	0	0	0	0	0	20.5	0.3	0.7	0	0
89-90	0	0	32.3	3.5	0	2.1	10.2	0	0	0	0
90-91	0	0	0	0	16.5	0	0	0	0	0	0
91-92	15.4	0.1	0	0	0	0	0	2	0.6	3	3.9
92-93	5.4	5.3	0	0	0	0	0	0	0	0	0
93-94	0	1.7	0	0.1	0	0	1.6	0	0	0	0
94-95	0	0	0	9.9	0	0	0	0	0	1.1	1.1
95-96	0	0	0	1	10.3	0	0	2.9	6	0	0
96-97	0	0	0	0	0	0	0	0	0	77	71.7
97-98	0	0.4	15.3	0	0	0	0	0	0	0	0

(Table 5 ... continued)

Day year	23	24	25	26	27	28	29
54-55	0	0	0	0	0	0	6.8
55-56	0.5	1	0	0	0	0.5	0
65-57	0	28	34	20	0	0	0
57-58	0	0	0	0	0	0	0
58-59	9.3	0	3.1	5.7	10.4	5.6	0
59-60	0	0	0	0	0	0	0
60-61	0	11.8	2.3	7	1	0	0
64-65	1.1	0	0	0	0	6	0
65-66	0	0	0	20.1	1.7	0	0
66-67	0.7	0	0.1	0	0	0	1.4
67-68	0	0	0	0	0	0	0
68-69	0	0	0	0	0	0	0
69-70	0.5	0	0	0	0	0	0
70-71	27.3	0.2	0	10	8	0	0
71-72	0	0	0	0	0	0	0
72-73	5.2	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0
74-75	0	0	2.4	0	0.2	14.7	0
75-76	21.4	26.6	11.6	15.5	0.5	4.2	0
76-77	0	0	0	0	0	0	0
77-78	10.2	0	0	0	0	0	0
78-79	0	0	0	0	0	0	0
79-80	3.6	2.1	15.8	1.6	1.3	16.6	5.7
80-81	1.9	43	10.6	0	0	6.4	0
81-82	3.4	0	0	0	6.4	1.4	0
82-83	0	14.6	7.1	14.1	2.4	0.2	0
83-84	0	0	0	0	0	0	0
84-85	52.9	0	0	12	0	0	0
85-86	0	1.4	0	0	0	0	0
86-87	0	0	2.2	5.3	8.9	0	0
87-88	0	70.2	2	0	0	1	0
88-89	0	0	0	0	0	0	0
89-90	0	0	0	0	0	2.4	0
90-91	0	0	1.7	10.3	7.5	0	0
91-92	78.8	65.3	30	3.6	3.5	0	0
92-93	0	0	0	0	0	3.9	0
93-94	9.2	15.4	0	6.6	13.4	0	0
94-95	0	0	0	0	0	0.6	0
95-96	0	0	0	1.8	0	0	0
96-97	15.2	12	4.2	4.3	0	0.8	3.1
97-98	0	0.4	0	0	0	32.6	0

Table 6 The daily rainfall for March for Nablus district

Day year	1	2	3	4	5	6	7	8	9	10	11
54-55	0	0	0.8	0	0	0	0	0	0	0	0
55-56	30.2	26	5	0	0	0	0	1	0	0	0
65-57	0	0.3	0.6	0	9	34.5	4.6	0	0	0	1.8
57-58	0.5	0	0	0	0	0	0	7.5	0	0	0
58-59	27.3	0	2.9	0.4	23.7	3.3	0	0	0	0	0
59-60	0	0	4	0	0	0	7.8	0	0	5.8	5.5
60-61	0	0	0	0	0	0	0	0	0	0	0
64-65	3	0	0	0	0	0	0	0	0	0	2.3
65-66	0	0	0	0	0	0	0	0	0	0.2	1.9
66-67	0	0	1.1	27.8	48.5	15.5	1.3	0	0	0	0
67-68	2.3	0	0	0	3.5	2.3	0	0	0	0.5	0
68-69	0	0	0	0	0	0	0	0	2.9	0.9	0
69-70	0	4	0	0	0	0	0	0.5	16.4	38.8	15.8
70-71	0	0	0	0	0	0	0	0	0	0	10
71-72	0	0	0	0	3.3	0	0	0	0	0	0
72-73	0	47.5	12.4	0.4	9.5	12.3	6.5	0	0	0	0
73-74	10.7	7.5	1.6	0	0	0	0	0	0	0	0
74-75	39.8	1.1	0	0	0	0	0	0	0	0	0
75-76	0	0	0	0	4.6	0	0	0.6	0	0	9.3
76-77	4.9	9.2	36.3	19.6	23.9	0.4	0	0	7.4	2.9	0
77-78	0	0	0	0	3.5	0	0	0	0	0	0.9
78-79	0	0	0	0	0	0	11.8	31.3	2	0	0
79-80	98.8	17.3	0	0	0	0	0	0	0.2	0	0.2
80-81	17.9	12.5	0	0	0	0	0	0	0	1.2	0.4
81-82	1.5	23.9	5.8	0	0.8	11.2	14	10.7	15.4	0.4	0
82-83	0	0	1.1	48	65.5	22	0	0	0	0.2	0
83-84	0	0	0	0	0	0	0	0	0	0	0
84-85	0	0	0	0	0	0	0	0	0	0	0
85-86	0	0	0	0	0	0	0	0	0	0	0
86-87	0.1	4	0	0	8.8	0.7	10.4	11.8	5.5	7.1	0.3
87-88	0	1.4	22.6	0.4	0	10.6	6.2	1.6	0	0.5	5.5
88-89	0	0	0	0	0	0	0	0	2.9	0.8	0
89-90	28.7	0	0	0	2.6	0	0	0	0	3.8	6.5
90-91	0	1.7	0	5.4	33.8	104	0.2	0.7	0	0	0
91-92	0	0	0	10.4	0	0	0	0	0	0	0
92-93	0	0	0	1.7	17.5	7.7	0	0	0	2.4	16.3
93-94	0	0	0	0	2.6	59.9	0.4	0	0	0	0.9
94-95	0	0	0	0	0	0	0	0	0	0	0.1
95-96	11.1	11.7	2.5	0	0	63.5	30	0	0	0	0
96-97	0	14.5	12.3	1.9	2.3	4.5	0	0	0	0	0
97-98	1.8	0.5	0	0	0	0	1.3	1	0	0	0

(Table 6 … continued)

Day year	12	13	14	15	16	17	18	19	20	21	22
54-55	7.5	0	0	7.5	21.8	12.2	2.5	0	0	0	0
55-56	0	0	0	1.6	0	0	0	0.7	0	0	0
65-57	8.5	19.6	26.5	1.6	0	0	0	0	0	0	0
57-58	0	0	0	0	0	0	0	0	0	0	0
58-59	0	0	0	0	2.2	0	0	0	0	8.4	9.2
59-60	0	0	0	0	0	0	0	0	0	2.4	8.5
60-61	0	3.6	0	0	0	5.8	1.3	0	0	0	0
64-65	0.8	0	0	0	0	0	0	0	0	4.3	23.6
65-66	0	1.3	0	0	0	0.6	30	42.8	4.2	20.6	17.3
66-67	0	0	0	0	4.3	13.4	0	0	0	0	0
67-68	0	1.2	0	0	0	0	0	0	0	0	0
68-69	0	0	0	0	0	0	8.5	27.6	25	18.4	23
69-70	0.5	0	0	0	0	0	2.8	5	0	21.7	40
70-71	1.6	10.5	11	0	0	0	0	0.4	0	0	0
71-72	0	5	0.8	10.2	30.8	1.8	0.2	0	11.4	10.6	0.8
72-73	0	0	0	0	0	0	0	0	2.3	3.4	1.2
73-74	0	0.8	0.6	0	6.8	0.5	8.8	0	0	0	0
74-75	0	0	0	0	0.9	35	4.4	0	0	0	0
75-76	31.7	35	3.3	0	3.1	0	0.3	3.4	58.4	0.4	0
76-77	1.7	0	0	0	0	16.9	3.6	0	0	0	0
77-78	17.7	28.7	4.8	0	0	0	0	0	0	0	0
78-79	0	1.1	0	0	0	0	0	0	0	0	0
79-80	0.4	0	0	0	0	2.4	30.5	0.4	0	0	0
80-81	0	0	0	0	0	0	0	0	0	3.7	0
81-82	6.8	0	0	0	7.8	0.6	0	0	0	0	0
82-83	0	0	0	8.8	2.6	0	0	0	0	0	72.9
83-84	0	0	0	0	0	0	0	0	0	0	0
84-85	0	0	0	0	0	0	0	0	0	0	13.4
85-86	0	0	1.1	0	0	0	7.5	0	0	0	0
86-87	12.9	10.2	17.9	0	1.4	0	3.2	0	0	0	0
87-88	0	6.9	0	0	0	0	0	14.5	22.2	1	1.3
88-89	0	15.9	60.4	30.8	0	1.5	0	0	0	0	0
89-90	9	2.7	0	0	0	0	0	0	0	0	0
90-91	0	5.8	0	0	0	0.5	0	0	0	52.8	41
91-92	0	0	4.8	0	0	0	0	0	0	12.7	37.3
92-93	0	0	0	0	4.8	14.4	3.3	0	0.4	0	22.4
93-94	0	9.7	25.9	1	0	0	0	0	0	0	0
94-95	0	0	0	3	10.1	0.3	0.3	0	0	0	3.6
95-96	0	0	0.5	0	0	19	26.5	0	2.8	6.8	18.7
96-97	0	3	9.8	62.2	27.2	0	0	0	0.1	0	0
97-98	0	0	0	0	10.3	58	76.2	37.2	0.8	0	0

(Table 6 ... continued)

Day year	23	24	25	26	27	28	29	30	31
54-55	0	0	6.2	13.5	7.5	0	0	0	0
55-56	0	0	0	0	0	25	15	11.4	0
65-57	0.4	10.2	0	0	0	0	0	4.1	2.4
57-58	0	0	0	0	0	0	0	0	0
58-59	3	0	0	0	0	0	0	0	0
59-60	31	51	15.7	0	0	0	0	0	0
60-61	0	0	8.8	0	0	5.2	1.8	14	0
64-65	14.8	0.6	10	12.2	1.4	0	0	0	7.6
65-66	0	0	0	2.1	5.1	0	0	0	0
66-67	14.9	8.9	33.8	29.6	12.2	0	0	0	0
67-68	0	0	0	0	6.3	1.7	0	0	9.1
68-69	7	0	0	0	0	0	0	0	1
69-70	0	0	0	0	0	0	0	0	0
70-71	0	0	0.4	1.9	1	0	0	0.2	1.5
71-72	0.9	0.3	0	0	0	0	0	0	0
72-73	0.2	0	0	0	0	0	0	0	0
73-74	0	0	0	0	0	0	0	0	0
74-75	0	0	0	0.8	0	0	0	0	0
75-76	0	0	0	0	0	0	0	0	0
76-77	0	0	0	0	0	1.4	0	0	0
77-78	4.5	1	0	0	0	0	0.9	10.8	0
78-79	2.4	1.6	7.4	18.3	0	0	0	0	0
79-80	0	0.1	0	0	1.5	0	0	0	0
80-81	0.4	0.5	17.1	10.6	3.3	0	0	0	0
81-82	1.8	8.5	9.8	0.6	0	0	0	0	0
82-83	0	0	0	0	0	0	0	0	0
83-84	0	0	0	0	0	0	0	0	0
84-85	3.4	2	0	0	0	0	0	0	1.3
85-86	0	0	0	0	0	0	14.8	24.3	1
86-87	1.5	9.7	9.1	5.5	0	0	0	0	0
87-88	0	0	0	0.2	0	0	0	0	0
88-89	0	0	0	0	0.5	2.4	0	0	0
89-90	0	0	0	0	0	0	0	0	21
90-91	8	2	0	0	0	0	0	0	0
91-92	3.9	0	0	0	0	0	0	0	0
92-93	0	0	0	0	0	0	0	0	0.2
93-94	0	0	0	0	0	0	0	0	0.4
94-95	0	11.3	18.2	0.4	0	0	0	0	11.6
95-96	32.5	13.8	9.3	0.7	0	0	0	0	0
96-97	15.1	16	0	0	0	0	0	0	0
97-98	0	2.2	0	0	0	7.1	27	18.5	0

ملخص

أن موضوع المياه من المواضيع الهامة في كل الأماكن والأوقات . وبالنسبة لنا كفلسطينيين فهو أساسي لقلة الموارد المتاح استخدامها وقلة الدراسات المتعلقة به بالنسبة للمناطق الفلسطينية.

يعتبر توزيع الأمطار وتغيرها من حيث الزمان والمكان و كميات الأمطار من أهم الأمور المتعلقة بالمياه وتصميم المنشآت والانظمة المائية.

في الضفة الغربية هناك نقص في البيانات المتوفرة حول المياه وخاصة كميات الأمطار الساقطة وعلاقتها الزمنية. لذلك كان من الضروري توفير الأشكال و العلاقات اللازمة لاستخدامها من قبل الجميع وذلك من خلال الاعتماد على البيانات المتوفرة. ومن اجل ذلك تم جمع البيانات المتعلقة بالمياه والمتوفرة في دائرة الأرصاد الجوية في نابلس. حيث تم تكوين المنحنيات والعلاقات الخاصة بشدة الأمطار و تغيرها الزمني وترددها (منحنيات الشدة والتردد) IDF curves.

ومن ثم تم تحليل الأمطار السنوية والشهرية واليومية. بالنسبة لتوزيع الأمطار السنوية تم إيجاد المنحنيات المتعلقة بعدد السنوات المتتالية بالنسبة لامطار تلك السنوات مقارنة مع المعدل السنوي للأمطار في منطقة نابلس. كذلك تم اعتماد التوزيع الاحتمالي Gumble Distribution للامطار السنوية.

أما تحليل الأمطار الشهرية فقد أظهرت أن شهر كانون الثاني يعطي اكبر كمية أمطار. ومن خلال دراسة التوزيع الشهري تبين أن التوزيع الشهري للمطر كان يعطي نفس الشكل أي انه لم يكن هناك إزاحة بأي اتجاه.

بالنسبة للعلاقة بين الأمطار والجريان لم يتم التمكن من قياس الجريان بسبب انجراف التربة في الوادي حول جهاز القياس عام 1998 اما في العام 1999 فلم يكن هناك جريان. وقد تبين كذلك أن الجريان يحدث بعد هطول الأمطار بكمية 48.5 ملم خلال مدة لا تزيد عن 15 ساعة. حيث امكن تقدير نسبة كمية الجريان إلى كمية المطر بحدود 13.5٪. هذا وقد اوصت الرسالة أن يكون هناك قياسات دقيقة ومتعددة لكميات الأمطار والجريان على حد سواء.