UNIVERSITY OF NAIROBI

A HYDROLOGICAL STUDY OF THE KIPKAREN CATCHMENT

By

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Abstract

The Kipkaren catchment is located in Nandi District of Rift Valley Province. The catchment covers three administrative locations namely; Kipkaren, Ndalat and Ngenyilel locations .The Kipkaren River Basin is part of Lake Victoria North Catchment Area (LVN) which is part of the Lake Victoria basin in Kenya. The catchment has an area of about 3234.4km^2.The main township in the area is Eldoret town.

Kipkaren catchment was chosen as the study catchment in order to study the rainfall and streamflow data. The study sets four objectives, the first is to derive the seasonal rainfall pattern of the catchment; the second is to determine the average rainfall of the catchment; the third is to estimate the Storage required for the catchment, and the fourth objective is to determine the flow duration and the low flow of the catchment.

In this study, the project assess the storage and flow durations in the catchment for the water resource development in the area. Kipkaren river would be useful for direct water supply. The information can also be used in flood control, energy generation and industrial use since there are industries in the Eldoret Region. Generally, land degradation in the upper parts of the catchment has caused frequent flooding in the lower catchment, as reduced forest cover and an increase in agricultural lands have generally been known to generate high surface runoff.

Analysis has also shown that the catchment has two rainy seasons: the short rain season from August to October and the long rain season from– March to May. From low flow analysis it was found out that for 5% low flow will be 9.5 cumecs meaning that for 5% low flow < 9.5 cumecs, 95% of the time the flow will be > 9.5 cumecs. Also from flow duration analysis it was gotten that for 5% low flow of 0.064cumecs, 5% of the time flow < 0.064cumecs and 95% of the time flow > 0.064 cumecs.

Dedication

To almighty God for the life and strength He has granted me. To my late father who had always believed in me even when I did not. To my mother, thank you for all the sacrifice you made to give me the gift of education. To my sister, thank you for the love and emotional support.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Basin Characterisation

The Kipkaren catchment is located in Nandi District of Rift Valley Province. The catchment covers three administrative locations namely; Kipkaren, Ndalat and Ngenyilel locations .The Kipkaren River Basin is part of Lake Victoria North Catchment Area (LVN) which is part of the Lake Victoria basin in Kenya.

Kipkaren River basin lies between latitudes 0°00’N and 1°15’N and longitudes 34°30’E and 35°45’E at an altitude of about 2000-2500m above sea level. The catchment area has a mean annual rainfall of about 1500mm and a mean annual temperature ranging from 18ºC and with a maximum of 24ºC .River Kipkaren originates from Kipchamo swamp in the Rift Valley and is about 50 Km long. It is joined by River Sosiani, about 6 Km before confluencing near Kipkaren Town downstream. Rivers Kipkaren and Sosiani catchments present a variety of human activities such as urbanization, agriculture, and livestock keeping. Figure 1.1 shows the location hydrometeorological network of the Kipkaren catchment.

The Kipkaren catchment has variable topographical characteristics which influence land use activities and water resource management. The main food crops in the region are maize, millet, bananas and cassavas while the cash crops consist of sugarcane, wheat, tea and vegetables, and also dairy farming is practiced together with traditional livestock keeping in the high potential areas.

The River Basin is of great economic importance at local as well as national levels especially in such sectors as agriculture, tourism, fishing, forestry, mining and transport. It is also the main source of water for domestic, (rural and urban water supply), agriculture and commercial sectors, as well as for very important industrial establishments in Western Kenya. There are other numerous minor sugar factories, coffee roasters, wood processors and tea factories in the Eldoret Region where the surrounding local communities provide labor to these industries from which they obtain income to supplement those from their subsistence activities.

The major issues and challenges in the Kipkaren Catchment area include soil erosion and sedimentation, pollution of water resources both from point and non-point sources and encroachment into water catchment areas. The main ones being Mt Elgon, Cherangani Hills and Kakamega forest. Consequently these areas and their foot slopes have suffered severe degradation resulting in drying of springs and wetlands, loss of valuable indigenous forest species that are water friendly and landslides.

The encroachment is aimed at gaining socio-economic benefits in terms of settlement, expansion of agricultural land, logging among others. These activities destroy surface cover resulting in increased surface runoff and soil erosion. The eroded soils are carried by overland flow and deposited in the rivers, lakes and ponds resulting in reduction in storage and carrying capacity. The increased surface runoff causes increased potential flooding and its associated consequences. Planting of exotic trees which are fast maturing and consumes a lot of water is also another issue.

Due to their economic gains and available ready markets, the growing of these trees has been widespread in river valleys and in wetlands and has resulted in reduction of these water resources. In marginal areas of the catchment where livestock keeping is prevalent overgrazing is experienced resulting in desertification leading to poor productivity as a result of soil loss and compaction of the land surface. The byproduct of these activities eventually impact negatively on water resources resulting in water scarcity.

The types of records available for the Kipkaren Catchment included:

- River flow records/Stream flow records
- Precipitation Records
- Suspended Sediment data of 1 DA02 which is the outlet recorder station.

1.2 River Gauging Stations

The Kipkaren Catchment has a total of 18 river gauging stations as shown in figure 1.2. These comprise of the following:-

- 17 staff gauging stations
- 1 stream recorder station (1DA02).

The stream recorder station (1DA02) acts as an outlet of the other staff gauging stations. The records available for the river gauging stations are of daily flows. Some of the stations have records that date back to as early as 1932 .For instance, the staff gauging station no. 1CD01 has records from 1932 to 1988 being one of the oldest records available.

The table below shows a list of all the stream gauging stations in the Kipkaren catchment.

Table 1: Table of the Network of Stream Gauging Stations of Kipkaren Basin

Station no and river	**Type of station**	**Latitude**	**Longitude**	**Basin Area(km²)**	**Records available**
1BG4 Kassowai	Staff	1°00’10”N	34°51’10”E	54.4	-
1BG3 Kabeyan	Staff	0°59’00”N	34°50’15”E	114	-
1BG7 Ewaso Rongai	Staff	0°46’25”N	34°55’30”E	684	-
1BD2 Nzoia	Staff	0°45’40”N	35°03’40”E	3825	-
1CE1 Kipkaren	Staff	0°36’30”N	34°57’55”E	2440	1948-1985
1CB5 Sosiani	Staff	0°37’35”N	35°03’25”E	697	1960-1995
1CA1 Sergoit	Staff	0°30’30”N	35°23’00”E	77	-
1CA2 Sergoit	Staff	0°38’00”N	35°04’00”E	717	1960-1990

1CB1 Sosiani	Staff	0°30’05”N	35°17’40”E	298	-
1CB6 Ellegirini	Staff	0°28’00”N	35°22’25”E	82.9	-
1CB9 Ellegirini	Staff	0°27’25”N	35°23’20”E	80	-
1CB3 Ellegirini	Staff	0°27’05”N	35°28’30”E	52	-
1CB7 Nundoroto	Staff	0°27’25”N	35°22’00”E	167	-
1CB8 Nundoroto	Staff	0°26’45”N	35°22’00”E	167	1964-1990
1CB2 Kipsanandi	Staff	0°25’40”N	35°27’50”E	62.2	-
1CD1 Kipkarren	Staff	0°24’55”N	35°13’25”E	67.3	1932-1988
1CC1 Onyoike	Staff	0°23’55”N	35°12’00”E	588	1948-1990
1DA2 Nzoia	Recorder	0°35’20”N	34°48’25”E	8544	1947-1996

Figure 1.3 shows the schematic network of the staff Gauging stations in the Catchment

1.2.1 Rainfall stations

Rainfall stations are those which measure and record daily rainfall only. There are a total of 21 rainfall stations in the Kipkaren River basin, three of which are meteorological stations. Figure 1.4 shows the network of the Rainfall recorders in the Kipkaren Catchment.

The type of records available is monthly summary of rainfall in the catchment area. The table below shows a list of all the Rainfall Station Network of the Kipkaren Catchment.

Table 2: Table of Rainfall Stations Network of the Kipkaren Catchment

Station I.D	**Station name**	**Latitude**	**Longitude**	**Height(m)**
8834013	Kitale , A.D.C Chorlini	1° 02’N	34° 48’E	1982
8834028	Kitale , Farm 66 Endebes	1° 01’N	34° 54 ’E	1860
8934005	Kitale , Aral Estate	0° 59’N	34° 50 ’E	1921
8934008	Kitale ,Gloucester Vale Estate	0° 54’N	34° 55 ’E	1830
8934011	Kitale ,Kapretwa Farm	0° 57’N	34° 49’E	2043
8934033	Kitale ,Kabweya Estate	0° 59’N	34° 48’E	2165
8934070	Kitale ,Kituwaba	0° 54’N	34° 48’E	2013
8934071	Turbo, Stanely Estate	0° 42’N	34° 59’E	1905
8934098	Kimilili ,Forest Station	0° 52’N	34° 41’E	2074
8934113	Kapsakwany Chief’s Camp	0° 51’N	34° 43 ’E	1830
8934138	Turbo Forest Station	0° 45’N	34° 58’E	1823
8935010	Kaptagat Forest Station	0° 22’N	35° 20’E	2440
8935015	Turbo Forest Land Estate	0° 39’N	35° 04 ’E	1830
8935045	Eldoret ,Kenya Cooperative	0° 30’N	35° 18 ’E	2074

	Creameries			
8935061	Kipkabus, Tilol	0° 18’N	35° 27’E	2440
8935067	Kaptagat, Mvita Estate	0° 24’N	35° 29 ’E	2440
8935074	Eldoret Gara Falls Estate	0° 22’N	35° 15’E	2135
8935076	Turbo Selborne Estate	0° 39 ’N	35° 01’E	1891
8935117	Kipkabus ,Logarini Estate	0° 19’N	35° 31 ’E	2501
8935133	Eldoret Large Scale F.T.C	0° 34 ’N	35° 18’E	2134
8935181	Eldoret Meteorological Station	0° 32’N	35° 17’E	2120

1.2.2 Meteorological stations

There are three meteorological stations in Kipkaren Catchment. The table of the meteorological stations is as shown below:

Table 3: List of meteorological stations

Station I.D	Station name	Latitude	Longitude	Altitude(m)
8934138	Turbo Forest Station	0° 45’N	34° 58’E	1823
8935015	Turbo Forest Land Estate	0° 39’N	35° 04 ’E	1829
8935181	Eldoret Meteorological Station	0° 32’N	35° 17’E	2120

1.3 Objective

1.3.1 Main Objective

The main objective of the study evaluates the rainfall and stream flow characteristics of the Kipkaren river basin.

1.3.2 Specific Objectives

- To derive the seasonal rainfall pattern of the catchment
- To determine the Average rainfall of the catchment
- To estimate the Storage required for the catchment
- To determine the flow duration and the low flow of the catchment

1.4 Scope of Study

The study only dealt with rainfall and stream flow data from the given period available .The period of study was majorly influenced by the available data for the particular stations. This was done by getting the information, and using the data that was available and analysis done at specific points.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

A drainage basin or river basin or a catchment is an extent of land where water from rain or snow melts drains downhill into a body of water, such as a river, lake, reservoir, estuary, wetland, sea or ocean. The drainage basin includes both the streams and rivers that convey the water as well as the land surfaces from which water drains into those channels, and is separated from adjacent basins by a drainage divide.

The drainage basin acts like a funnel, collecting all the water within the area covered by the basin and channeling it into a waterway. Each drainage basin is separated topographically from adjacent basins by a geographical barrier such as a ridge, hill or mountain, which is known as a water divide or a watershed.

2.2 Rainfall

Rainfall is known as the main contributor to the generation of surface runoff. Therefore there is a significant and unique relationship between rainfall and surface runoff. By basic principle of hydrologic cycle, when rain falls, the first drops of water are intercepted by the leaves and stems of the vegetation. This is usually referred to as interception storage. Once they reach the ground surface, the water will infiltrate through the soil until it reaches a stage where the rate of rainfall intensity exceeds the infiltration capacity of the soil.

The infiltration capacity of soil may vary depending on the soil texture and structure. For instant, soil composed of a high percentage of sand allows water to infiltrate through it quite rapidly because it has large, well connected pore spaces. Soils comprising of clay have low infiltration rates due to their smaller sized pore spaces. However, there is actually less total pore space in a unit volume of coarse, sandy soil than that of soil composed mostly of clay. As a result, sandy soils fill rapidly and commonly generate runoff sooner than clay soils.

2.2.1 Rainfall Seasonality in the Nzoia Basin.

Across most of the country, rainfall is strongly seasonal, although its pattern, timing and extent vary greatly from place to place and from year to year. The relatively wet coastal belt along the Indian Ocean receives 1,000 mm or more rain per year. Most rain falls from April to July as a result of the southeasterly monsoon. Another moist belt occurs in the Lake Victoria basin and its surrounding scarps and uplands, mainly due to moist westerly winds originating over the Atlantic Ocean and Congo Basin. Except immediately adjacent to the Lake, rainfall occurs reliably from March to November. The upland plateau adjacent to this area is less influenced by the lake, and rain falls mainly in March-May and July-September. In much of the central highlands, there is also a bimodal rainfall pattern, with rainy seasons in March-May and October-December.

Except for the coast and Lake Victoria region, altitude is the main determinant of precipitation. The high altitude areas in the central Kenya highlands usually have substantial rainfall, reaching over 2,000 mm per year in parts of the Mau Escarpment. However, topography also has a major influence, with strong rain shadow effects east of Mt. Kenya and the Aberdare mountains. Here, even areas higher than 1,800 m may be relatively dry. In the arid lowlands the peaks of isolated mountains attract cloud and mist, and may support very different vegetation to that of the surrounding plains. (NRI, 1996)
Mean annual rainfall in Nzoia basin varies from a maximum of 1100-2700 mm and a minimum of 600-1100mm. The area experiences four seasons in a year as a result of the inter-tropical convergence zone. There are two rainy seasons and two dry seasons, namely, short rains (October-December) and the long rains (March-May). The dry seasons occur in the months of January to February and June to September. However the local relief and influences of the Lake Victoria modify the regular weather pattern.

2.2.2 Rainfall Abstraction

Rainfall abstraction is the component of rainfall that does not turn to direct runoff. This hydrological abstraction generally comprises the following:-

- interception
- infiltration
- depression storage
- evaporation
- evapotranspiration

After the initial abstraction is fulfilled, any excess rainfall will become direct runoff. In rural catchment, interception, evapotranspiration and evaporation do not serve as important factors for study on runoff and river discharge; however, they are not important in urban catchment. This is mainly because of its less significant impact. Infiltration depends upon factors such as tillage, soil structure, antecedent moisture content, infiltrating water quality and the soil air status. At the early stage, initial abstraction is caused by infiltration, commonly known as the rainfall that is absorbed by the soil prior to the start of direct runoff; while some assume that it is the extent of water that penetrates before the infiltration reaches a constant rate. The approaches to determine initial abstraction are very subjective. (McCuen, 1989).

Until today, there is no definite way to compute the initial abstraction. In common practices, the initial abstraction is just construed as a part of rainfall losses computed through various models. Despite that, in many hydrological studies, especially in the humid tropics, initial abstraction is usually estimated through the linear regression model. The initial abstraction can then be predicted through the x- intercept of the runoff versus rainfall chart.

2.3 Runoff

Runoff is that part of precipitation, as well as any other flow contribution which appears in surface streams or rivers of either perennial or intermittent forms. This is the flow collected from a catchment or drainage basin, and it appears at an outlet of the basin. According to the source from which the flow is derived, runoff may consist of surface runoff, subsurface runoff and groundwater runoff.

The surface runoff is that part of the runoff which travels over the ground surface and through channels to reach the basin outlet. The part of surface runoff that flows over the land surface towards stream/river channels is called overland flow, and after the flows enters a stream, it joins with other components of flow to form total runoff.

The subsurface runoff is also called as the subsurface flow, interflow, storm seepage or subsurface storm flow. It is that runoff due to that part of the precipitation which infiltrates the surface soil and moves laterally through the upper soil zone towards the streams as ephemeral, shallow, perched groundwater above the main ground water level. Some part of the subsurface runoff may enter the river promptly, while the remaining part may take a long time before joining the river flow.

The Groundwater runoff or groundwater flow is that part of the runoff due to deep percolation of the infiltrated water which has passed into the ground and has become groundwater, and has been discharged into the river or stream.

For runoff analysis, the total runoff in river channels is generally classified as direct runoff and base flow. Direct runoff is the runoff which enters the river promptly after the rain or snow melting. It consists of surface runoff, prompt subsurface runoff and channel precipitation, while base flow run off is the sustained or fair-weather runoff. It is composed of ground water runoff and delayed subsurface runoff.

During a run off producing storm, the total runoff may be assumed to consist of excess precipitation and abstractions. The part of precipitation that contributes entirely to direct runoff is known as effective precipitation or effective rainfall if only rainfall is involved.

2.3.1 Runoff Cycle

The Runoff cycle is comprised of five stages as discussed below.

The first stage relates to the rainless periods just prior to the beginning of rainfall and after an extended dry period. During this phase, the groundwater table is low and its elevation continues to decrease gradually. Water is lost through evaporation on land and water surface and by transpiration from plants.

The second stage relates to initial period of rain. As the rain starts, its amount is divided among channel precipitation, interception by vegetation, infiltration into the soil, and temporary retention in surface depressions. The infiltrated water results into a gradual increase of water in the zone of aeration after the natural storage or field moisture capacity is satisfied. During this phase, there is little overland flow except on impervious surfaces, while evaporation and transpiration are slight. Ground water runoff to the streams may or may not continue, depending on whether the first phase continued until stream flow ceased.

The third stage relates to a continuation of rain at varying intensities .As rain continues, the capacity of vegetation interception and retention of surface depressions are reached, and the excess rain becomes a source of runoff and detention storage on land surfaces and in channels. Overland flow occurs when the net rate of rain exceeds the infiltration rate; but it may or may not reach the stream or river channel depending on the retention and detention capacities of the land surface over which it travels. The infiltrated water will saturate the upper part of the zone of aeration and will then move down to the water table. If rain continues, the water table will rise and the ground water contribution to the stream flow will increase.

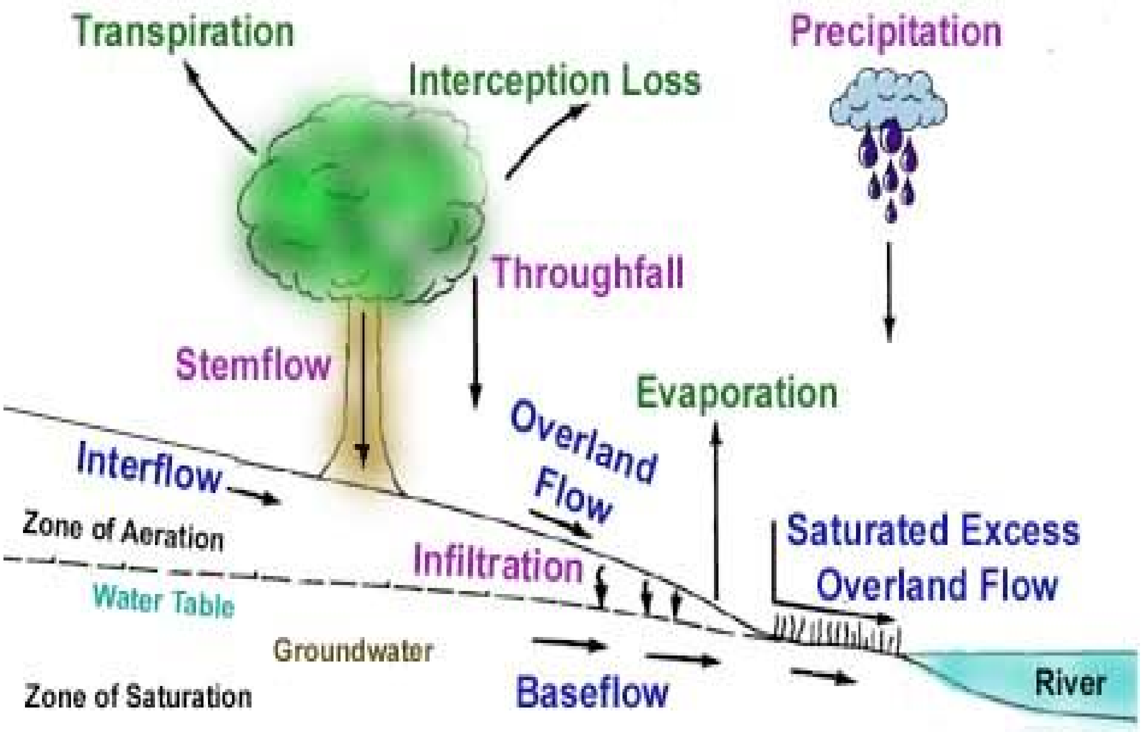
The fourth stage relates to continuation of rainfall until all natural storage has been satisfied. The infiltration rate will approach the rate of water transmission through the zone of aeration to both groundwater table and subsurface runoff. As rain continues, the water table rises constantly until the groundwater runoff balances the maximum rate of recharge possible and additional rain results in direct increment of runoff.

The last stage relates to period between the termination of rain and the time when the first stage is to be reached. It usually involves a long time for channel storage and surface retention to become depleted. Evapotranspiration is active and infiltration continues. Water in the zone of aeration is reaching the water table or the river channels .Stream flow is sustained by releasing stored water from the river channels, subsurface flow and groundwater flow. The water table is rising and then falling when its peak stage is over and the stored water is diminishing.

It should be noted that, the actual process is more complicated and variable since it is affected by numerous factors. The above description is just a simplified way of understanding the runoff cycle.

The figure below show some processes in the runoff cycle.

Fig 2.3.1 Illustration of runoff processes



2.3.2 Factors affecting runoff

From the hydrologic point of view, the runoff from a catchment may be considered as a product of the hydrologic cycle which is influenced by two major groups of factors:-

- Climatic factors
- Physiographic factors

Climatic factors include mainly the effects of various form and types of precipitation, interception, evaporation and transpiration, all of which exhibit seasonal variations in accordance with climatic environment. Physiographic factors may further be classified as into two types namely: catchment characteristics and channel characteristics.

Catchment characteristics encompass such factors as size, shape and slope of drainage area, permeability and capacity of groundwater formation, presence of water bodies e.g. swamps and lakes, and land use. Whereas channel characteristics are related mostly to hydraulic properties of the channel which govern the movement of river flows and determines the channel storage capacity. It should however be noted that the above classification of the factors is by no means exact because many factors are independent to a certain extent.

The following is summary of the major factors that affect runoff:-

i) Vegetation cover

The amount of rain lost to interception storage on the foliage depends on the kind of vegetation and its growth stage. Values of interception are between 1 and 4 mm. A cereal crop, for example, has a smaller storage capacity than a dense grass cover. More significant is the effect the vegetation has on the infiltration capacity of the soil. A dense vegetation cover shields the soil from the raindrop impact and reduces the crusting effect as described earlier. In addition, the root system as well as organic matter in the soil increases the soil porosity thus allowing more water to infiltrate. Vegetation also retards the surface flow particularly on gentle slopes, giving the water more time to infiltrate and to evaporate. In conclusion, an area densely covered with vegetation, yields less runoff than bare ground.

ii) Slope and catchment size

Investigations on experimental runoff plots (Sharma et al. 1986) have shown that steep slope plots yield more runoff than those with gentle slopes. In addition, it was observed that the quantity of runoff decreased with increasing slope length. This is mainly due to lower flow velocities and subsequently a longer time of concentration (defined as the time needed for a drop of water to reach the outlet of a catchment from the most remote location in the catchment). This means that the water is exposed for a longer duration to infiltration and evaporation before it reaches the measuring point. The same applies when catchment areas of different sizes are compared. The runoff efficiency (volume of runoff per unit of area) increases with the decreasing size of the catchment i.e. the larger the size of the catchment the larger the time of concentration and the smaller the runoff efficiency. Figure 2.4 clearly illustrates this relationship.

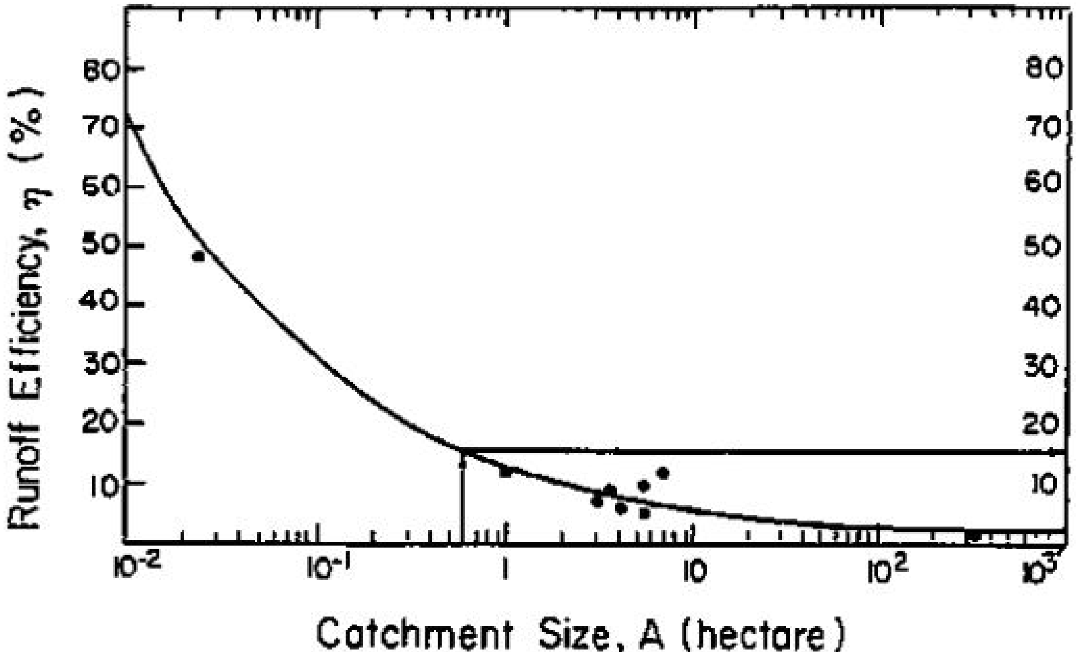


Figure 2.4: Runoff efficiency as a function of catchment size

The purpose of this diagram is to demonstrate the general trend between runoff and catchment size.

iii)Soil type

The infiltration capacity is among others dependent on the porosity of a soil which determines the water storage capacity and affects the resistance of water to flow into deeper layers. Porosity differs from one soil type to the other. The highest infiltration capacities are observed in loose, sandy soils while heavy clay or loamy soils have considerable smaller infiltration capacities. The infiltration capacity depends furthermore on the moisture content prevailing in a soil at the onset of a rainstorm. The initial high capacity decreases with time (provided the rain does not stop) until it reaches a constant value as the soil profile becomes saturated.

This however, is only valid when the soil surface remains undisturbed. It is well known that the average size of raindrops increases with the intensity of a rainstorm. In a high intensity storm the kinetic energy of raindrops are considerable when hitting the soil surface. This causes a breakdown of the soil aggregate as well as soil dispersion with the consequence of driving fine soil particles into the upper soil pores. This results in clogging of the pores, formation of a thin but dense and compacted layer at the surface which highly reduces the infiltration capacity. This effect, often referred to as capping, crusting or sealing, explains why in arid and semi-arid areas where rainstorms with high intensities are frequent, considerable quantities of surface runoff are observed even when the rainfall duration is short and the rainfall depth is comparatively small. Soils with a high clay or loam content are the most sensitive for forming a cap with subsequently lower infiltration capacities. On coarse, sandy soils the capping effect is comparatively small.

The factors affecting runoff generally tend to cause most large catchment areas to behave differently from most small catchment area on the basis of hydrologic behavior. A distinct characteristic of small basins is that the effect of overland flow rather than the effect of channel flow is a dominating factor. Also, small basins are very sensitive both to high intensity rainfall of short durations and to land use.

CHAPTER THREE

3.0 Methodology

The methodology has been split into two phases. The first phase is the methods used for analysis and the other phase is the collection of data.

3.1 Research Approach

The study deals with point rainfall and runoff data, and therefore uses statistical analysis method to obtain an estimate of the mean areal rainfall in the area from the rainfall stations and also the stream flow data.

3.1.1 Data Processing

Visual scrutiny was also used to compare and pick the most beneficial data that was used in the study since some years had a lot of missing data that could not be filled up.

It was difficult to find data on stations since some of the stations had been closed a couple of year's back; however the available data that was collected was used for the study.

It has to be noted that in the collection of both the precipitation and stream flow data from the relevant authorities, some of the data was missing, where there was missing data, the data was filled up by interpolation. For instance, the missing precipitation data of station 8935181 was interpolated as shown in Table 4 below:

Table 4: Table showing the filling in of missing data

Year/Month	**April**	**May**	**June**
1990	128.7	122.3	21.2
1991	50.1	**94.5**	138.9
1992	202.1	87.1	100

$$(50.1 + 138.9)/2$$

$$=94.5$$

3.1.2 Rainfall Analysis

3.1.2 .1 Determination of Seasonal Rainfall patterns

The average rainfall in each month for the whole record of the station was obtained; monthly averages were plotted and compared to observe variations of rainfall in each month.

The local relief modifies the regular weather pattern and therefore the study determines the mean monthly rainfall over the entire period of study to obtain the seasonal patterns of rainfall in the Kipkaren catchment. The monthly rainfall for the whole period of study i.e. 1980-2013 (33 years) was summed up and then divided by the total number of years for the period of study to give the Normal value e.g. March data for all years was summed up and divided by 33 to give the average March data.

3.1.2.2 Determination of the Average Rainfall

There are several methods used to determine the average rainfall at a station. These include:

- Thiessens Method
- Isohyetal Method
- Simple Mathematical average or Arithmetic mean
- Percent Normal
- Hysometric methods

Of the methods listed the two most common methods used are the Thiessens Method and Isohyetal Method. In this study, the Theissen Polygon Method was used because the local relief or topography had a minimal change in the contours there was no big difference in the heights.

3.1.2.3 Theissen Polygon Method

The catchment area was drawn, and then the triangles were joined using the positions of the rainfall stations.

Perpendicular bisectors bisecting the sides of the triangle were used to obtain the theissens polygons. Then the areas were calculated of the different Theissen polygons and the results were tabulated in the format below

The average rainfall for the Kipkaren catchment was then calculated.

Table 5: Table format of the results.

Station no.	Polygon	Area	Rain	Weighted Proportion	Average
1	A	P1	R1	P 1/P	R1*(P 1/P)
2	B	P2	R2	P 2/P	R2*(P 2/P)
3	C	P3	R3	P 3/P	R3*(P 3/P)
4	D	P4	R4	P 4/P	R4*(P 4/P)
5	E	P5	R5	P 5/P	R5*(P 5/P)
6	F	P6	R6	P 6/P	R6*(P 6/P)
	Total	P			$\Sigma (R_n * P_n / P)$

3.1.2.4 Probability analysis of Precipitation

The first step is to obtain annual rainfall totals from the area of concern i.e. Kipkaren catchment for the whole year of study. For statistical analysis it is usually necessary to have a record of more than 25 years. In the study, a period of 33 years was used.

The next step was to rank the annual totals in ascending order. The probability of occurrence P (%) for each of the ranked observations was then calculated from the equation:

$$P = m/(n + 1)$$

Where:

P = probability in % of the observation of the rank m
m = the rank of the observation
N = total number of observations used

The next step is to plot the ranked observations against the corresponding probabilities. For this purpose normal probability paper was used .Finally a curve is fitted to the plotted observations in such a way that the distance of observations above or below the curve should be as close as possible to the curve. The curve may be a straight line.

From this curve it is now possible to obtain the probability of occurrence or exceedance of a rainfall value of a specific magnitude. Inversely, it is also possible to obtain the magnitude of the rain corresponding to a given probability.

3.2 Streamflow Analysis

3.2.1 Flow Duration Analysis

A flow duration curve is a plot of discharge vs. percent of time that a particular discharge was equaled or exceeded. The area under the flow duration curve (with arithmetic scales) gives the average daily flow, and the median daily flow is the 50% value. It is useful to graph the data on probability paper.

The available records were analyzed to develop a flow duration curve. It is a cumulative frequency curve that represents the flow characteristics of a stream throughout the range of river flows or discharges. It is used in determining the percent of time specified discharges are equalled or exceeded during a given period.

The year of record must be complete for analysis; however these may not be in consecutive years; the physical conditions in the basin such as artificial storage, diversions and other manmade influences must essentially be the same during the period of flow analyzed.
Analysis period for assessment - The period selected can either be daily, weekly or monthly flows in a given period of record. The results of analysis can be used to show the characteristics of flows when time unit is very short, i.e. daily rather than monthly or annual and to estimate the percent of time that a specified discharge will be equalled or exceeded in the future if a reasonable long record of flows is available.

The mid-pts were plotted against Cumulative Probability on Log Probability paper
The value 95% low flow was obtained using the x value of (100 – 95) % = 5%. This is the value of flow which will be equaled or exceeded 95% of the Time or if the river used for water supply, the supply would be available 95% of the time; there is a chance of 5% failure.
Note that, usually for an Urban centre, 99% probability is used or maximum probable precipitation is used.

3.2.2 Low flow analysis

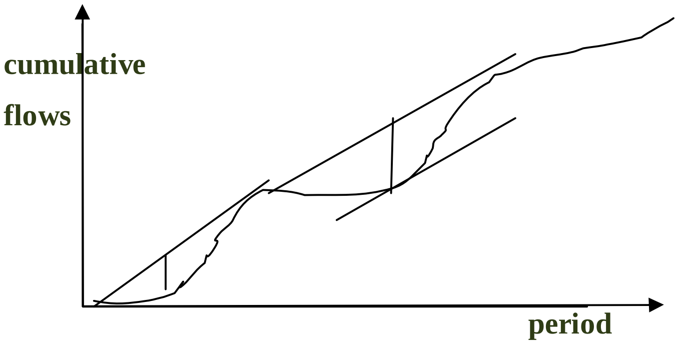
It is used to assess the low flows in the source of water. If adequate and appropriate records are available it provides a very accurate assessment of low flows.

A low flow frequency analysis evaluates the probability of lows occurring and remaining below a specified (low) design threshold for a given length of time. Customarily the analysis is carried out with regard to the minimum discharge aggregated over a period of days in each year –the minimum discharges are derived from daily flow series.
The analysis requires independent low flow values. Generally the daily, monthly values are not independent. The daily values should therefore not be used for this analysis; monthly data may be used but it must be made sure that the values are not dependent. Annual values are generally acceptable for this analysis. It is very important that the data available is adequate, generally over 25 year records.
The low flow values are arranged in ascending order; they are ranked (m), Probabilities are assigned using plotting position, (m/N+1) where N is the Total number of values; the flow data and the corresponding probabilities are plotted on Log probability paper. The low flow with the accepted probability of failure is obtained from the graph.

3.2.3 Storage Analysis

After careful visual scrutiny of the stream flow data, the dry period was chosen, that was done where there was minimum flow for the entire period. This was guided largely by looking at the minimum annual flow which gave the hint of the dry periods.

The flows during the period were then combined to obtain the cumulative flows. The cumulative flows were then plotted against the period that was taken e.g. for the study the period taken was from October1964 64 to January 1967.



There are two methods for storage analysis namely:

- Mass Curve Technique
- Ripple Method

Only one method was used i.e. the mass curve technique which comprises the graphical and mathematical solution.

Analysis was done using the graphical method and the results tabulated.

3.3 Data Collection

The study only dealt with secondary data of rainfall and stream flow of the Kipkaren catchment.

3.3.1 Rainfall and Streamflow data

The rainfall and stream flow data was obtained from the Kenya Meteorological Department and the Ministry of Environment, Water and Natural Resources. The study uses two rainfall stations (8935181 and 8935076) and two stream flow station (1CE01 and 1CA02). The stream flow stations were chosen on the basis that it provided tangible data over the study period compared to the other stream flow stations in the area and according to World Meteorological Organization (WMO) standard, it is not recommended to fill more than 10%

of missing data**.** The rainfall stations were chosen on the basis of their distance from the stream flow station.

Table 6: Rainfall and stream flow stations used in this study

STATION NO	STATION I.D	STATION NAME	LONGITUDE	LATITUDE
1	8935181	Eldoret Meteorological Station	35° 17’E	0° 32’N
2	8935076	Turbo Selborne Estate	35° 01’E	0° 39 ’N
3	1CE01		0°36’30”N	34°57’55”E
4	1CA02		0°38’00”N	35°04’00”E

CHAPTER FOUR

4.0 ANALYSIS AND DISCUSSION

4.1 RAINFALL ANALYSIS AND DISCUSSION

Table 7: Mean monthly and mean annual rainfall of Station 8935181

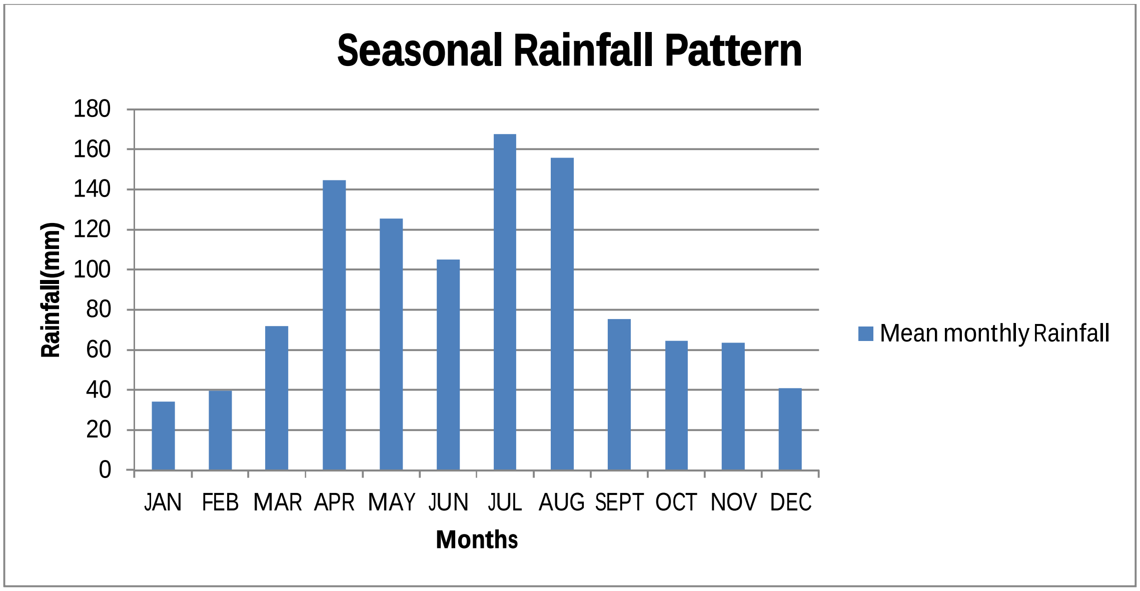
RAINFALL STATION I.D.8935181-ELDORET METEOROLOGICAL STATION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	Annual Mean
1980	42.6	**41.5**	40.4	169.8	231.9	96.5	127.7	112.4	43.1	18.2	40.6	7.2	**80.99**
1981	1	3.7	183	175.2	98.6	85.9	142.7	208.5	82.9	12.6	11.3	2.3	**83.98**
1982	4.1	36.3	63	214.7	182.1	47.4	91.1	179.8	63.5	68.6	239.1	38.9	**102.4**
1983	5.4	49	55.1	178.6	165	153.8	117.7	361.7	54.2	137.4	69	36	**115.2**
1984	7	8.2	13.7	88.4	45.4	58.5	150.3	44	50.2	34.4	79.2	39.9	**51.6**
1985	11.2	24.3	155.2	193.6	105.6	81	156.5	90.6	36.5	5.4	76.3	**53.7**	**82.49**
1986	4.7	7	54.3	137.6	62.5	123.9	136.6	87.6	92.3	9.1	10.2	44.8	**64.22**
1987	60.5	66.5	71.6	118.2	273.4	150	61	154.9	20.3	38.7	129.9	3.1	**95.68**
1988	55.7	8.7	35.5	192.1	40.5	146.4	178.8	107.9	134.2	58.8	24.8	16.3	**83.31**
1989	15	46	121.3	159	151.8	101.2	206.9	125.7	110	57.9	41.2	116.2	**104.4**
1990	45.3	156.3	65.8	128.7	122.3	21.2	164.7	106.9	68.1	21.4	61	48.2	**84.16**
1991	38	11.6	129.3	50.1	**99.6**	138.9	222.7	192.5	41.8	48.9	68.6	15.7	**88.14**
1992	3	14.1	13.3	202.1	87.1	100	179.9	244.7	95.8	127.8	42.4	12.4	**93.55**
1993	62.5	67.5	0.4	23.5	110.7	80.9	96.9	97	79.3	14.2	39.9	15.6	**57.37**
1994	0	5.8	95.5	188.5	238.7	142.4	208	151.1	25.4	13.6	100	5	**97.83**
1995	0.3	36	84.5	193.1	52.9	71.4	156.6	141.6	63.6	85.1	69.7	23.4	**81.52**
1996	26.9	54.6	180.2	58.5	76.7	144.8	246.8	165.2	70.1	13.7	50.9	1.8	**90.85**
1997	19.6	**55.5**	56.5	285.1	25	152.3	174.5	101	0.8	155.8	176.7	64.7	**105.6**
1998	231.5	91.2	37	74	133.1	179.4	320.9	232.6	95.2	100.4	32	0.6	**127.3**
1999	38.3	**79**	183.3	108.8	57.4	68.4	192	119.7	29.6	196.8	38.8	29.3	**95.12**
2000	4.8	3.1	13.7	38.5	162.1	72.4	147.7	195.9	91.7	105.6	14.9	8.5	**71.58**
2001	125.8	2.3	78.9	154.3	77.2	142.9	144.8	233.5	26.5	106.2	65.1	1	**96.54**
2002	42.5	29.6	39.2	88.3	182.2	37.1	91.1	109.9	1.5	64.4	31.9	174.5	**74.35**
2003	2	2.4	47.4	282.1	170.4	102.8	85.6	198.7	28.4	5.2	7.6	42.3	**81.24**
2004	55.1	3.2	57.5	226.1	57.2	104.2	125.9	115.5	95.6	54.2	121.9	17	**86.12**
2005	37.3	18.5	97.7	61.2	201.7	82.2	264.5	179.8	103.5	5	10.9	4	**88.86**
2007	39	145.3	43.4	86	101.1	129.2	164.8	174.3	219.6	2.7	29.5	**59**	**99.49**
2008	5.3	3.9	74.7	99.3	79.9	77.6	182	87.1	156.4	134.1	123.2	**32.1**	**87.97**
2009	8.3	0.8	7.4	84.4	160.6	20.5	147.4	73.2	48.7	120.4	16.4	180.1	**72.35**
2010	68.3	167.9	76.1	87.7	217.1	68.2	334.7	198.2	42.7	51	4.2	35.8	**112.7**
2011	1.3	43.5	56.3	68.8	76.4	128.1	196.2	144.4	130.3	58.4	175.5	19.8	**91.58**
2012	0	11.8	20.2	296.4	177.2	215.9	**168.3**	116.3	123.3	124.5	34.1	152.8	**120.1**
2013	58.7	3.9	118	262.9	119.3	143.9	144.7	284.8	166.1	79.6	**56.9**	**48**	**123.9**
Monthly mean	**33.97**	**39.36**	**71.8**	**144.7**	**125.5**	**105.1**	**167.6**	**155.7**	**75.49**	**64.55**	**63.45**	**40.91**	

From the table above it can be clearly seen that the period with the heaviest amount of rainfall was 1998 with an annual mean rainfall of 127.3 mm. It can also be seen that the period with the least amount of rainfall was 1984 with an annual mean of 51.6mm.

4.1.1 Determination of Seasonal Rainfall patterns

Figure 4.1.1: Seasonal rainfall pattern of station no.8935181



From the figure above, it can be shown that the area has two rainy seasons and one dry season. The dry season occurs from November to February whereas the rainy season occurs from March to May and July to September. The climate is characterized by a regime of two rainy seasons per year occurring generally in March to May and in August to October (The months of April/May have the highest rainfall followed by July and then August.

Table 8: Table of the Annual Total Rainfall of station I.D.8935181-Eldoret Meteorological Station

YEAR	Annual Total	RANK(m)	P=m/(n+1)	Percentage (%)
1984	619.2	1	0.0294	2.94
1993	688.4	2	0.0588	5.88
1986	770.6	3	0.0882	8.82
2000	858.9	4	0.1176	11.8
2009	868.2	5	0.1471	14.7
2002	892.2	6	0.1765	17.6
1980	971.9	7	0.2059	20.6
2003	974.9	8	0.2353	23.5
1995	978.2	9	0.2647	26.5
1985	989.9	10	0.2941	29.4
1988	999.7	11	0.3235	32.4
1981	1007.7	12	0.3529	35.3
1990	1009.9	13	0.3824	38.2
2004	1033.4	14	0.4118	41.2
2008	1055.6	15	0.4412	44.1
1991	1057.7	16	0.4706	47.1
2005	1066.3	17	0.5	50
1996	1090.2	18	0.5294	52.9
2011	1099	19	0.5588	55.9
1992	1122.6	20	0.5882	58.8
1999	1141.4	21	0.6176	61.8
1987	1148.1	22	0.6471	64.7
2001	1158.5	23	0.6765	67.6
1994	1174	24	0.7059	70.6
2007	1193.9	25	0.7353	73.5
1982	1228.6	26	0.7647	76.5
1989	1252.2	27	0.7941	79.4
1997	1267.5	28	0.8235	82.4
2010	1351.9	29	0.8529	85.3
1983	1382.9	30	0.8824	88.2
2012	1440.8	31	0.9118	91.2
2013	1486.8	32	0.9412	94.1
1998	1527.9	33	0.9706	97.1

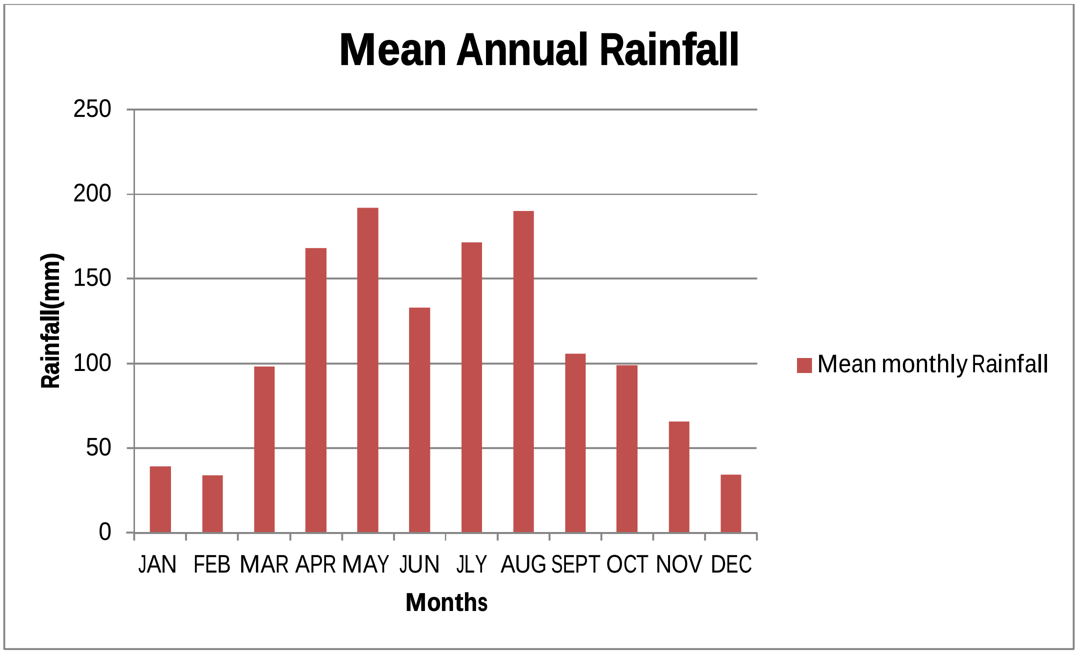
Figure 4.1.2 shows the probability plot of the annual total rainfall of Station 8935181.

From the graph, it is seen that for the probability of 50%,the total annual precipitation is 1100mm for the period of 1980 to 2013 whereas for 5% of precipitation will be 60mm.The 95% of precipitation will be 1400mm.

Table 9: Mean monthly and mean annual rainfall of Station no.8935076

RAINFALL STATION I.D.8935076-TURBO SELBORNE ESTATE													
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JLY**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**MEAN ANNUAL**
1980	16.4	1.4	51	177.8	333.3	207.3	162.7	149.1	90.2	31.4	30.4	7.4	**104.87**
1981	8.6	37.6	274.6	268	137.9	119	145.5	232.3	150	50.8	5.6	22.9	**121.07**
1982	97.3	20.6	48.2	187.5	281.4	169.8	148.3	287.6	94.2	112.9	215.4	20.3	**140.29**
1983	40.2	17.5	90	137.5	200.3	148	153.3	231.9	130.8	156.7	54.1	56.7	**118.08**
1984	14	8.3	22.3	96.7	222.3	159.7	292.1	204	145.5	46.8	65.2	47.5	**110.37**
1985	32	58	154.5	203.2	295.1	128.3	224.9	193.6	55.6	53.1	136.9	7.5	**128.56**
1986	6	10	97.6	230.5	190.9	131.2	164.1	91.2	131.7	32.8	7.1	83.6	**98.058**
1987	37.7	48.3	144	166.6	243.5	155.7	73.3	214.7	46	115.5	178.5	12.6	**119.7**
1988	57	34.8	24.7	286.3	161.9	110.8	246.6	145.4	229.5	91.5	22.3	4.5	**117.94**
1989	6.7	42.2	**80.4**	154.3	145.3	118.7	179.6	188.9	99.9	139.2	52.2	94.6	**108.5**
1990	50.6	63.9	100.3	224.5	182.8	58.2	149.4	265.9	85.2	71	51.7	**54.4**	**113.16**
1991	36.7	26.4	117.1	76.2	164.6	218	209.5	188.3	84	116.9	18.5	17	**106.1**
1992	17.6	48.7	80.4	200.7	159.1	119.3	446.4	291.7	262.9	65.7	0.3	44.1	**144.74**
1993	84.2	121.6	**119.2**	160.1	309.9	228	72	167.8	138.1	11.2	73.4	88.1	**131.13**
1994	2.1	30.8	114.5	199.2	307.3	127.5	147.5	231.4	119.7	42	135.4	0	**121.45**
1995	28.8	60.4	113.2	196.4	110.8	219.1	232.4	167.6	125.1	**97**	125.9	22.1	**124.9**
1996	71.9	88.1	148.4	120.7	145.6	109.4	151.5	**133.2**	**77.7**	95.1	79.2	8.6	**102.45**
1997	17.8	0	70.5	234.8	69.2	61.2	163.3	135.9	13	194.5	189.9	75.4	**102.13**
1998	102.6	76.1	12	126.6	293.1	32	327.1	240.5	186.6	365.3	6.8	0	**147.39**
1999	20.4	1.9	255.1	87.3	79.7	128.6	65.9	158.3	40.8	196.6	32.7	33.3	**91.717**
2000	0	0	29	108.4	191.6	217.8	110.5	319.8	114.1	134.3	27.5	28.1	**106.76**
2001	174.6	3.9	141.2	286	255.9	128.8	125.6	260.8	76.1	127.9	57.7	9.3	**137.32**
2002	17.4	0	49.3	59.5	60.2	39.9	70.5	20.2	2.4	12.9	13.6	82	**35.658**
2003	0	11.5	17.3	47.3	65.4	54.2	58.1	41.8	43.2	9.6	0	2	**29.2**
Monthly Mean	**39.19**	**33.83**	**98.12**	**168.17**	**191.96**	**132.94**	**171.67**	**190.08**	**105.93**	**98.78**	**65.85**	**34.25**	

Figure 4.1.3: Seasonal rainfall pattern of Station no. 8935076



Taking another meteorological station in the catchment (8935076),this to compare the results with the station 8935181. It was seen that it produced the same seasonal pattern as we found out. From figure 4.1.3 it can be seen that there are two rainy seasons and one dry season. The rainy seasons were from March to May and July to October while the dry season was from November to February.

Table 10: Table of the Annual Rainfall of Station No.8935076-Turbo Selborne Estate

Year	Annual Total	Rank(m)	P=m/(n+1)	Percentage (%)
2003	350.4	1	0.04	4
2002	427.9	2	0.08	8
1999	1100.6	3	0.12	12
1986	1176.7	4	0.16	16
1997	1225.5	5	0.2	20
1980	1258.4	6	0.24	24
1996	1271	7	0.28	28
1991	1273.2	8	0.32	32
2000	1281.1	9	0.36	36
1989	1315.5	10	0.4	40
1984	1324.4	11	0.44	44
1990	1344.3	12	0.48	48
1995	1401.8	13	0.52	52
1988	1415.3	14	0.56	56
1983	1417	15	0.6	60
1987	1436.4	16	0.64	64
1981	1452.8	17	0.68	68
1994	1457.4	18	0.72	72
1985	1542.7	19	0.76	76
1993	1595.2	20	0.8	80
2001	1647.8	21	0.84	84
1982	1683.5	22	0.88	88
1992	1736.9	23	0.92	92
1998	1768.7	24	0.96	96

Figure 4.1.5 in page 30(a) shows the probability plot of the annual total rainfall of Station 8935076.

From the figure 4.1.5, it is seen that for the probability of 50%, the total annual precipitation is 1400mm for the period of 1980 to 2003 whereas 95% of precipitation will be 1800mm.

4.1.4: Determination of average rainfall by use of Theissen polygon method

Table 11: Theissen Polygon method of finding average rainfall

Gauge No.	Polygon	Area(km2)	Precipitation(mm)	Weighted	Average
1	A	1009.375	127.2	0.312077	39.696
2	B	325	134.61	0.100483	13.526
3	C	481.25	101.6	0.148792	15.117
4	D	296.875	101.63	0.091787	9.3284
5	E	331.25	126.35	0.102415	12.94
6	F	90.625	122.04	0.028019	3.4195
7	G	362.5	122.05	0.112077	13.679
8	H	243.75	126.81	0.075362	9.5567
9	I	93.75	116.06	0.028986	3.3641
Total		**3234.375**			**120.63**

Figure 4.1.9 shows how the Theissen polygon method was done.

By using the Theissen polygon method, the average rainfall in the Kipkaren Catchment was found out to be 120.63 mm.

4.2 Stream flow analysis

Table 12: Monthly Summary of the Flow (cumecs) of Gauging Station 1CE01

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	Mean	Max	Min
1954	0.047	0.01	0.001	0.103	1.801	2.227	5.257	17.39	20.49	3.327	0.58	0.501	4.31	20.49	0.001
1955	0.065	0.2	0.035	0.094	0.096	0.231	1.885	43.09	42.9	11.58	2.525	1.501	8.68	43.09	0.035
1956	4.428	1.109	0.223	1.483	3.73	2.532	11.14	50.8	28.93	6.209	1.864	0.76	9.43	50.8	0.223
1957	0.219	0.216	0.264	0.214	2.269	7.525	4.498	10.29	3.758	0.502	0.4	0.22	2.53	10.29	0.214
1958	0.083	0.381	0.103	0.057	1.706	2.566	9.087	18.95	15.27	13.68	1.312	0.635	5.32	18.95	0.057
1959	0.157	0.055	0.183	0.287	1.37	0.894	2.588	6.616	9.136	4.292	1.92	1.181	2.39	9.136	0.055
1960	0.247	0.075	0.253	0.606	1.737	0.992	2.229	9.335	13.02	2.531	1.226	0.346	2.72	13.02	0.075
1961	0.106	0.043	0.031	0.109	0.422	0.938	1.358	26.46	17.34	8.221	70.34	38.27	13.6	70.34	0.031
1962	18.536	4.311	1.705	2.02	16.008	6.2	8.379	28.85	27.76	**5.69**	**3.615**	1.54	10.4	28.85	1.54
1963	1.182	0.665	0.624	6.455	43.418	12.23	9.251	27.7	12.52	3.159	2.12	24.88	12	43.42	0.624
1964	3.724	1.02	1.039	4.075	3.677	1.732	16.27	75.67	37.11	20.18	5.199	2.439	14.3	75.67	1.02
1965	1.434	0.469	0.357	0.497	0.763	0.243	0.337	0.879	0.237	0.553	0.824	0.213	0.57	1.434	0.213
1966	0.053	0.034	0.031	3.015	1.857	0.866	1.923	9.956	16.92	1.782	0.839	0.167	3.12	16.92	0.031
1967	0.023	0.012	0.007	0.228	18.961	5.912	31.71	28.67	13.54	6.9	4.384	6.968	9.78	31.71	0.007
1968	0.324	0.798	1.827	4.673	10.449	4.662	5.441	27.3	3.158	1.369	0.439	5.332	5.48	27.3	0.324
1969	1.007	1.177	1.048	0.508	2.062	0.862	1.842	4.34	7.174	1.953	1.08	0.508	1.96	7.174	0.508
1970	1.072	1.26	0.791	3.916	10.014	5.363	5.287	32.3	27.09	9.275	3.549	1.652	8.46	32.3	0.791
1971	0.891	0.476	0.195	0.341	1.251	3.939	12.28	25.06	18.08	8.733	2.77	1.659	6.31	25.06	0.195
1972	1.21	1.393	0.427	0.256	1.628	3.5	13.39	16.65	6.899	4.324	9.28	5.088	5.34	16.65	0.256
1973	1.632	0.799	0.301	0.133	0.535	1.295	0.999	7.495	7.72	3.232	1.961	0.688	2.23	7.72	0.133
1974	0.318	0.126	0.199	0.597	0.634	0.942	4.684	8.297	8.02	2.435	0.829	0.302	2.28	8.297	0.126
1975	0.124	0.056	0.092	0.756	3.282	6.725	10.53	65.89	41.91	19.41	4.807	2.389	13	65.89	0.056
1976	1.013	0.485	0.238	0.358	1.3	1.281	4.842	5.199	8.603	1.501	0.876	0.407	2.18	8.603	0.238
1977	0.344	0.289	0.146	7.275	78.036	40.94	72.22	69.27	39.01	35.79	129.1	45.47	43.2	129.1	0.146
1978	22.268	21.31	52.502	41.58	26.054	19.1	52.12	84.2	74.99	35.53	20.01	14.31	38.7	84.2	14.31
1979	8.453	22.02	12.785	14.72	14.766	18.01	23.61	42.27	15.83	8.533	4.934	3.162	15.8	42.27	3.162
1980	1.895	1.55	1.351	4.51	16.721	12.95	28.1	18.13	13.4	5.412	3.83	2.256	9.18	28.1	1.351
1981	1.462	1.22	4.24	35.97	24.971	13.27	24.62	67.17	43.85	21.99	10.15	5.402	21.2	67.17	1.22
1982	3.157	2.326	1.503	6.997	18.538	21.19	11.26	30.18	18.69	10.9	30.61	41.25	16.4	41.25	1.503
1983	**4.858**	6.867	4.043	4.157	8.417	9.85	17.5	60.22	66.45	45.58	18.23	8.644	21.2	66.45	4.043
1984	4.551	3.017	1.885	2.357	2.105	2.838	5.634	5.971	4.798	2.603	2.282	1.75	3.32	5.971	1.75
M.M.F	2.7382	2.38	2.8525	4.786	10.277	6.833	12.91	29.83	21.44	9.909	11.03	7.093			
MAX.FLOW	22.268	22.02	52.502	41.58	78.036	40.94	72.22	84.2	74.99	45.58	129.1	45.47			
MIN.FLOW	0.023	0.01	0.001	0.057	0.096	0.231	0.337	0.879	0.237	0.502	0.4	0.167			

4.2.1 STATISTICAL FLOW DURATION ANALYSIS OF 1CE01-1954-1984

Table 13: Statistical Flow Duration Analysis

Classes	Mid-pt	Tally	Freq(f)	C.F	P=m/(n+1)
0.001-0.01	**0.0055**	**III**	3	3	**0.008**
0.01-0.05	**0.03**	**~~IIII~~ III**	8	11	**0.03**
0.05-0.1	**0.075**	**~~IIII~~ ~~IIII~~**	10	21	**0.056**
0.1-0.2	**0.15**	**~~IIII~~ ~~IIII~~ IIII**	14	35	**0.094**
0.2-0.3	**0.25**	**~~IIII~~ ~~IIII~~ ~~IIII~~ II**	17	52	**0.14**
0.3-0.4	**0.35**	**~~IIII~~ ~~IIII~~ II**	12	64	**0.172**
0.4-0.6	**0.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ I**	16	80	**0.215**
0.6-0.8	**0.7**	**~~IIII~~ ~~IIII~~ II**	12	92	**0.247**
0.8-1.0	**0.9**	**~~IIII~~ ~~IIII~~ III**	13	105	**0.282**
1.0-2.0	**1.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII**	54	159	**0.427**
2.0-3.0	**2.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ II**	22	181	**0.487**
3.0-4.0	**3.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ IIII**	19	200	**0.538**
4.0-6.0	**5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~**	35	235	**0.632**
6.0-8.0	**7**	**~~IIII~~ ~~IIII~~ ~~IIII~~**	15	250	**0.672**
8.0-10.0	**9**	**~~IIII~~ ~~IIII~~ ~~IIII~~ III**	18	268	**0.72**
10.0-15.0	**12.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III**	23	291	**0.782**
15.0-20.0	**17.5**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ I**	21	312	**0.839**
20.0-30.0	**25**	**~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III**	23	335	**0.901**
30.0-40.0	**35**	**~~IIII~~ ~~IIII~~**	10	345	**0.927**
40.0-60.0	**50**	**~~IIII~~ ~~IIII~~ IIII**	14	359	**0.965**
60.0-80.0	**70**	**~~IIII~~ ~~IIII~~**	10	369	**0.992**
80.0-100.0	**90**	**I**	1	370	**0.995**
100.0-150.0	**125**	**I**	1	371	**0.997**

From the flow duration curve plotted in Figure 4.1.6, it can be seen that for 5% low flow, the flow will be 0.064cumecs.Tthis means that for 5% low flow less than 0.064 cumecs,95% of the time the flow will be greater than 0.064cumecs.

Since we have Eldoret town as the nearby urban centre, the 99% low flow will be 80 cumecs for the 30 years duration. This is the flow of water that will be available 99% of the time for the supply of water. For Rural Water supply, we use 95% low flow, for this case it will be 42 cumecs. 90% low flow will be 26 cumecs. The 50% low flow gives an average value of the flow for the duration considered as 2.6 cumecs.

4.2.2 Low flow analysis and Discussion

Table 14: Statistical Low flow Analysis 1954-1984 (1CE01)

Year	Annual Flow	Rank(m)	P=m/(n+1)	Percentage (%)
1955	2.94	1	0.031	3.1
1954	10.527	2	0.063	6.3
1956	14.102	3	0.094	9.4
1959	16.986	4	0.125	13
1961	20.32	5	0.156	16
1960	22.448	6	0.188	19
1963	24.83	7	0.219	22
1964	27.109	8	0.25	25
1957	31.319	9	0.281	28
1962	33.273	10	0.313	31
1966	44.494	11	0.344	34
1958	47.548	12	0.375	38
1973	50.52	13	0.406	41
1967	52.758	14	0.438	44
1969	62.615	15	0.469	47
1971	69.048	16	0.5	50
1965	74.966	17	0.531	53
1975	79.759	18	0.563	56
1978	85.81	19	0.594	59
1979	94.152	20	0.625	63
1968	102.011	21	0.656	66
1974	115.987	22	0.688	69
1970	135.533	23	0.719	72
1972	146.892	24	0.75	75
1976	175.942	25	0.781	78
1977	207.571	26	0.813	81
1980	233.802	27	0.844	84
1983	268.519	28	0.875	88
1981	328.671	29	0.906	91
1984	494.837	30	0.938	94
1982	708.945	31	0.969	97

From the graph plotted in figure 4.1.7 in page 34(a), it can be seen that for 5% low flow will be 9.5 cumecs meaning that for 5% low flow < 9.5 cumecs, 95% of the time the flow will be > 9.5 cumecs.

4.2.3 Storage analysis

The Graphical Solution was used on the Station 1CA02 because it had a longer period of the dry periods.

Graphical Method-Station 1CA02

Table 17: Cumulative flow of station 1CA02

Period	Flow(cumecs)	Cumulative flow(cumecs)
Oct-64	4.707	4.707
Nov-64	1.278	5.985
Dec-64	0.777	6.762
Jan-65	0.603	7.365
Feb-65	0.179	7.544
Mar-65	0.108	7.652
Apr-65	0.152	7.804
May-65	0.305	8.109
Jun-65	0.095	8.204
Jul-65	0.176	8.38
Aug-65	0.294	8.674
Sep-65	0.112	8.786
Oct-65	0.079	8.865
Nov-65	0.104	8.969
Dec-65	0.049	9.018
Jan-66	0.039	9.057
Feb-66	0.034	9.091
Mar-66	0.025	9.116
Apr-66	0.906	10.022
May-66	0.99	11.012
Jun-66	0.492	11.504
Jul-66	1.416	12.92
Aug-66	7.153	20.073
Sep-66	7.62	27.693
Oct-66	1.08	28.773
Nov-66	0.75	29.523
Dec-66	0.197	29.72
Jan-67	0.058	29.778
Feb-67	0.052	29.83
Mar-67	0.063	29.893
Apr-67	0.119	30.012
May-67	10.09	40.102
Jun-67	3.728	43.83

From the mass curve plotted in page 36(a), the storage required for the various ranges of demand were gotten and tabulated as shown below.

Table 16: Demand and Storage required

Demand(cumecs)	Storage Required (cumecs)	Volume(m^3)
d_1 = 1.0	s_1 = 12.3	31,881,600
d_2 =0.8	s_2 = 10.1	26,179,200
d_3 =0.6	s_3 =7.1	18,403,200
d_4=0.4	s_4 = 4.4	11,404,800
d_5=0.7	s_5=3.2	8,294,400
d_6=1.2	s_6=13.4	34,732,800

For instance assuming a demand of 1.2cumecs the storage required will be 13.4 cumecs. This translates to (13.4*86400*30) = 34,732,800 m^3.

From the graph (figure 4.1.8) x_1 is the time it takes for the storage to be full, this is between March 1966 and September 1966.

At point P, that is the time the storage is empty.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The hydrological study of the Kipkaren River Basin has revealed very important results. The objectives which were set for this study were generally achieved to average extent taking into account the constraints of missing data sets and inaccurate data. Kipkaren River is one of the largest tributary on the Nzoia River. The following conclusions have been arrived at after the analysis of both rainfall and stream flow data obtained:

- The catchment has two rainy seasons: the short rain season from August to October and the long rain season from– March to May. Also from the statistical analysis the 50% average precipitation was found to be 1100mm for station.8935181 and 1400mm for station 8935076 which was close to 1500 which is the mean annual rainfall for the catchment area. The average rainfall was also found out to be 120.63mm.
- Different storage values have been found out, this can be used to estimate the amount of storage required if the demand in the township is known, for instance the nearby town is Eldoret Township, so if the demand is 1.0cumecs storage of $31.9*10^6m^3$ can reserved for the water supply in the Township. To put up a dam, one has to do the survey on the catchment area and take the nearest gauging station, take the flows and then probability analysis can be further done here for a longer period of records to get the best storage required.
- In the flow duration analysis it was found out that:

5% low flow ⟶ 0.064cumecs

5% of the time flow < 0.064cumecs

95% of the time flow > 0.064 cumecs

For urban water supply project the 99% flow available would be 80 cumecs.

- It is also apparent that the forest cover has decreased remarkably while in contrast, the agricultural area has increased. This could be attributed to the cutting of trees in the forests for various uses such as firewood, timber and clearing for agricultural purposes. This has an effect on the stream flow since the surface runoff will increase and there will be high level sedimentation due to the eroded river banks that have cultivated.
-

5.2 Recommendations

- In order to provide a sufficient storage, accurate and up-to –date records should be used because of the changing demands in the Eldoret region. This may be due to the population growth, industrial use e.tc

- In order to reduce flooding and sedimentation more attention should be paid to land-use patterns and some control measures should be built i.e. afforestation should be promoted in the basin as one long term measure of managing floods in the basin.

- Although the stream flow may shows an increasing tendency in the short rain season and decreasing tendency in the long rain season, there is a need to study a longer period than that considered in this study, for better indications of the trends

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APPENNDIX

APPENDIX A: TABLES

APPENDIX B: MAPS