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ANALYSES OF SURFACE AND GROUNDWATER FLOW PROCESS IN WESTERN GHAT OF DAKSHINA KANNADA DISTRICT, KARNATAKA STATE

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ABSTRACT

Though the study area receives more than 4000 mm rainfall annually, the area faces acute shortage of fresh water during summer months. Besides, the river and the adjoining wells turns saline during summer months. These problems have a great impact on human settlement and their socio-economic conditions. In order to identify the cause for scarcity of water during dry months inspite of high rainfall in the area, geohydrological and geomorphological studies are the need of the hour. With this in view, a detailed study has been taken up for Sithanadhi and Nethravathi basins by the following analyses to identify the surface and sub-surface flow process of the study area.

The distribution of rainfall has been analysed and the importance in peak discharge and quantum of yield from the basin and also in recharging the groundwater aquifer is studied. The annual rainfall departure analysis has shown the deviation of the rainfall from the normal rainfall over a period of time. The probability analysis of annual rainfall is used to predict the relative frequency of occurrence in different group of intervals of annual rainfall.

The rainfall recharge and discharge condition of the study area is reflected by the relationships between the water level fluctuation and monthly rainfall.

Water balance components such as precipitation, surface runoff, baseflow, wetting, and vaporisation are estimated to analyse each components with respect to the annual precipitation using conceptual catchment water balance model and relationship between the components have been analysed.

Geomhorpological parameters which are influencing on movement of water and thereby the effect on volume of runoff is studied.

Land use and geology considered for the effect on runoff process of the basin as the variation of abstraction factors depend on the land use and its cover. The range of infiltration rate is correlated with surface runoff, recharge and drainage condition.

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1.0 INTRODUCTION

The natural distribution of water is extremely uneven. This unevenness is aggravated by geohydrological charges still greater unevenness of the geographical distribution of human settlement. Shortage of fresh water is noticed in areas where there is an excess of population and industry. Besides, modern industry with its manufacture of increasingly complex and diverse products requires not just fresh, but exceptionally clean water.

The value of groundwater as a source of irrigation lies in the fact that it is widely distributed and dependable even during the periods of scarcity and drought and can be put to use as and when it is needed. Many irrigated crops take more than 400 litres of water to yield one kilogram of food grain.

Water resources development holds the key in the socioeconomic property of a region. Selection of proper method of irrigation can be one of the most important sources of conservation of irrigation water.

The conservation processes are inter-related to integrated catchment management. Integrated catchment management is a process or tool which allows consideration of the linkage among natural resources, as well as consideration of diverse interest and values. This is necessary for a variety of reasons as land and environmental resources together, rather than focusing on each in isolation.

Water resources development is essential for economic and social progress of mankind. Rapid growth of population and ever increasing living standards in India have resulted sharp rise in requirements of water necessitating expeditious development of the available water resources, and their proper management. The time is perhaps not too far when suitable technologies may have to be evolved for augmenting water resources to cater to the needs of areas with inadequate water supplies.

It is a fact that the district receives an average annual rainfall of about 4000 mm and major west flowing rivers drain fresh water from the western ghats into the Arabian sea. All surface water resources go as runoff without any use. Though there is enormous surface water resources available, it cannot be utilised or stored, because of uneven topography and unsuitable geological formations. Reservoirs, if constructed in flat terrain near the coastal belt, inundate large cultivable and inhabited areas. Further, the area is covered with laterites which are highly porous and permeable. So no water can be stored in these formations. Also a considerable quantity of stored water could be lost due to high rate of evaporation during summer months. Hence construction of reservoirs is not feasible in Dakshina Kannada district(Ranganna, 1989).

During summer months the river water gets contaminated by the back waters from sea during high tides, thus rendering it unsuitable for any use. Due to uneven distribution of rainfall in terms of time and space, the utilisable surface water is limited and groundwater development activity has increased considerably during the last few years. So, the people have to depend upon groundwater for their needs. Deepening of wells near the sea shore and on the banks of the river for purposes of tapping more groundwater results in salt water intrusion into the fresh water wells. The saline water from the rivers and wells would in turn increase the salinity of irrigated soils. This, in turn, results in considerable drop in soil productivity and farm yield.

The coastal tract consisting of forest laterite soil is unable to hold the rain water for a longer period, result in quick depletion of the subsurface water potential

Over irrigation and excessive application of chemical fertilizers and pesticides are common practices which lead to health hazards.

Due to deforestation in the western ghats region high rate soil erosion and siltation of the river courses are experienced. Due to the above facts, the water resources in the region are inadequate to meet the ever growing demand for fresh water. These problems have a great impact on human settlement and their socio-economic conditions. In order to asses the quantum of water available for utilisation, systematic geohydrological and hydrogeochemical studies are the need of the hour.

1.1.0 Scope of the study

Though the study area receives more than 4000 mm rainfall annually, the area faces acute shortage of fresh water during summer months. Besides, the river and the adjoining wells turns saline during summer months. Groundwater is the only dependable source for irrigation and domestic purposes during the summer months. The groundwater table goes down at a faster rate and dry up during early summer months. These problems have a great impact on human settlement and their socio-economic conditions. In order to identify the cause for scarcity of water during dry months inspite of high rainfall in the area, geohydrological and geomorphological studies are the need of the hour. With this in view, a detailed study has been taken up for Sithanadhi and Nethravathi basins by the following investigations.

1. Rainfall analyses - The distribution of rainfall assumes considerable importance in peak discharge and quantum of yield from the basin and also in recharging the groundwater aquifer. The annual rainfall departure analysis is a good indicator of the deviation of the rainfall from the normal rainfall over a period of time. The probability analysis of annual rainfall is useful to predict the relative frequency of occurrence in different group of intervals of annual rainfall.
2. Groundwater table Analyses - The rainfall recharge and discharge condition of the study area is also reflected by the relationships between the water

level fluctuation and monthly rainfall. The recharge and discharge of groundwater table is influenced by soil cover and its characters, weathered rocks at the surface, open joints etc.

3. Conceptual catchment water balance model - Water balance components such as precipitation, surface runoff, baseflow, wetting, and vaporisation are estimated to analyse each components with respect to the annual precipitation using conceptual catchment water balance model.

4. Geomorphology - Geomhorpological parameters which are influencing on movement of water and thereby the effect on volume of runoff is studied.

5. Geology and land use - Land use and geology considered for the effect on runoff process of the basin as the variation of abstraction factors depend on the land use and its cover.

6. Infiltration study - Infiltration rates are very widely depending on condition of the land surface, the type, extent, and density of vegetative cover, physical properties of the soil, the storm characters i.e., intensity depth duration, and etc.. It affects not only the timing but also the distribution and magnitude of surface runoff. In the present case the range of infiltration rate is to be correlated with surface runoff, recharge and drainage condition.

1.2.0 Rainfall Analysis

Rainfall forms the input for all hydrological studies over a catchment area for which the distribution of rainfall assumes considerable importance. Among the several meterological factors, rainfall is considered as of utmost importance especially for agricultural activity and water balance components. Besides providing water to the growing crops, rain brings out a favourable change in the climate surrounding the plants thereby promoting active vegetative growth. Apart from the quantum of rainfall, its time distribution also plays a decisive role in the cropping pattern of a particular region (Subrahmanyam and Upadhayay, 1982).

The analysis of rainfall trend over the study area is carried out by annual rainfall departure analysis and probability analysis of annual rainfall. The annual rainfall departure analysis is a good indicator of the deviation of the rainfall from the normal rainfall over a period of time. The probability analysis of annual rainfall is useful to predict the relative frequency of occurrence in different group of intervals of annual rainfall.

Probability is a constant characterising a given set of objects or incidents in a particular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy the relative frequency of occurrence in different group intervals of annual rainfall. It is also possible to work out the percentage probability of occurrence of 75% of annual rainfall or more for identification of drought proneness of the study area. Sarma and Narayan swamy(1982) have computed the coefficients of variation in order to study the distribution of rainfall. They classified them into following classes as given in table 1.2.1.

Table 1.2.1. Rainfall distribution classification

	Rainfall Distribution	CV
1	Uniform	0 - 0.25
2	Normal	0.25 - 0.50
3	Medium scattered	0.50 - 0.75
4	heavy scattered	0.75 - 1.0
5	very heavy scattered	> 1.00

1.3.0 Groundwater Level Analysis

The change in storage of groundwater in an aquifer is reflected by change in groundwater level. Groundwater levels are influenced by precipitation, evapotranspiration and discharge from the groundwater reservoir. Usually change in groundwater storage is a seasonal phenomenon and shows a seasonal pattern of fluctuation.

The seasonal water level fluctuations are tested by the statistical analyses to find the trend of groundwater over the several years. The rainfall recharge and discharge condition of the study area is also reflected by the relationships between the water level fluctuation and monthly rainfall. The recharge and discharge of groundwater table is influenced by soil cover and its characters, weathered rocks at the surface, open joints etc..

1.4.0 Estimation of Water Balance Components

Several approaches are available for the computation of water balance components. These vary in complexity from the simple empirical formulae to the complex models based on continuous simulation. However, conceptual catchment water balance model(Ponce and Shetty)is the alternative model which use the water balance equation to separate precipitation into it's various components. Water balance components such as precipitation, surface runoff, baseflow, wetting, and vaporisation are estimated to analyse each components with respect to the precipitation.

1.4.1 Conceptual model of water balance

The conceptual model of water balance(Ponce and Shetty) is suitable for wide range of climatic conditions. The model separates annual precipitation into its three major components: surface runoff, baseflow, and vaporization. It is based on two-step sequential application of a proportional relation linking with two variables such as precipitation and surface runoff, and wetting and baseflow.

L'vovich(1979) has shown that the wetting reaches an upper bound symptotically($W-W_p$) as precipitation and surface runoff increases unbounded($P \rightarrow \infty$; $S \rightarrow \infty$) and Vaporization reaches an upper bound asymptotically($V \rightarrow V_p$) as wetting and baseflow increases unbounded ($W \rightarrow \infty$; $U \rightarrow \infty$). In this way, two-step separation of annual precipitation into its three major components such as surface runoff, baseflow and vaporization is accomplished.

The surface runoff submodel is :

$S = (P - W_p)^2/[P + (1-2\lambda_s) W_p]$

subjected to $P \geq \lambda_s W_p$, $S = 0$ otherwise,

With λ_s = surface runoff initial abstraction coefficient.

Likewise, baseflow model is :

$U = (W - \lambda_u V_p)^2/[W + (1-2\lambda_u) V_p]$

subjected to $W \geq \lambda_u V_p$, $U = 0$ otherwise,

With λ_U = baseflow initial abstraction coefficient.

The initial abstraction coefficient of surface flow and baseflow, and potentials of wetting and vaporization has to be calibrated .In order to calibrate the initial abstraction coefficient of surface flow and baseflow, and potentials of wetting and vaporization, the observed data set for the paired values of precipitation and surface runoff, and wetting and baseflow is used. In the absence of data, the initial abstraction coefficients and potentials are estimated from past experience in similar climatic and biogeographical settings.

1.5.0 Geomorphology

Geomorphology is study of land forms, the distribution of land rivers and geological interpretations. The drainage basin, regardless of it's dimensions is composed of drainage network stream channels, and drainage divide that is boundary of the system(smart,1972). Investigations of drainage basins morphology has the following two diverse courses. On the one hand, geologists mostly study the morphology of the existing system in order to obtain clues to the structural and lithological nature of the drainage basin and its drainage basins is of great importance in understanding their hydrological behaviour. The basin morphology can be considered in terms of various hydromorphometric parameters like slope, shape, stream density etc.. The interrelationship between various geometric parameters are quite complex (Roohani and Gupta,1988).

Qualitative geomorphic methods developed of late provide means of measuring size and form properties of drainage basins. The composition of the stream system of a drainage basin can be expressed qualitatively in terms of stream order, drainage density, bifurcation ratio and stream-length ratio

Quantitative studies of drainage characteristics in a given catchment help in understanding the physical and hydrological characteristics. To quantify the geometry of the, fundamental dimension of length, time and mass are used. Many drainage basin features, that are important to hydrologists, can be quantified in terms of depth, square of length or cube of length, examples being elevation, stream length basin parameter, drainage are and volume. The concept of geometric similarity can be applied to drainage basin just as it is to many other systems. Perfect similarity will never be realised if natural drainage systems are compared, but striking similarities have been observed which can often be put to practical use.

Morphometry is the measurement of the slope or geometry of any natural form. It is the systematic description of the geometry of a drainage basin and its stream channel system which requires measurements of linear aspects, areal aspects and relief aspects of channel network and contributing ground slopes. While the linear aspects of the drainage basin are planimetric, the relief aspects of channel network and contributing ground slopes treat the vertical inequalities of the drainage basin forms. It is possible to establish correlation between various geometric characteristics of a basin with its runoff and other hydrological characteristics(Marisawa, 1959; Vorst and Bell, 1977).

In the present study, geomhorpological parameters which are influencing on movement of water and thereby the effect on volume of runoff is studied.

1.6.0 Land use and Geology

Land use refers to human activities for various use carried out on land and cover refers to natural vegetation, water bodies, rock, soil, artificial cover and others resulting due to land transformations. Land use generally inferred based on the cover. Land use and vegetation cover in a watershed have a significant influences on quality and quantity of runoff from it. Change in land use pattern influences the hydrological regime of the basin(James et al, 1987). Various hydrological processes such as infiltration, evapotranspiration, soil moisture status etc. are influenced by land use characteristics of a watershed. The deforestation may cause peak flows in the river due to reduced infiltration leading to floods. Due to increased soil erosion, removal of too fertile soil layer may result in drop in soil fertility.

The spatial information on land use and geology and their pattern of changes are essential for planning, management and utilization of land for agriculture, forestry, urban industries, environmental studies etc.. However in the present case, land use and geology considered for the effect on runoff process of the basin as the variation of abstraction factors depend on the land use and its cover.

1.7.0 Infiltration

When water continues to fall beyond the limit of interception and reaches the soil surface, the fraction of water will enter the soil subsurface. The process which enters the subsurface of soil is known as infiltration or is the process by which precipitation is abstracted by seeping into the soil below the land surface

Infiltration rates are very widely depending on condition of the land surface, the type, extent, and density of vegetative cover, physical properties of the soil, the storm characters i.e., intensity depth duration, and etc..

Infiltration has an important place in the hydrological cycle. Detailed study of infiltration process helps planners, hydrologists, farmers, and decision makers in number of ways. The infiltration rate of the area which helps in estimating peak rate and volume of runoff, estimation of surface runoff and overland flow, estimation of groundwater recharge and estimation of soil moisture deficits. Typical infiltration rates are at the end of one hour after the commencement of the storm are presented in table 1.6.1

Table.1.6.1 Typical Infiltration rate

Sl.No.	Soil Type	Infiltration rate cm/hr
1	High(sandy soil)	1.25 - 2.54
2	Intermediate(loam-clay-silt)	0.25 - 1.25
3	Low(clay-clay loam)	0.025- 0.25

(Source: ASCE Manual of Engg. Practice,No.28)

2.0 DESCRIPTION OF THE STUDY AREA

Dakishina Kannada district of Karnataka extends NNW-SSE. It lies between the Arabian Sea on the west and the western ghats on the east (12 27 - 13 58 north latitude and 74 35 - 74 40 east longitude) covering an area of 8441 sq.km. The coastal length of the district is 140 km and has four ports, namely the fishing port at Malpe, the all weather major port, viz., New Mangalore port at Panambur, the old port at Mangalore and the ore loading port at Kundapur.

The district runs almost parallel to the coast and western ghats. It is broader at the south about 80 km and becomes narrower in the north about 40 km. The entire district can be broadly divided into three regions: low land, mid land and high land depending on terrain features and their altitudes (Nielsen, 1972).

On the western side, the 'low land' runs parallel to the coast and it varies in width. Along the river courses, the flat land extends upto a distance of 16 km in the southern part of the district. It has a number of small lateritic ridges with cultivable low lands in between. In the northern part of the district the low land reduces to 4-5 km. The low land has a width of about 100 to 500 m of beach sand and clay layers. Solitary mounds of gneiss and lateritic hillocks with sparse vegetation of palms, arid plants and thorny bushes are noticeable.

Rivers of the west coast of India take their origin in the Western ghats and flow westwards over shorter distances in contrast to east flowing rivers which also take their origin in the western ghats. The velocity of flow in these rivers gradually reduces and when the rivers reach the low land they meander on a level ground. These rivers have the peculiarity of flowing upto the coast and taking a right angled turn towards north or south so as to flow almost parallel to the coast. Such rivers join together at some point before they empty into the Arabian sea. Thus the river mouth is always found to be the confluence of two rivers; Netravathi and Gurpur rivers near Mangalore city, Pavanje ana Mulki rivers at Mulki town are typical pairs of such rivers. Swarna Nadi, Sita Nadi and Kodi Hole form a triplet near Brahmawar town. At Maravanthe, the meandering river course runs very close to the coast so much so that National Highway No.17 (Mumbai-Kanyakumari) is often threatened from erosion point of view by the roughness of the sea on one side and the impact of the river flow on the other during mid-monsoon period.

In 'low land' regions, the rivers take a meandering course with wide channels and some large land masses in the centre. Such an island - a 'holm', is locally known as 'Kudru'. Uppinakudru of Kundapur taluk is the best example. The holms are fertile lands mostly covered by coconut palms.

The 'mid-land' region is wide enough and is covered with a large number of sporadic, lateritic hillocks and their height ranges from 30- 70 m above the mean sea level. 22 west flowing rivers cut across this mid-land region and a number of wide valleys are formed. Shoulders of the valleys are used for coconut and arecanut plantations. Higher lands barren laterite ridges. This intermediate region between low land and constitutes the largest belt.

The 'high-land' region forms the eastern part of the district. It covers a portion of the western slopes of the western ghats. It consists of steep hills and valleys interspersed with thick vegetation. The intensity and quantum of rainfall increases gradually from the coast towards the highland of the western ghats. Many of the west flowing rivers take their origin on the western slopes or at the Piedmont zone.

2.1.0 Geology of Dakshina Kannada District

The Indian sub-continent is divided into three well marked regions, each having distinguishing characteristics of its own. The peninsula or Peninsular Shield is to the south of the plains of the Indus and Ganges river systems.

The 'Indo-Gangetic Alluvial Plains' stretched across northern India. The 'Extra Peninsular' occupies the mountainous region of the Himalayas.

Dakshina Kannada district is situated in the peninsular region. The peninsula is composed of geologically ancient rocks of diverse origin and most of them have under gone metamorphism. It represents a stable land of the earth's crust. The geological formations of the district are similar to those of Karnataka state but for the costal sedimentary deposits and laterites. The geological features of Dakshina Kannada district is shown in figure 2.1.1.

2.2.0 Vegetation

Vegetation reflects the environment under which it is grown. Good water, soil and climate favour the luxurious growth of vegetation. Dakshina Kannada district enjoys favourable conditions for vegetation from seashore to the western ghats along the low land, mid-land and forest region of the high land.

The limitations imposed by the scorching sun, shifting sands and salt, chloride-laden winds are overcome by growing a special variety of plants. Their leaves and the stems are succulent and spiny to store water. The sandy beaches are studded with talipot palms which can survive under arid conditions. Wherever clay is associated with sand, trees like cashew, casurina and eucalyptus can thrive. Fruit bearing trees of mango, plantation, papaya, pineapple, guava, etc., are not uncommon even in house yards. In the northern part of the district mangroves are found in the estuarine portions where trees and shrubs have grown and they are resistant to saline habitat, strong tidal currents and fluctuations of water levels. Mangroves stabilise the river embankments against erosion.

The mid- land region of the district has thick vegetation or cultivated coconut and arecanut palms on the shoulders of the valley. The higher elevated areas are mostly covered by laterite and lateritic soils Sparse vegetation is noticed on the lateritic hills. Dakshina Kannada district has 4368 sq.km. of

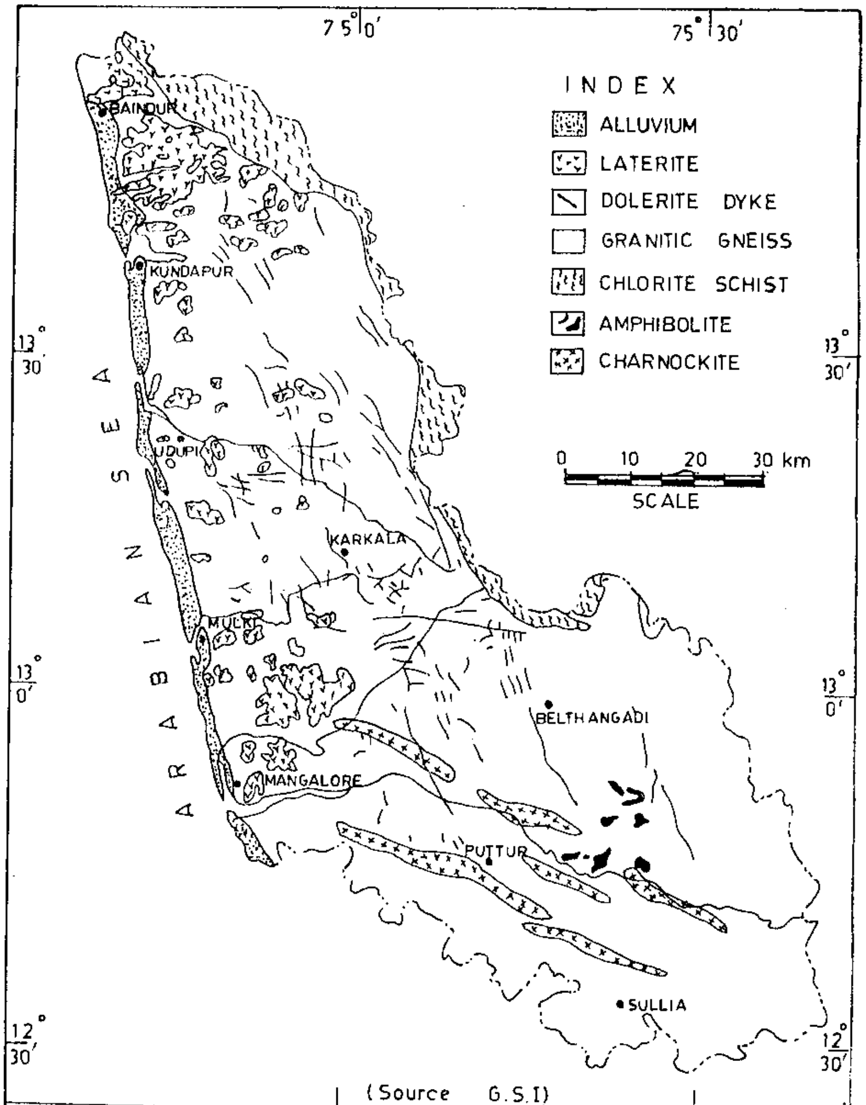


FIG. 2.1.1. GEOLOGICAL MAP OF DAKSHINA KANNADA DIST

forest area out of its total geographical area of 8441 sq.km. The vegetation map of Dakshina Kannada district is presented in the figure 2.2.1.

2.3.0 Rainfall

The rainfall in the district is mainly due to convention and orography. The convective precipitation, typical of the tropics, is caused by the heating of air at the interface with the ground and characterised by light showers or storms of extremely high intensity. The convective storms experienced by the Karnataka coast are usually local in nature and often result in very intense rainfall. Orographic rainfall in the district is the result of mechanical lifting of moist horizontal air currents over the western ghats region. The highland of the district experiences mainly orographic rainfall.

The annual depth of rainfall over the district works out to 3942 mm. The average annual rainfall is more on the eastern belt of the district characterised by the western ghats. This is mainly attributed to the orographic effect. The rainfall in the ghats section ranges from 4900 mm to 5900 mm and in the coastal belt from 3500 mm to 4500 mm.

2.4.0 Sithanadi Basin

Sitanadi is one of the west flowing rivers of Dakshina Kannada district of Karnataka state. It takes its origin in the slopes of Western Ghats near Agumbe and flows towards west. The catchment area with an area of 650 sq.km. lies between 13°20' and 13°35' north latitudes and 74°40' and 75°10' east longitude (fig.2.4.1) after descending the ghats, it flows in west direction cutting across the district on three typical topographic terrains and finally empties into the Arabian sea. The river valleys which are quite shallow cannot hold the flow but results in flooding.

Catchment area is relatively short in length and river flows in a meandering course on a level ground in low land region. It confluences with

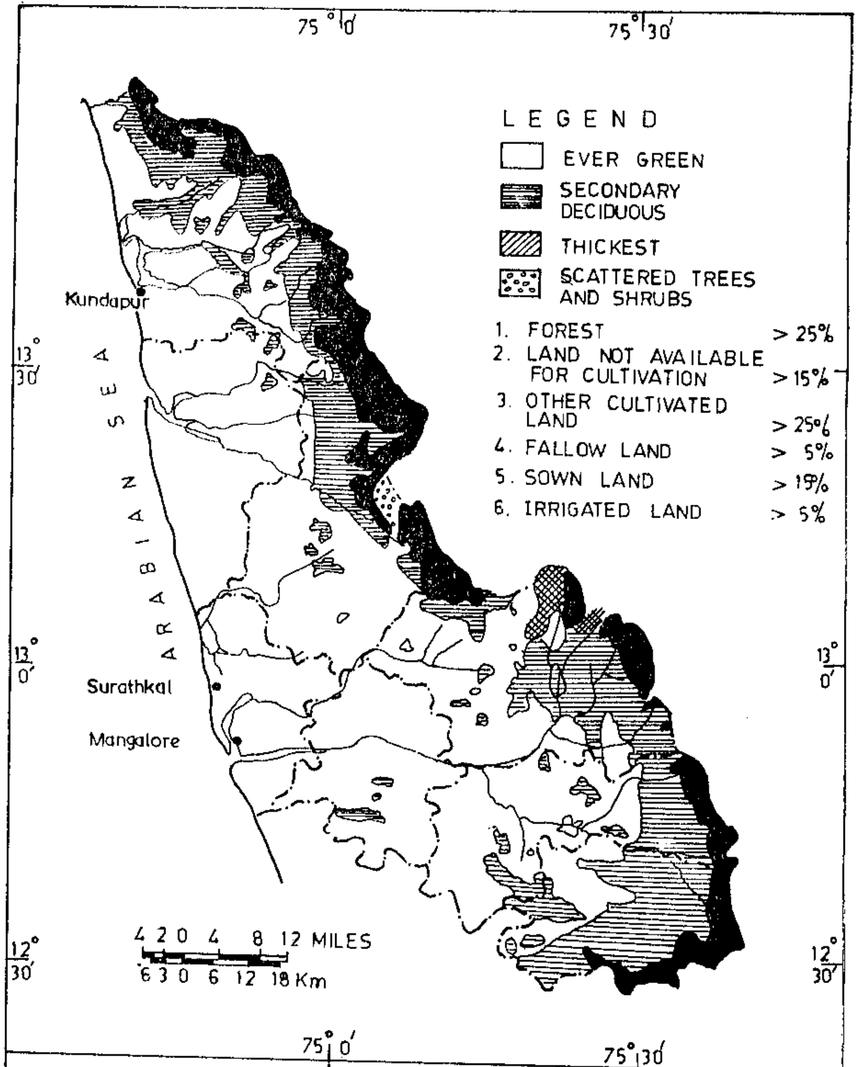
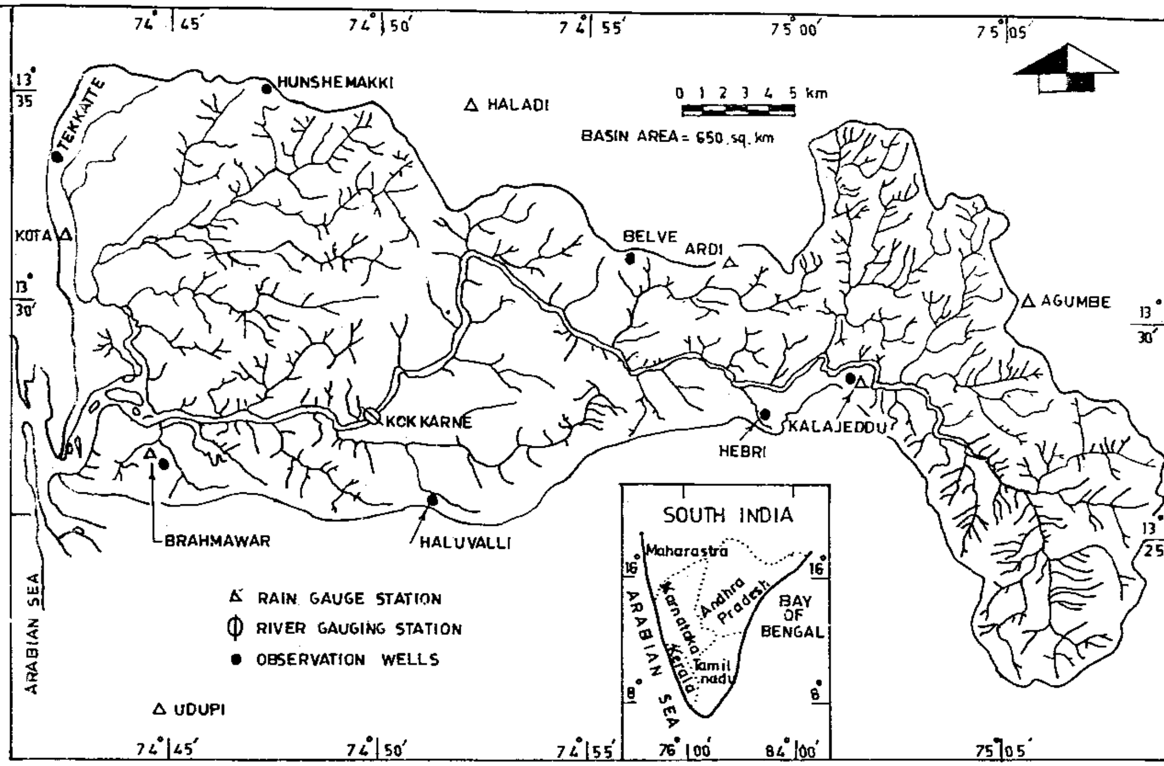


FIG. 2.2.1 DAKSHINA KANNADA DISTRICT - VEGETATION MAP



F.I.G. 2.4.1. SITANADI BASIN

Swarna river before joining Arabian sea and becomes susceptible to salt water ingression during high tides. The water in the river thus turns saline upto 15 to 20 km from the river mouth during high tides.

The catchment area is physiographically divided into three divisions on the basis of terrain and altitude.

The low land region is 2-8 km wide sandy tract running parallel to the coast. It extends upto a distance of 16 km along the river course. It has small lateritic ridges with cultivable low lands in between small exposures of gneiss and laterite hillocks with sparse vegetation. In low land region, the river follows a meandering course with wide channels and from some large land masses in the centre.

The mid-land region consists of laterite ridges, mesas and also residual hills composed of gneiss with incised narrow valleys of younger cycle. The laterite ridges exhibit step like topography. The regional elevation varies from 30-70 m. The mid-land region situated between low land and high land constitutes the largest belt. The region consists of dissected low hills with or without laterite capping.

High land region consists of dissection high hills and ridges forming part of the foot hills of the western ghats. It consists of steep hills and valleys interspersed with thick vegetation. These high hills are mostly archaean gneiss and metavolcanics and metasediments of Dharwar supergroup of proterozoic age. Scarp faces bounding these hills are steep having a drop of more than 250 m.

Vegetation reflects the environment in which it is grown. Good water, soil and climate favours the growth of luxurious vegetation. Sitanadi catchment is one of the catchments which lies in the foot hills of Agumbe ghats.

Agumbe is well known for highest rainfall region in Karnataka. High rainfall and humid climatic conditions favour luxurious growth of vegetation.

Nearly 53.86% of Sitanadi catchment area is covered by forest vegetation. About 233.48 sq.km. area is covered with dense forest vegetation, 71.73 sq.km. area is covered with open forest vegetation and 68.88 sq.km area is covered with scrub type of forest vegetation (Srinivas, 1990).

The low land region of the basin consists of shrubs and bushes like vegetation commonly known as mangroves. Typical species are Rhizophora and Avicannia (Untawale and Wafar, 1986). Mangroves are resistant to saline habitat, strong tidal currents and fluctuations of water level stabilise the river embankments against erosion.

The mid land region has patches of thick natural vegetation with cultivated coconut and arecanut palms on the shoulders of the valley region. Natural vegetation comprises mainly of forest vegetation with trees, shrubs, creepers etc., common species are ote, kokke, kendage, nenale, banni, bamboo, mango, jack, tamarind etc..

On the western part, the slopes of the Western Ghats from north to south are beautifully clothed with dense forest of magnificent timber. Rose wood is common in north eastern part of the catchment. The principal timber yielding trees in this area are, matti,maravu, benteak, jack, wild jack etc. (Gazetteer,1973).

2.5.0 Nethravathi Basin

The Netravathi river is one of the important West flowing rivers of Karnataka. It rises at an elevation of +1000 m., in Western ghats between Kudremukh and Ballalrayan durga in the South Kanara district of Karnataka. The map of Netravati basin is shown in figure 2.5.1. The latitude and longitude of its origin are 13°10'N and 75°20E respectively. It flows in North-South direction for the first 40 km., upto Gohattu where it takes a turn towards the west and flows in East-West direction upto its outfall into Arabian sea near Mangalore. Kumaradhari is its major left bank tributary joining it near the

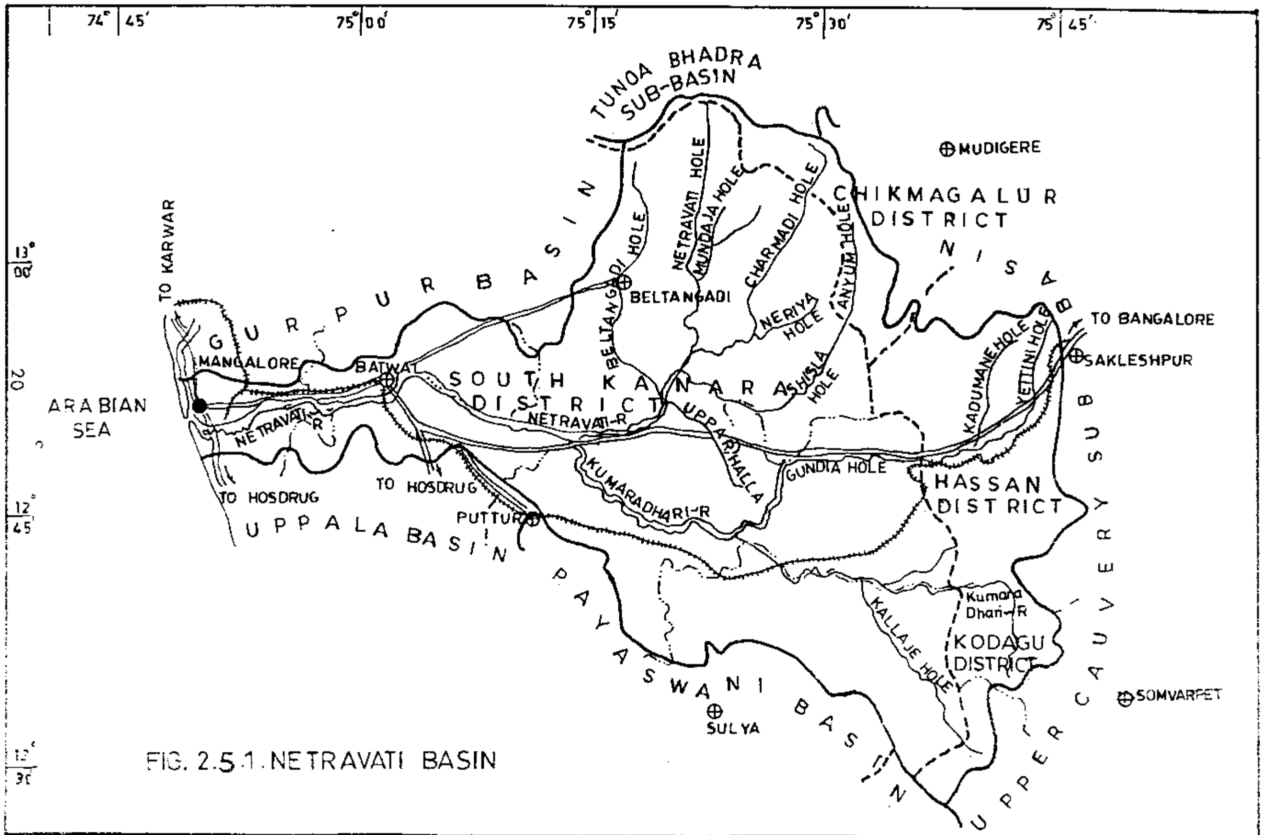


FIG. 2.5.1. NETRAVATI BASIN

village of Uppinangadi. The total length of the Netravati river is 103km from its origin to its outfall into in Arabian sea. Other small tributaries namely Gundiahole, Charmadihole, Gowri hole, Neriahole, Shislahole, Mundajahole, Upparhalla, Kallajehole, Beltangadi hole, Aniyurhole and Yettin hole also join the main Netravati river at different places from its both the sides. The Netravati river basin lies between the latitudes of 12°29'11"N and 13°11'11" and longitude of 74°49'08"E and 75°47'53"E. It is surrounded on the North by Tungabhadra sub-basin, on the North-West by Gurpur basin, on the East by Cauvery basin, on the South by Payaswani basin, on the South-West by Uppala basin and on the West by Arabian sea. The basin is nearly fan shaped. The basin drains an area of about 3657 Km^2.

The catchment area of Netravati basin can be broadly divided into three distinct sub-regions namely, coastal plains, the intermediate or transitory sub-mountains region with undulating upland or spurs and hilly region or western ghats. The coastal lands are best developed areas with a high degree of economic development and a high density of population. The intermediate or transitory regions is mostly covered with forest and human activity is seen only along the roads and at crossings in the ghats. Undulating uplands are partly under forest and partially under agriculture. The basin consists of recent and sub-recent which includes alluvial formation, clays red and dark clay soils and lateroid formation.

Intrusive includes dolerite, basic and ultra basic rocks, charnockity and granitic gneiss.

Dharwars includes older metamorphic rocks, graniteferrous quartz, sillimanite, talc-schists, hornblende schists, chlorite schists and banded haematite quartzite. These soils generated from the formations are mostly permeable.

Structurally the area has been subjected to folding and faulting. These fractured rocks are favourable locations for groundwater storages.

3.0.0 METHODOLOGY

In order to identify the cause for scarcity of water during dry months, inspite of high rainfall in the area, geohydrological and geomorphological studies are the need of the hour. With this in view, a detailed study has been taken up for Sithanadhi and Nethravathi basins by the following investigations.

3.1.0 RAINFALL ANALYSIS

Raingauge stations selected for the rainfall analyses is as shown in the figures 3.1.1 and 3.1.2 for both the study area. The rainfall values of the raingauge station are taken by giving Theissen weights.

The analysis of rainfall trend over the study area is carried out by annual rainfall departure analysis and probability analysis of annual rainfall. The annual rainfall departure analysis is a good indicator of the deviation of the rainfall from the normal rainfall over a period of time. The probability analysis of annual rainfall is useful to predict the relative frequency of occurrence in different group of intervals of annual rainfall.

3.1.1 Distribution of rainfall

Rainfall over the years ranges from 3700mm to 6900mm with standard deviation 834.32mm. The symmetry of the rainfall pattern is +0.302 with variability +0.151. The normal annual rainfall is estimated to be 5533.0mm for Sithanadi basin. For Netharavathi basin, rainfall over the years ranges from 3000mm to 5700mm with standard deviation 670.00mm. The symmetry of the rainfall pattern is +0.331 with variability +0.166. The normal annual rainfall is estimated to be 4046.0mm. The distribution of rainfall presented in the table 3.1.1.1. The spatial distribution of rainfall for both the catchments is as shown in the figure 3.1.1.1 and 3.1.1.2 However the Sithanadi

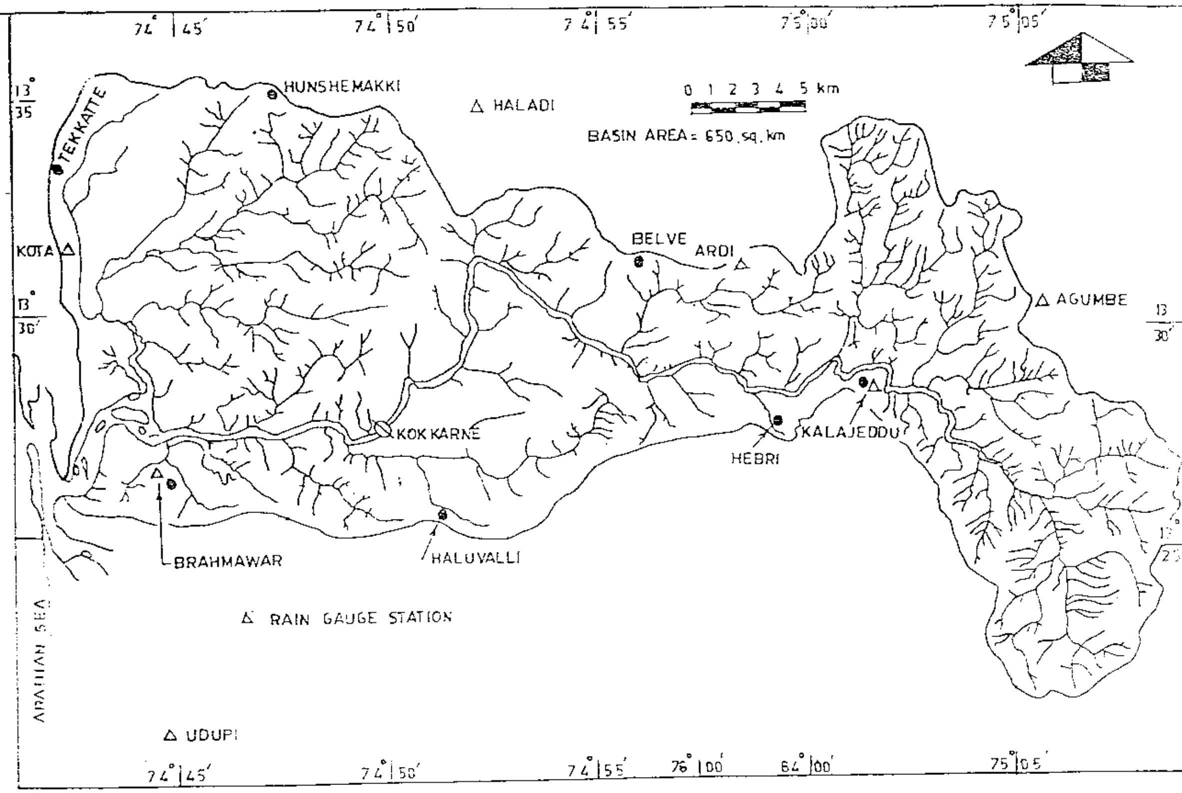


Figure 3.1.1 Location of Rain gauge Station(Sitanadi)

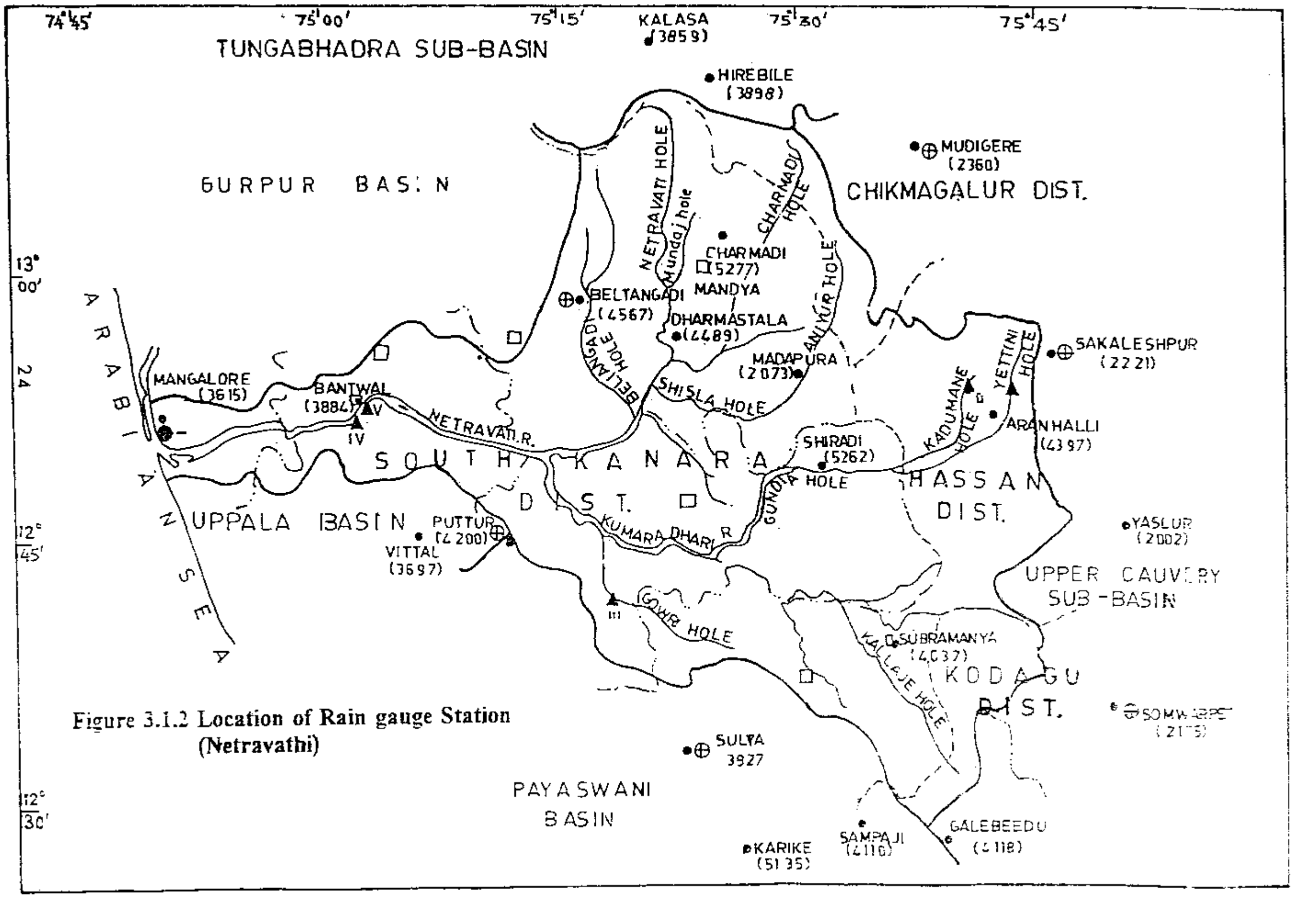


Figure 3.1.2 Location of Rain gauge Station
(Netravathi)

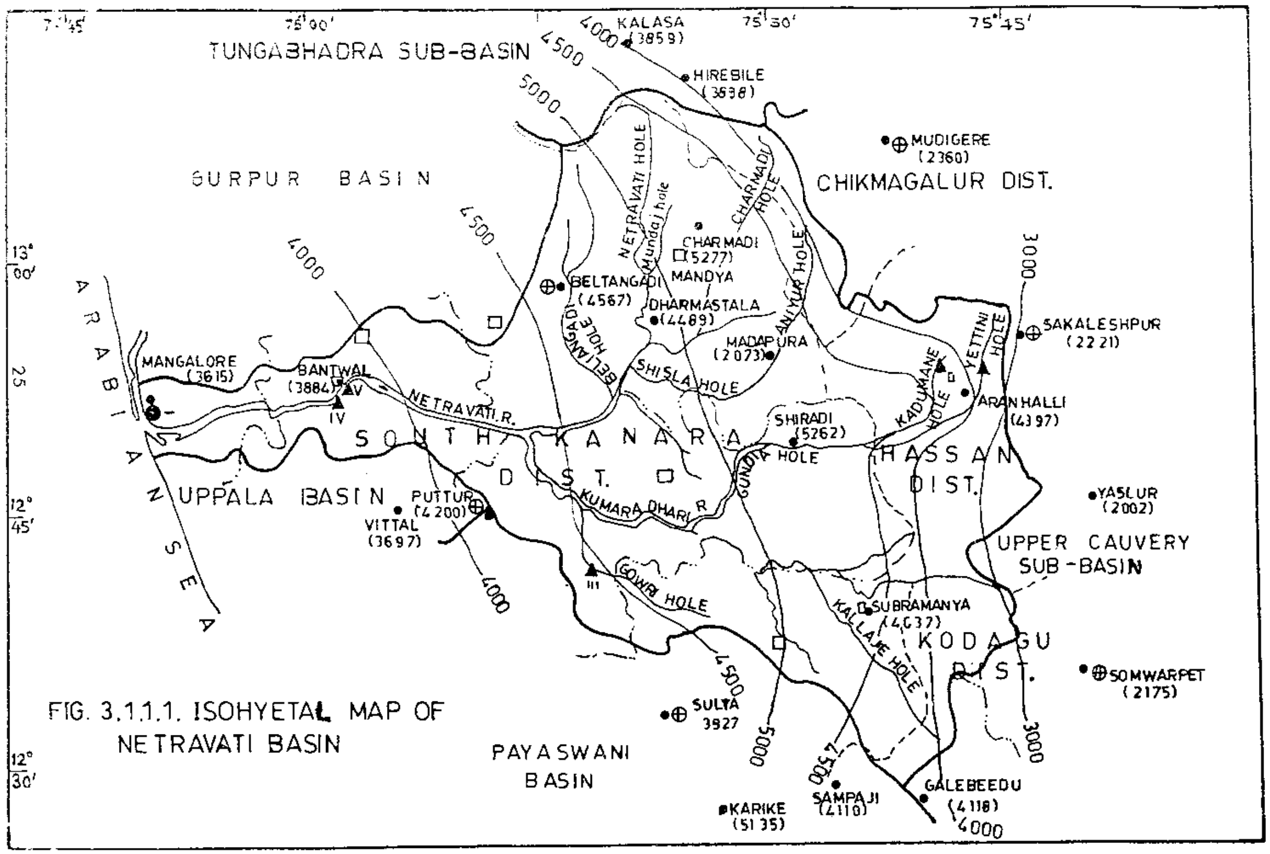


FIG. 3.1.1.1. ISOHYETAL MAP OF NETRAVATI BASIN

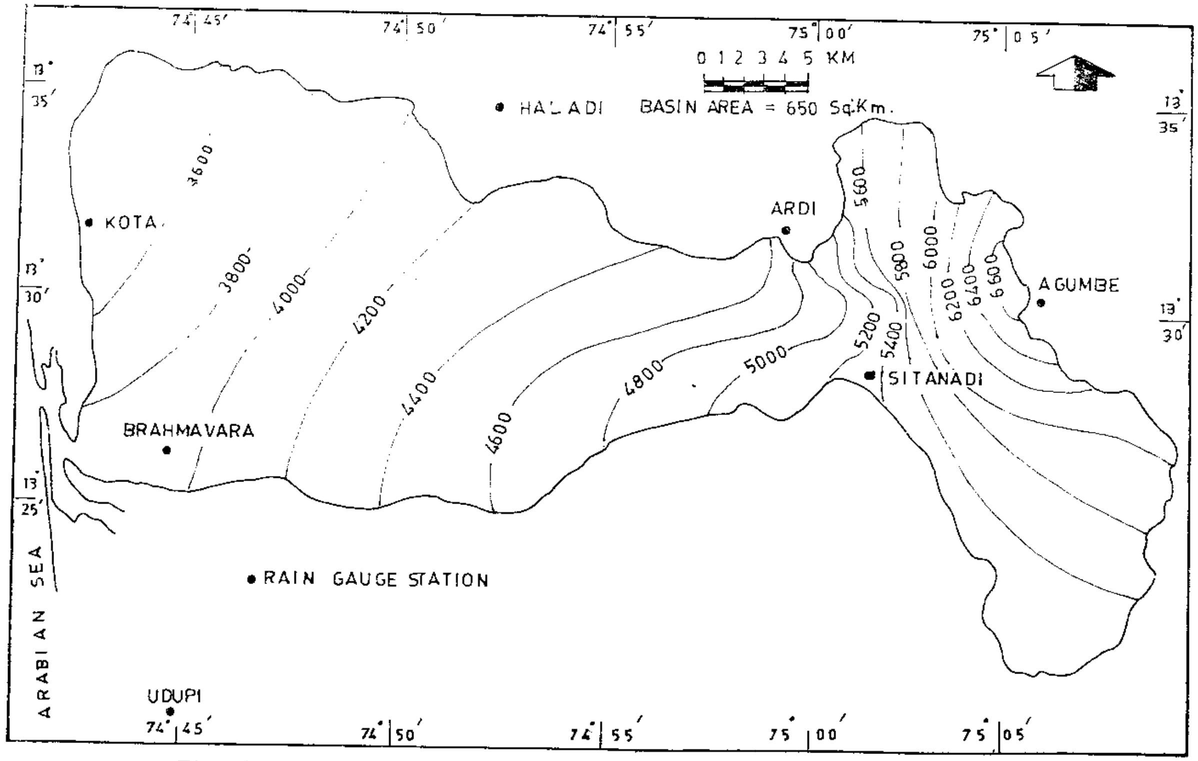


FIG. 3.1.1.2. Isohyetal Map of Sitanadi Basin

and Nethravathi basins receives about 90 per cent of rainfall from June to September. October to December is about 7 per cent and January to May about 3 per cent.

Table 3.1.1.1. Rainfall Distribution

Sl.No.	Parameters	Sithanadi	Netravathi
1	Normal Rainfall	5533.00	4046.00
2	Sd. deviation	834.32	670.00
3	Co. of variation	+0.151	+0.166
4	Co. of assymetry	+0.302	+0.331
5	75% probability	4981.00	3612.00
6	Probability of occurence of 75% Normal rainfal	95 per cent	95 per cent

3.1.2 Annual rainfall departure analysis

For analysis purpose the yearly rainfall data of every year has been used. In order to work out the normal rainfall for a study area, the weightage of each raingauge station taken on the basis of Thiessen polygon method and then estimated the rainfall values of the basin. Percentage of departures on annual basis are worked out based on rainfall and normal annual values. The difference of annual rainfall and annual normal gives the departure which is converted into percentage as has been presented in the table 3.1.2.1 and 3.1.2.2. The departure from the normal expressed in percentage from 1957 to 1986 for Nethravathi basin and for Sithanadi from 1972 to 1992 have been plotted and shown in the figure 3.1.2.1 and 3.1.2.2 The Sithanadi basin recorded annual rainfall deficit in the order of 30 % in the year 1972. Nethravathi basin has recorded annual rainfall deficit of 25 per cent in the year 1966.

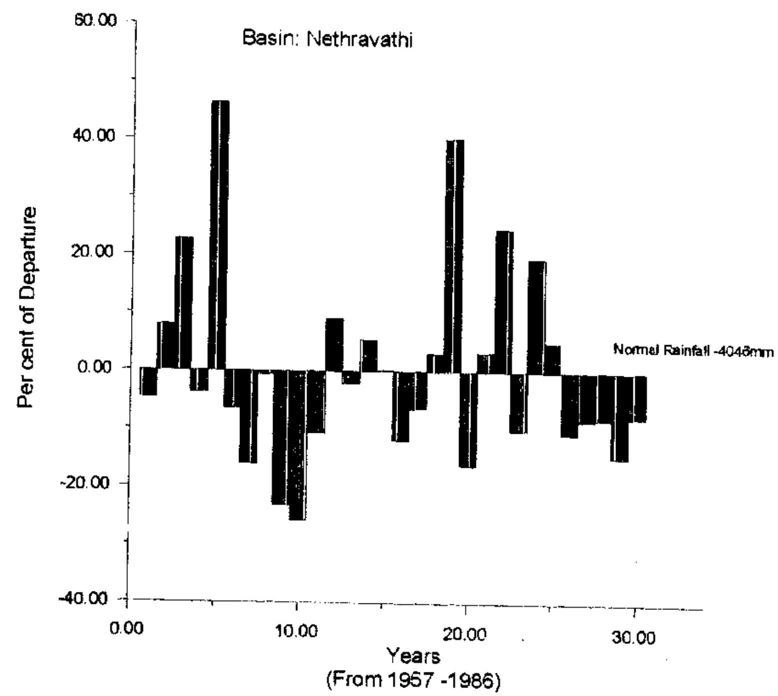


Figure 3.1.2.1 Annual Rainfall Departure

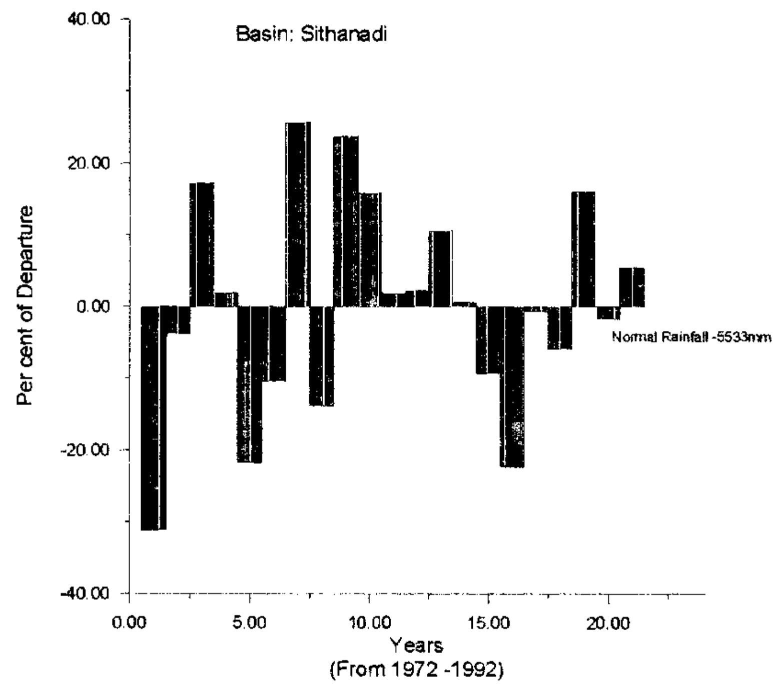


Figure 3.1.2.2 Annual Rainfall Departure

Table 3.1.2.1. Annual Rainfall Departure (Netravathi)

Sl. No.	Year	Annual Rainfall	Normal Rainfall	Percentage Departure
1	1957	3855	4046	-4.7
2	1958	4367		7.9
3	1959	4964		22.7
4	1960	3893		-3.8
5	1961	5923		46.4
6	1962	3782		-6.5
7	1963	3397		-16.0
8	1964	4021		-0.6
9	1965	3108		-23.2
10	1966	3001		-25.8
11	1967	3612		-10.7
12	1968	4415		9.1
13	1969	3958		-2.2
14	1970	4266		5.4
15	1971	4055		0.2
16	1972	3566		-11.9
17	1973	3788		-6.4
18	1974	4173		3.1
19	1975	5674		40.2
20	1976	3395		-16.1
21	1977	4178		3.3
22	1978	5046		24.7
23	1979	3636		-10.1
24	1980	4841		19.6
25	1981	4253		5.1
26	1982	3612		-10.7
27	1983	3708		-8.3
28	1984	3716		-8.1
29	1985	3453		-14.6
30	1986	3726		-7.9

Table 3.1.2.2. Annual Rainfall Departure (Sithanadi)

Sl. No.	Year	Annual Rainfall	Normal Rainfall	Percentage Departure
1	1972	3813	5533	-31.1
2	1973	5322		-3.8
3	1974	6486		17.2
4	1975	5641		1.9
5	1976	4334		-21.7
6	1977	4955		-10.4
7	1978	6951		25.6
8	1979	4768		-13.8
9	1980	6843		23.7
10	1981	6410		15.8
11	1982	5631		1.8
12	1983	5656		2.2
13	1984	6116		10.5
14	1985	5569		0.6
15	1986	5019		-9.3
16	1987	4297		-22.3
17	1988	5492		-0.7
18	1989	5208		-5.9
19	1990	6418		16.0
20	1991	5439		-1.7
21	1992	5831		5.4

3.1.3 Probability analysis of annual rainfall

Probability is a constant characterising a given set of objects or incidents in a particular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy, the relative frequency of occurrence in different group intervals of annual rainfall. It is also possible to work out the percentage probability of occurrence of 75% of annual rainfall or more for identification of drought proneness of the study area.

Rainfall events in the study area have been selected for probability analysis of annual rainfall. The analysis has been carried out based on the data availability and probability expressed both in number of years of occurrence and the percentage of years for each group interval. Group interval of 250mm has been considered for the analysis.

The probability distribution curves have been drawn by plotting the values of percentage of cumulative probability in respect of various groups at their corresponding midpoint. The cumulative percentages are worked out starting from the maximum rainfall group downwards adding the successive percentage(table 3.1.3.1 and 3.1.3.2). Probability graph for the study area have been shown in the figure 3.1.3.1 and 3.1.3.2.

Table 3.1.3.1. Probability Analysis of Annual Rainfall (Netravathi)

Sl. No.	Class Interval	No. of Years	Percentage	Cumulative Probability
1	3000-3250	2	6.6	100
2	3250-3500	3	10.0	93.4
3	3500-3750	7	23.3	83.4
4	3750-4000	5	16.6	60.1
5	4000-4250	4	13.3	43.5
6	4250-4500	4	13.3	30.2
7	4500-4750	0	0.0	16.9
8	4750-5000	2	6.6	16.9
9	5000-5250	1	3.3	10.3
10	5250-5500	0	0.0	7.0
11	5500-5750	1	3.3	7.0
12	5750-6000	1	3.3	3.7

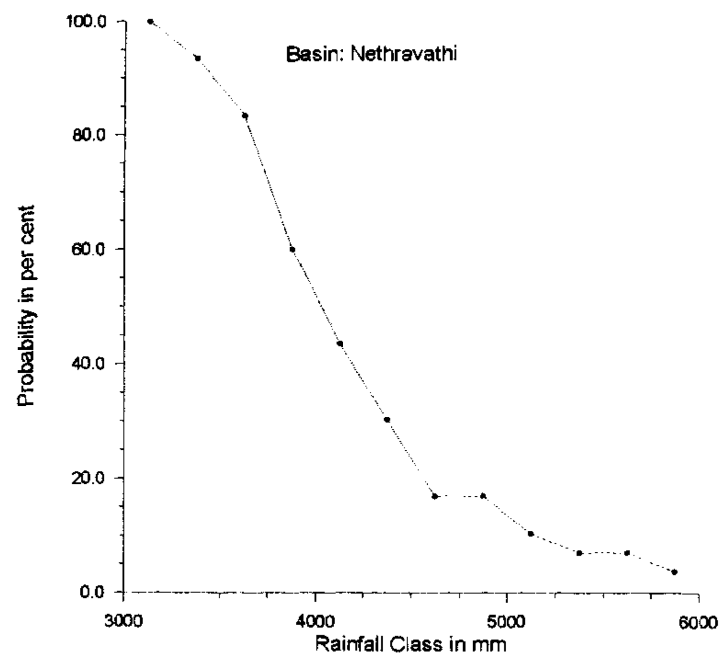


Figure 3.1.3.1 Probability Curve

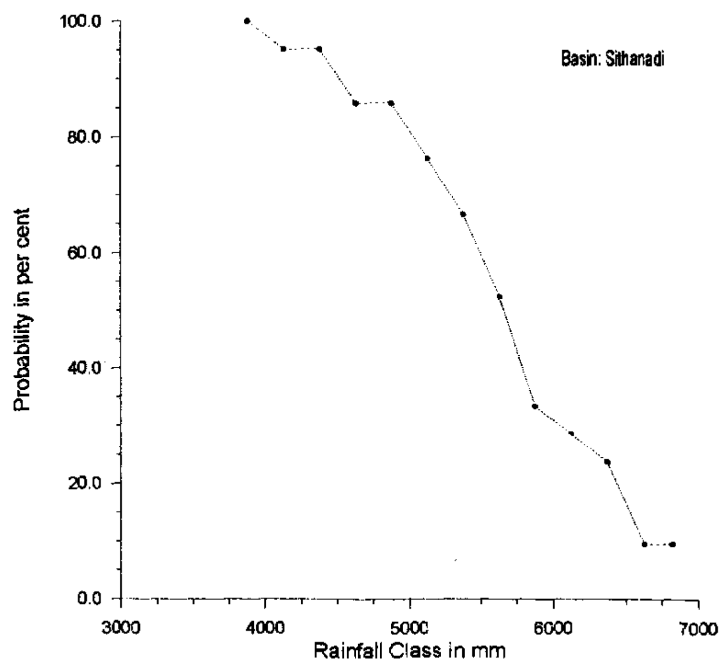


Figure 3.1.3.2 Probability Curve

Table 3.1.3.2. Probability Analysis of Annual Rainfall (Sithanadi)

Sl. No.	Class Interval	No. of Years	Percentage	Cumulative Probability
1	3750-4000	1	4.8	100
2	4000-4250	0	9.5	95.2
3	4250-4500	2	0.0	95.2
4	4500-4750	0	0.0	85.7
5	4750-5000	2	9.5	85.7
6	5000-5250	2	9.5	76.2
7	5250-5500	3	14.3	66.7
8	5500-5750	4	19.0	52.4
9	5750-6000	1	4.8	33.4
10	6000-6250	1	4.8	28.6
11	6250-6500	3	14.3	23.8
12	6500-6750	0	0.0	9.5
13	6750-7000	2	9.5	9.5

The range of rainfall group for the study area which has a probability occurrence of 75% or more has been read from probability distribution graphs and tabulated in the tables. As can be seen from the above table, the study area has a 75% or more probability of getting rainfall is about 4981.0mm for Sithanadi and for Nethravathi 3612.00mm. Probability of occurrence of rainfall equivalent to 75% of normal rainfall for both basins is only 95 per cent.

3.2.0 Groundwater Level Analysis

The change in storage of groundwater in an aquifer is reflected by change in groundwater level. Usually change in groundwater storage is a seasonal phenomenon. Representative wells uniformly distributed over the study area as shown in the figure 3.2.1 and 3.2.2 has been chosen for the analysis based on the availability of data. The analysis is carried out using quarterly data for the desired period depending on the data availability.

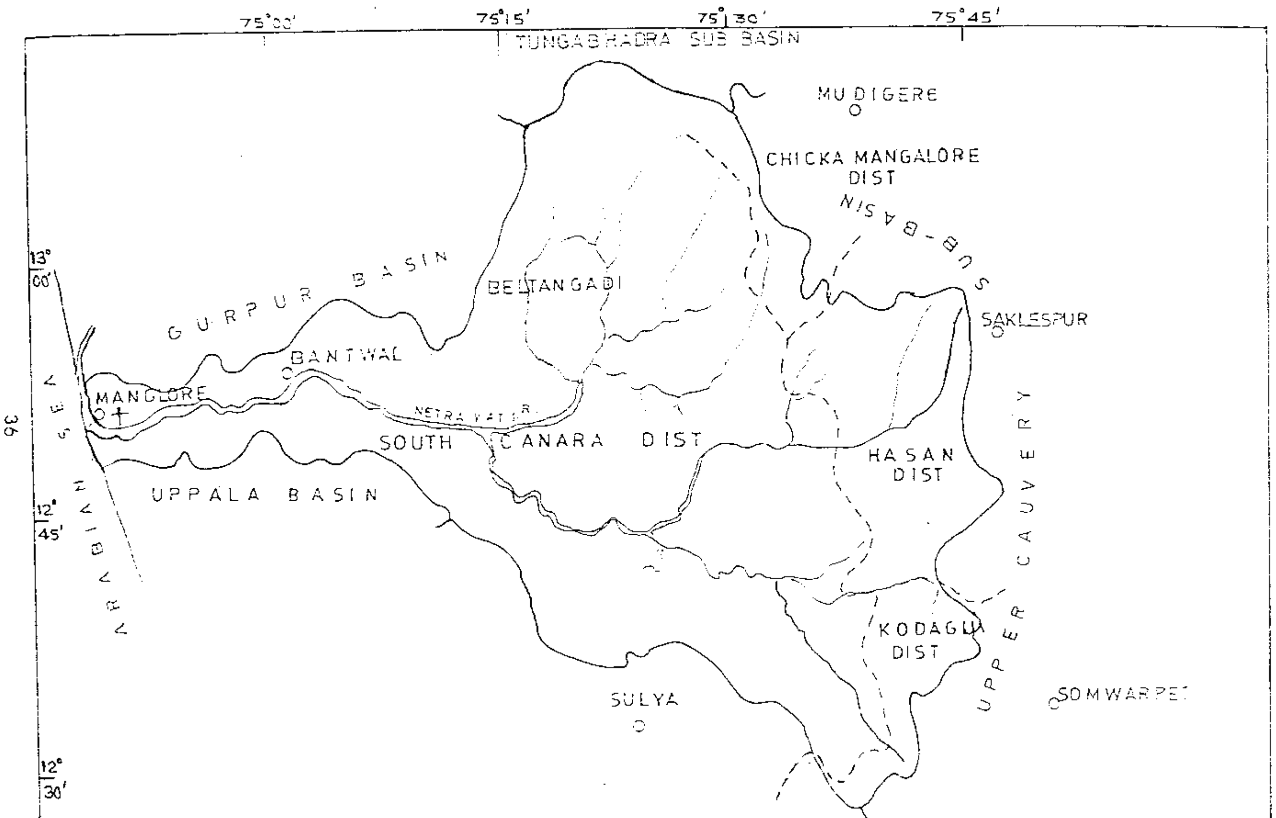


Figure 3.2.1 Location of Observation wells(Netravathi)

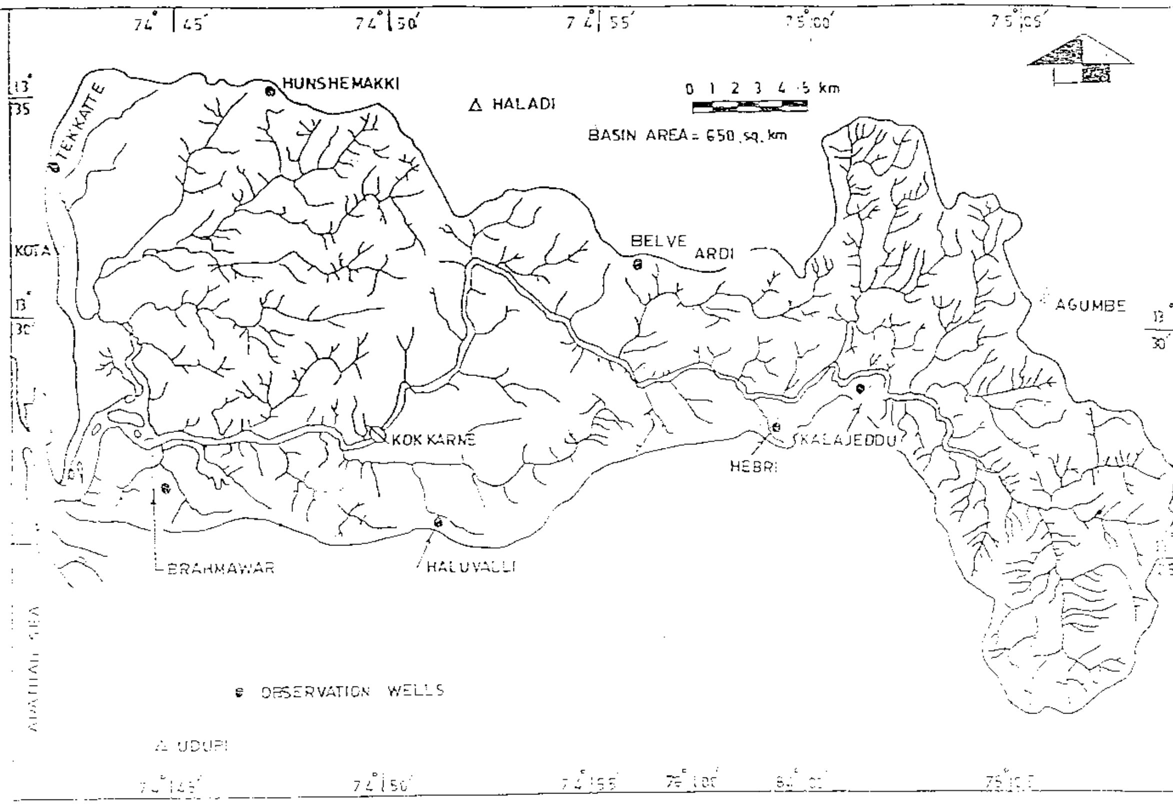


Figure 3.2.2 Location of Observation wells(sitanadi

3.2.1 Trend analysis of groundwater level

The trend in groundwater level fluctuations was worked out by carrying out simple regression analysis. In order to work out the trend of groundwater level, the seasonal values (monsoon season) of groundwater level were plotted for each year of available data. A simple regression line was fitted to show the trend of groundwater level over the period.

Wells have been selected such a way that, they are representative of coastal low land, middle land, and high land to find out the trend of groundwater regime. Groundwater levels have been plotted against time for the study area. These graphs showing trends seasonal rainfall and groundwater levels over the periods of analysis. The graphs showing trends of groundwater levels over the period of analyses are shown in figures 3.2.1.1 to 3.2.1.9.

3.2.2 Response of water table with respect to rainfall

In order to know the relationship between rainfall and water table fluctuation, monthly water level and corresponding rainfall of the site are plotted and presented in figures 3.2.2.1, 3.2.2.5, 3.2.2.10, 3.2.2.14, 3.2.2.19 and 3.2.2.24. It can be seen from the figures that water level fluctuations exhibit a uniform rise and fall. It is also noticed that water level will rise to the maximum during the months of June-July and minimum during April or May. Water level response to the rainfall established by plotting monthly rainfall and water level for a year as shown in figures 3.2.2.2 to 3.2.2.4, 3.2.2.6 to 3.2.2.9, 3.2.2.11 to 3.2.2.13, 3.2.2.15 to 3.2.2.18, 3.2.2.20 to 3.2.2.23, and 3.2.2.25 to 3.2.2.28. The annual rainfall and the status of the water table regime is compared over number of years.

3.3.0 Estimation of Water Balance Components

The catchment water balance model has been applied to separate the precipitation into wetting and surface runoff, and wetting into vaporization

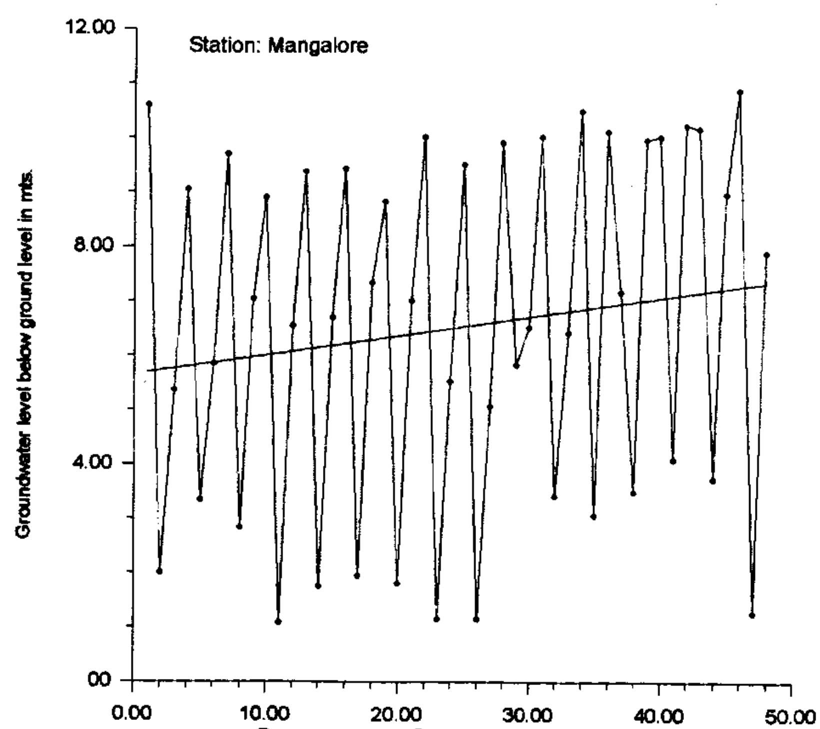


Figure 3.2.1.1 Variation of Groundwater Table

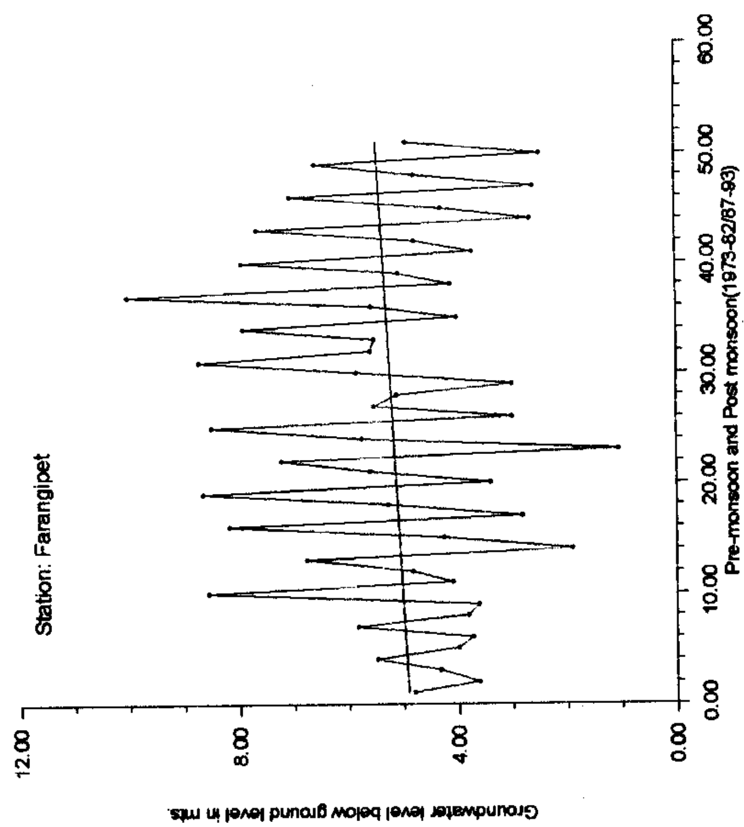


Figure 3.2.1.2 Variation of Groundwater Table

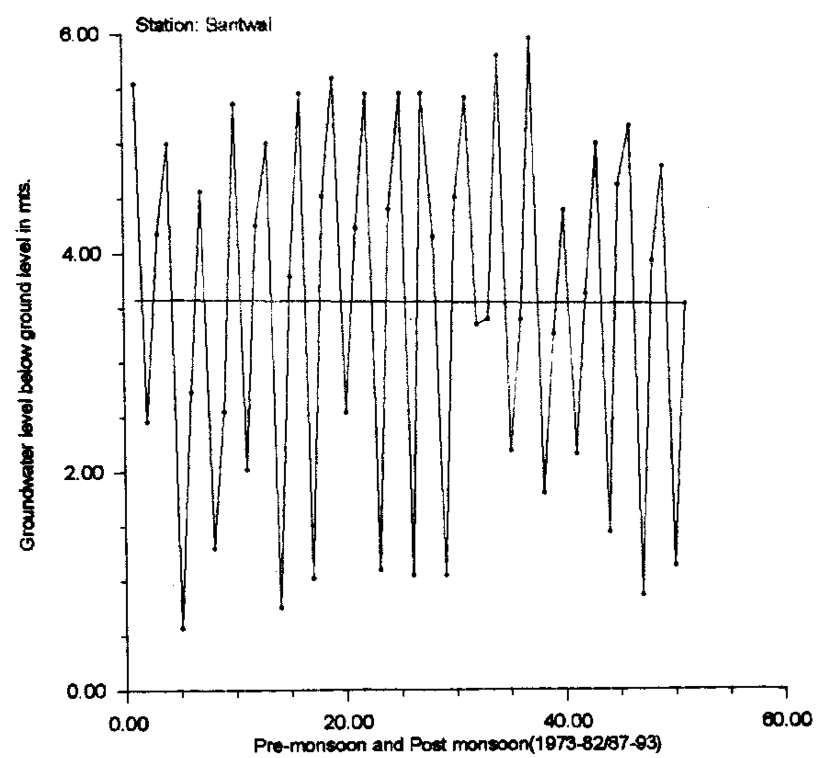


Figure 3.2.1.3 Variation of Groundwater Table

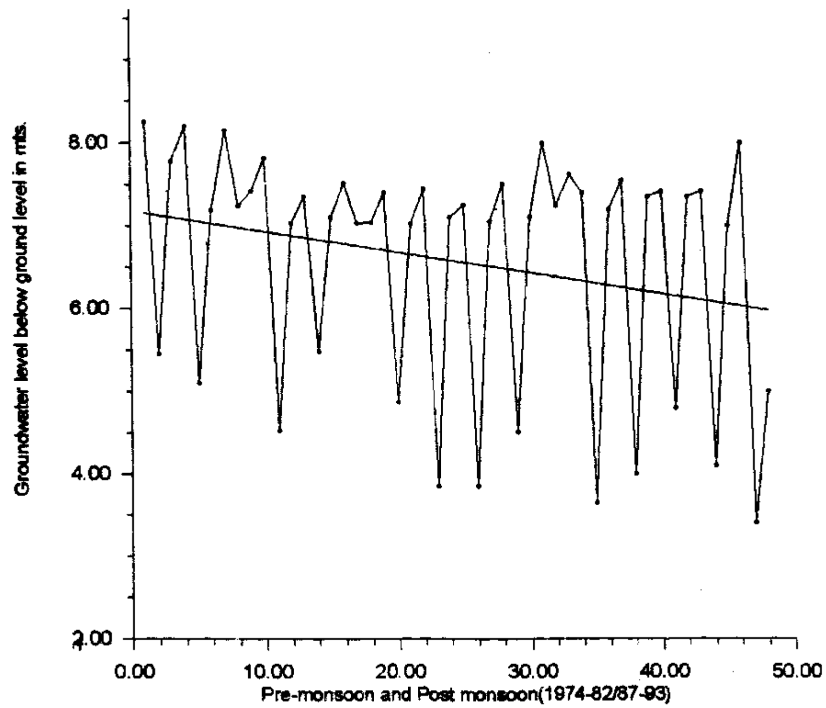


Figure 3.2.1.4 Variation of Groundwater Table

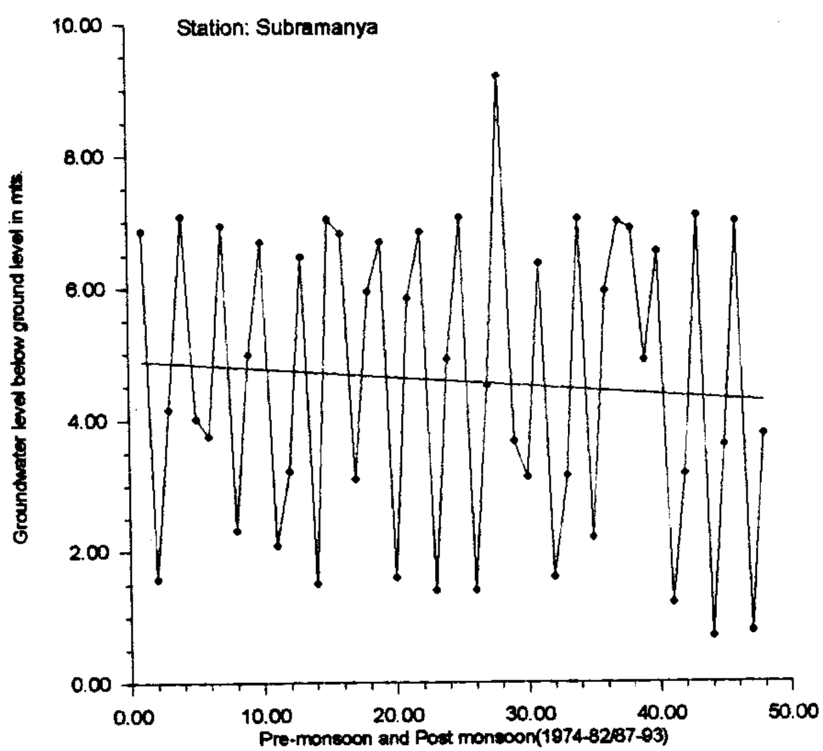


Figure 3.2.1.5 Variation of Groundwater Table

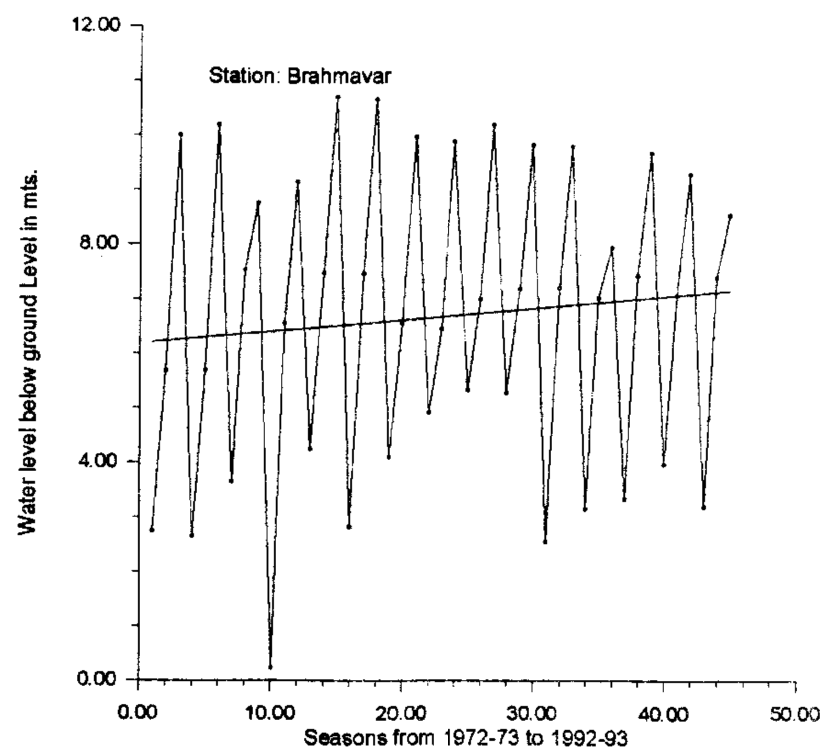


Figure 3.2.1.6 Variation of Groundwater Table

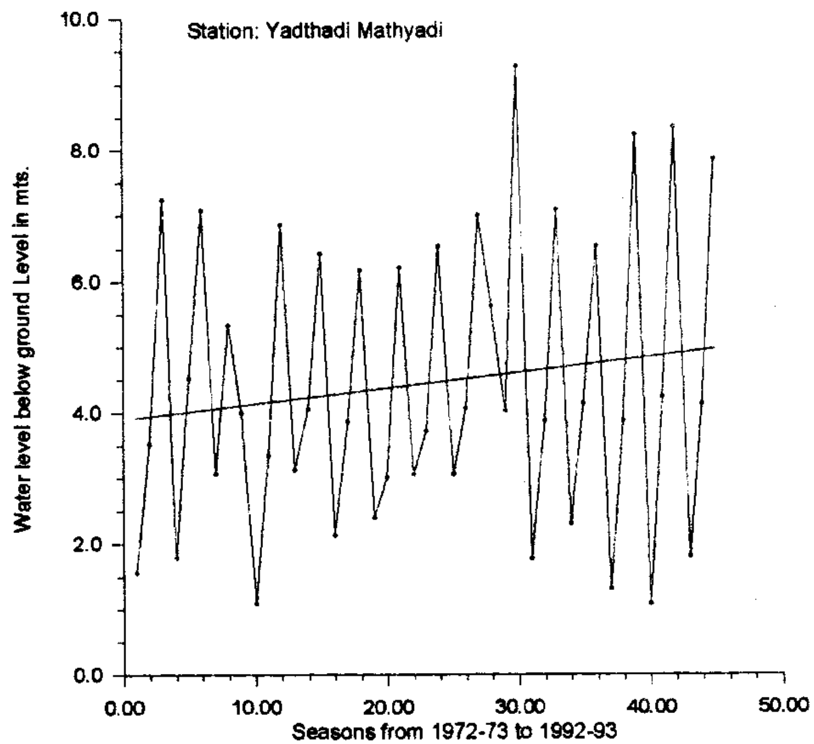


Figure 3.2.1.7 Variation of Groundwater Table

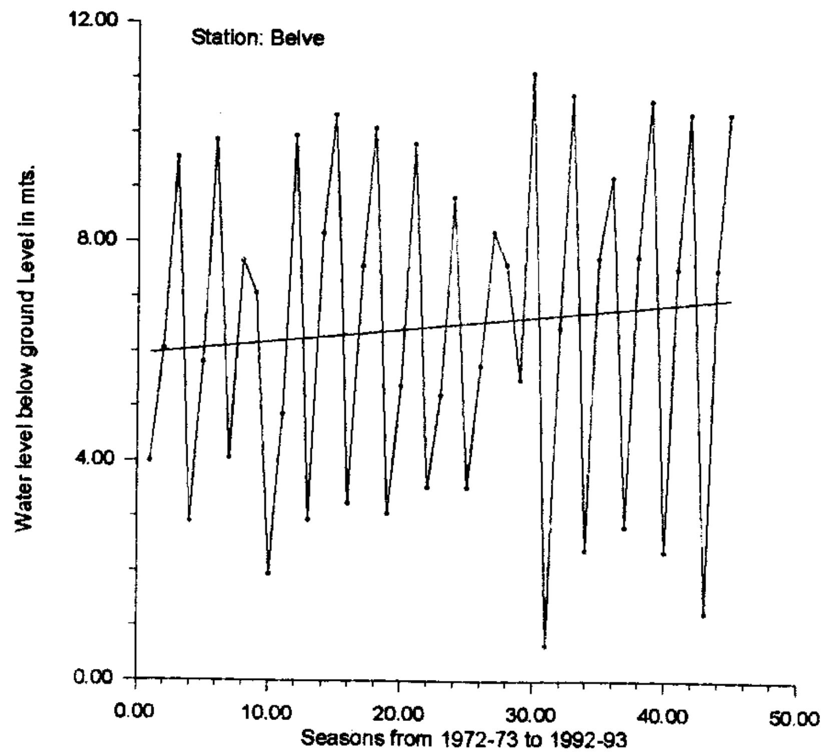


Figure 3.2.1.8 Variation of Groundwater Table

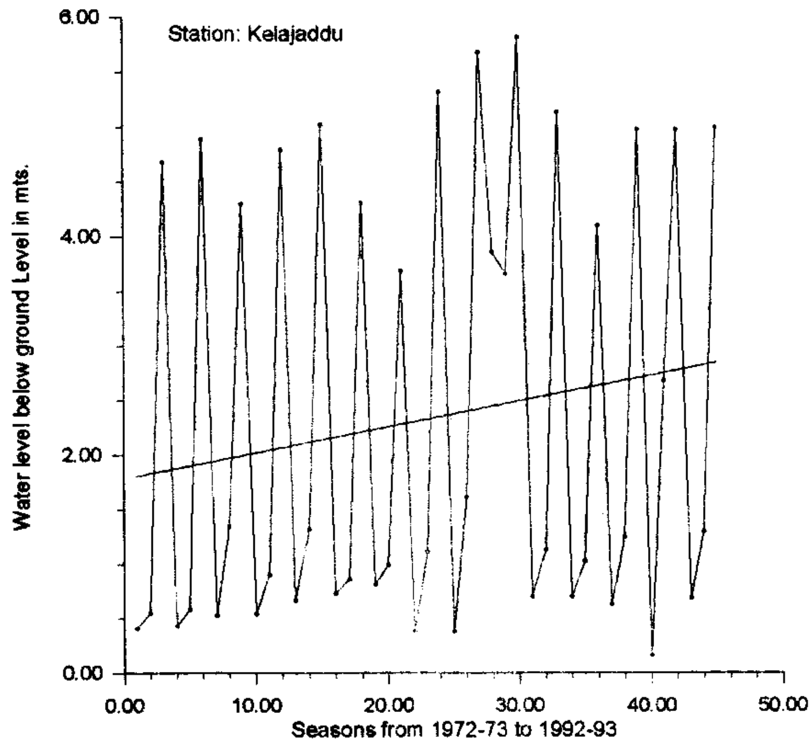


Figure 3.2.1.9 Variation of Groundwater Table

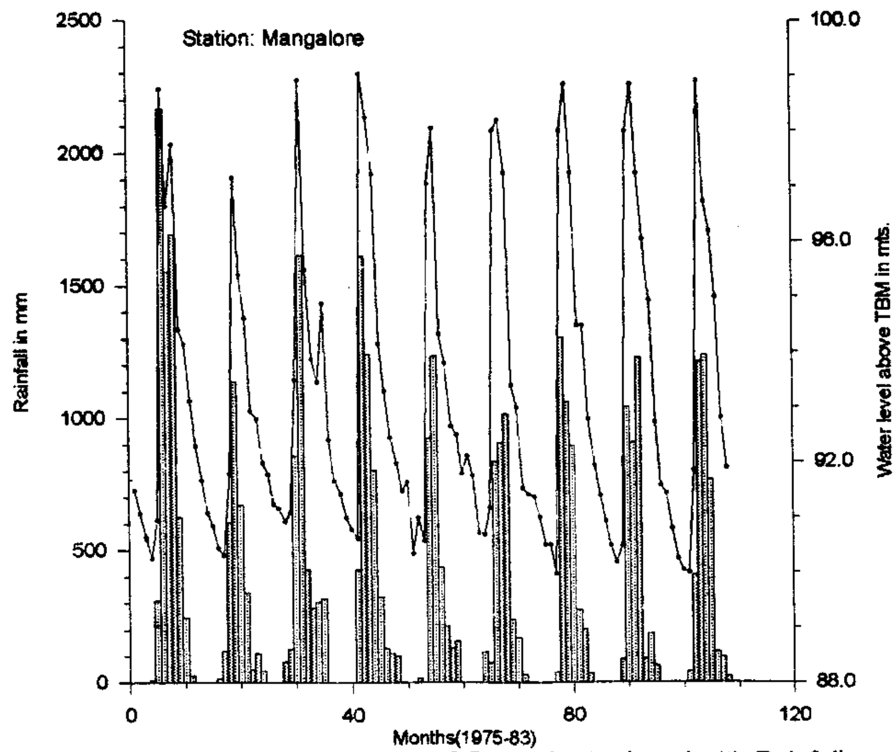


Figure 3.2 2.1 Variation of Groundwater Level with Rainfall

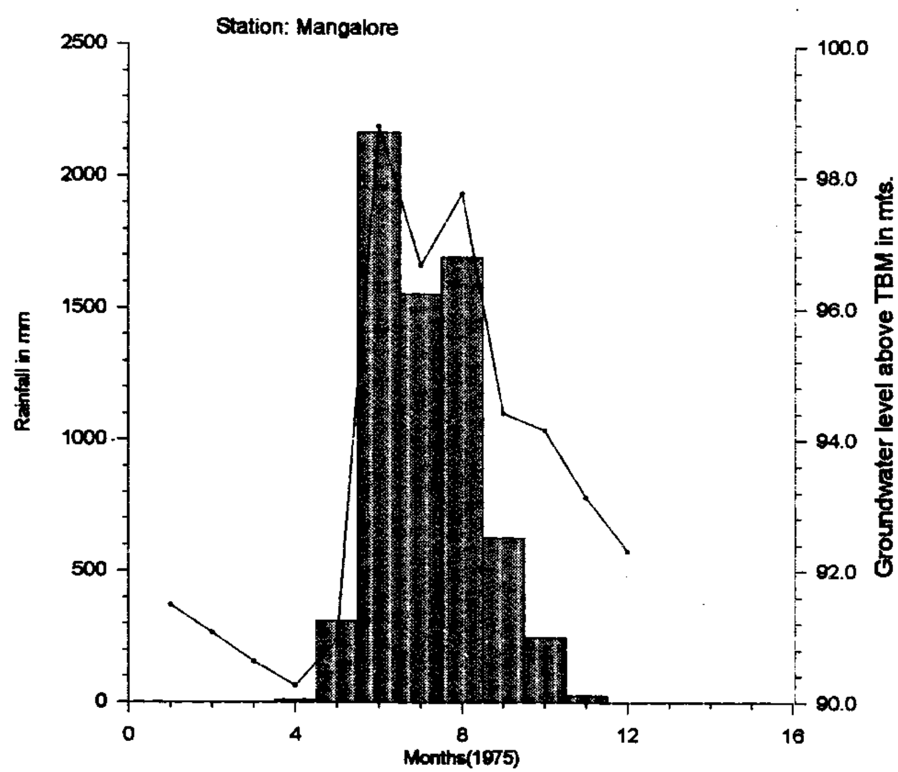


Figure 3.2.2.2 Response of Groundwater Level with Monthly Rainfall

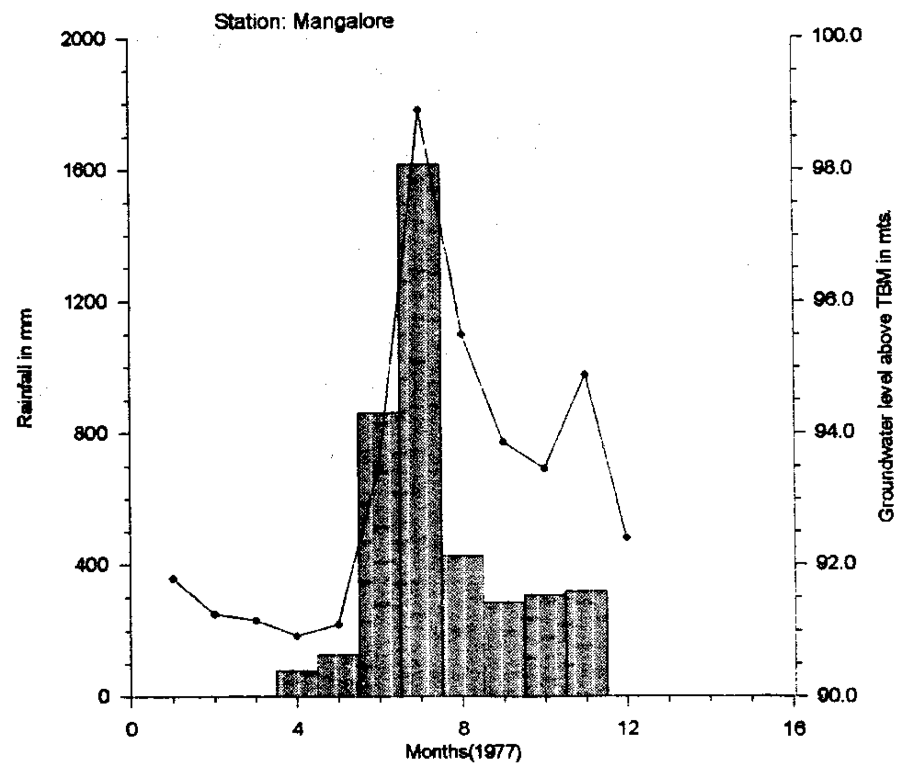


Figure 3.2.2.3 Response of Groundwater Level with Monthly Rainfall

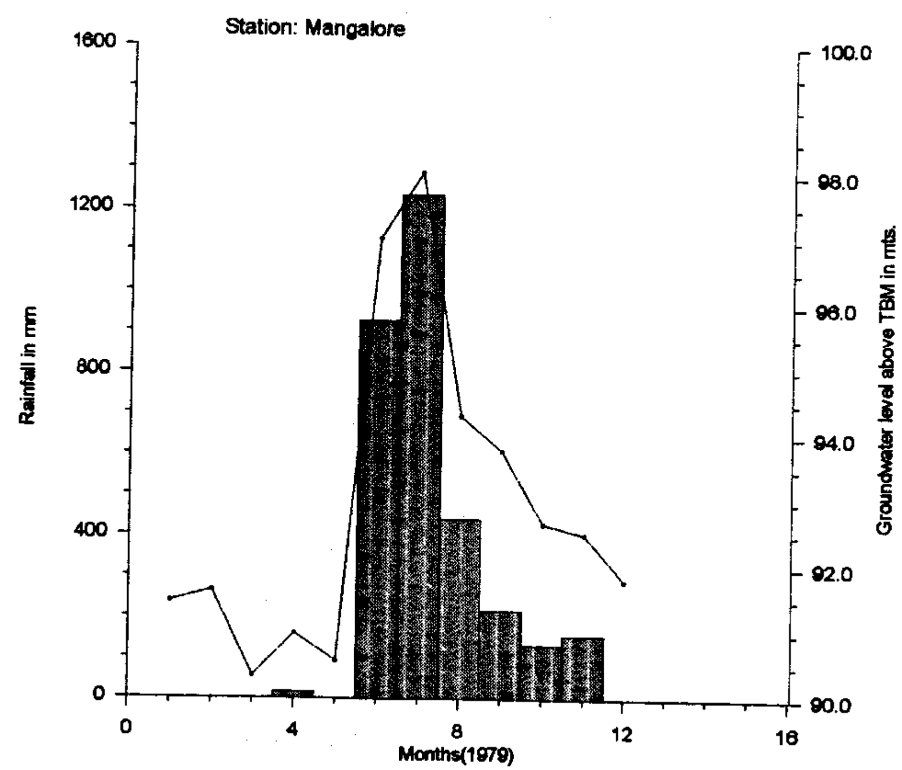


Figure 3.2.2.4 Response of Groundwater Level with Monthly Rainfall

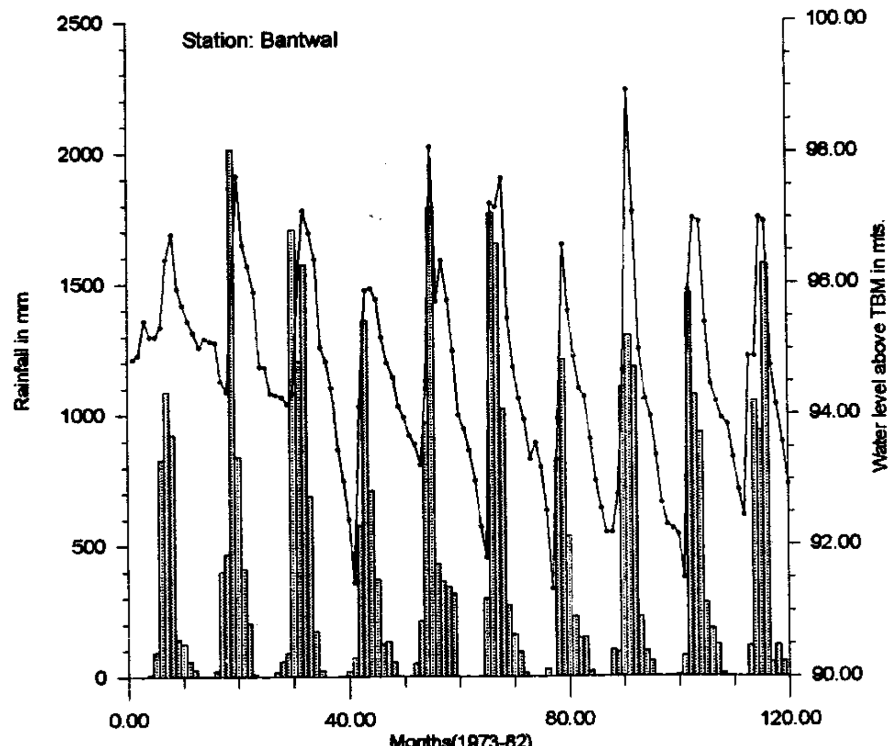


Figure 3.2.2.5 Variation of Groundwater Level with Rainfall

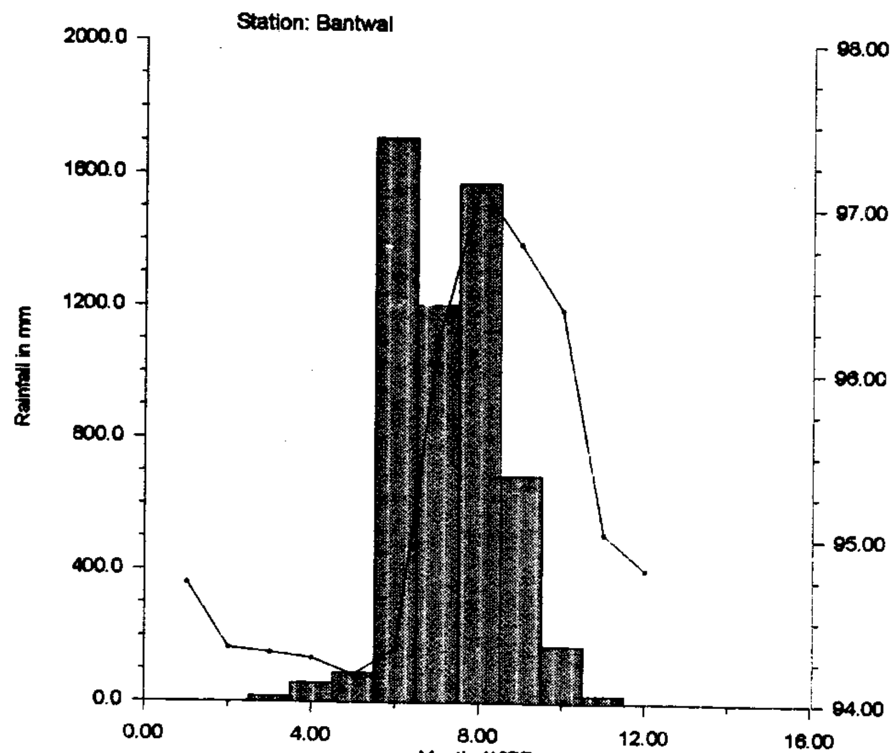


Figure 3.2.2.6 Response of Groundwater level with monthly rainfall

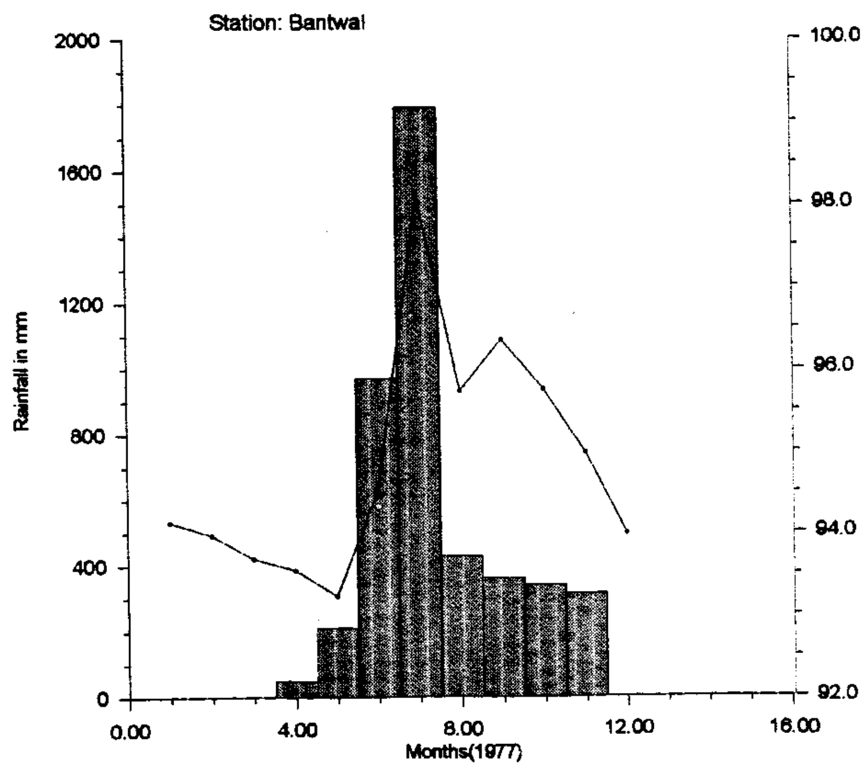


Figure 3.2.2.7 Response of Groundwater level with monthly rainfall

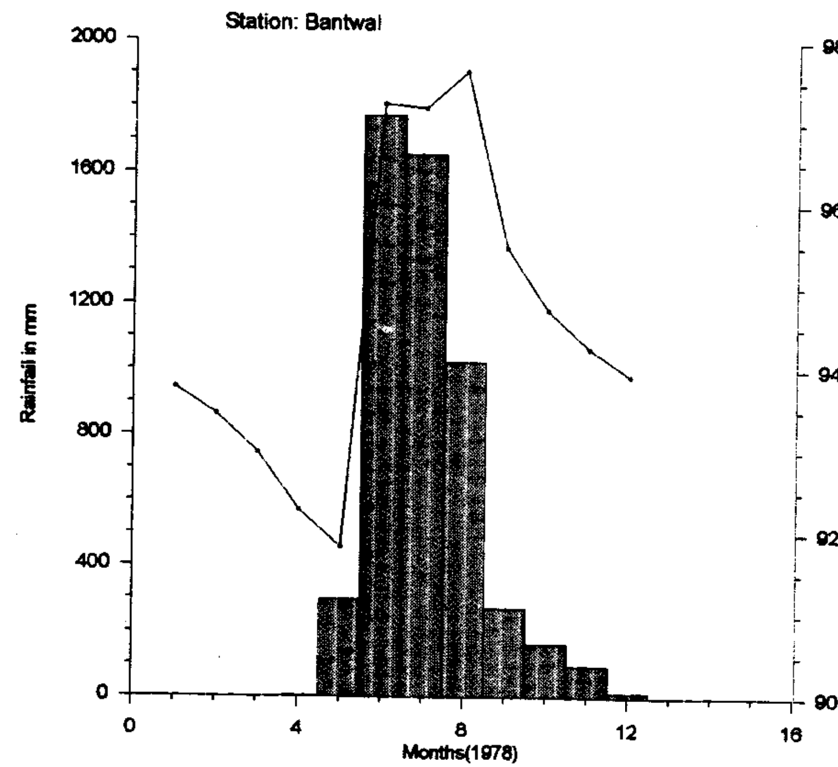


Figure 3.2.2.8 Response of Groundwater level with monthly rainfall

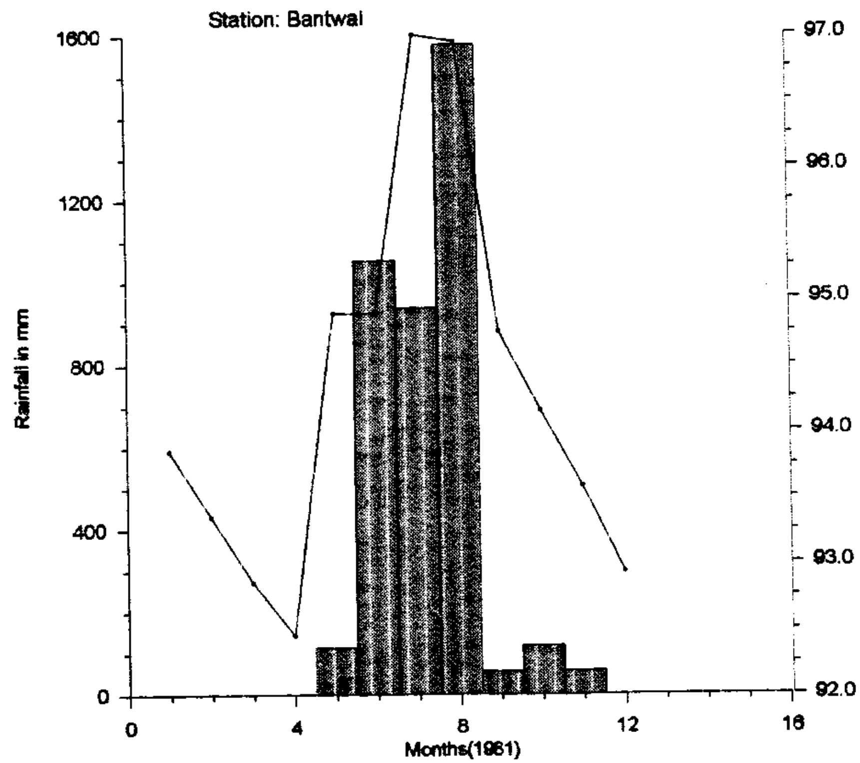


Figure 3.2.2.9 Response of Groundwater level with monthly rainfall

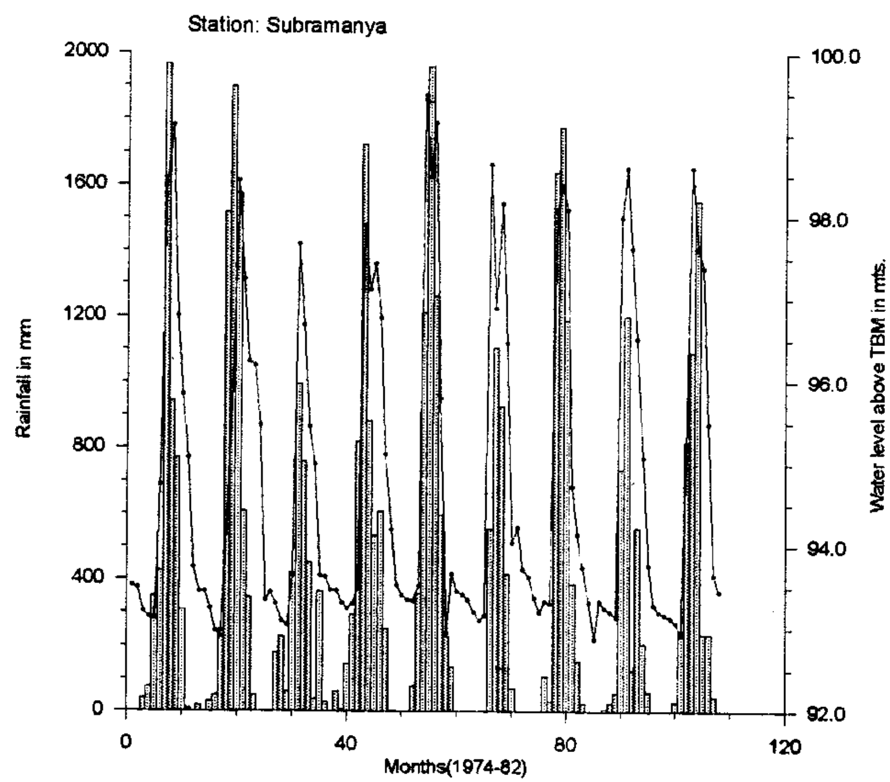


Figure 3.2.2.10 Variation of Groundwater Level with Rainfall

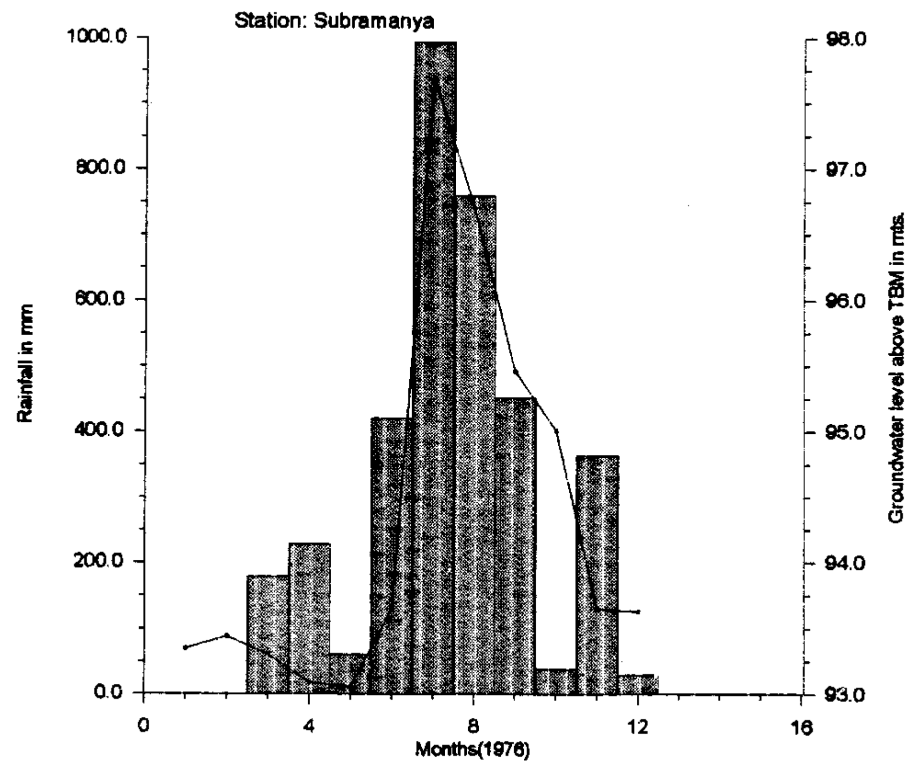


Figure 3.2.2.11 Response of Groundwater Level with Monthly Rainfall

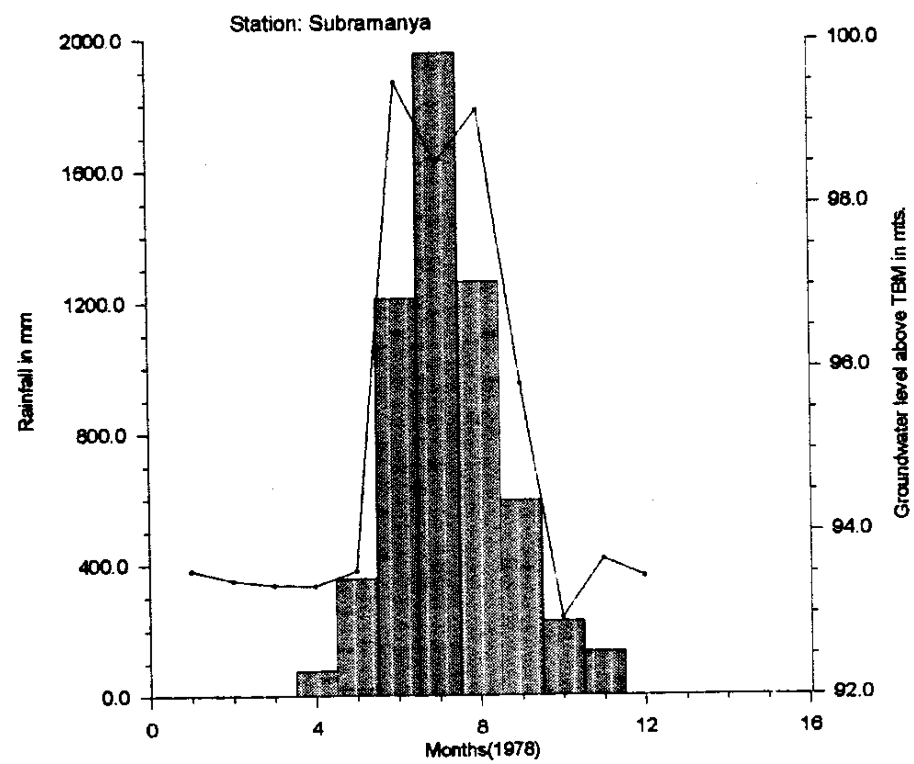


Figure 3.2.2.12 Response of Groundwater Level with Monthly Rainfall

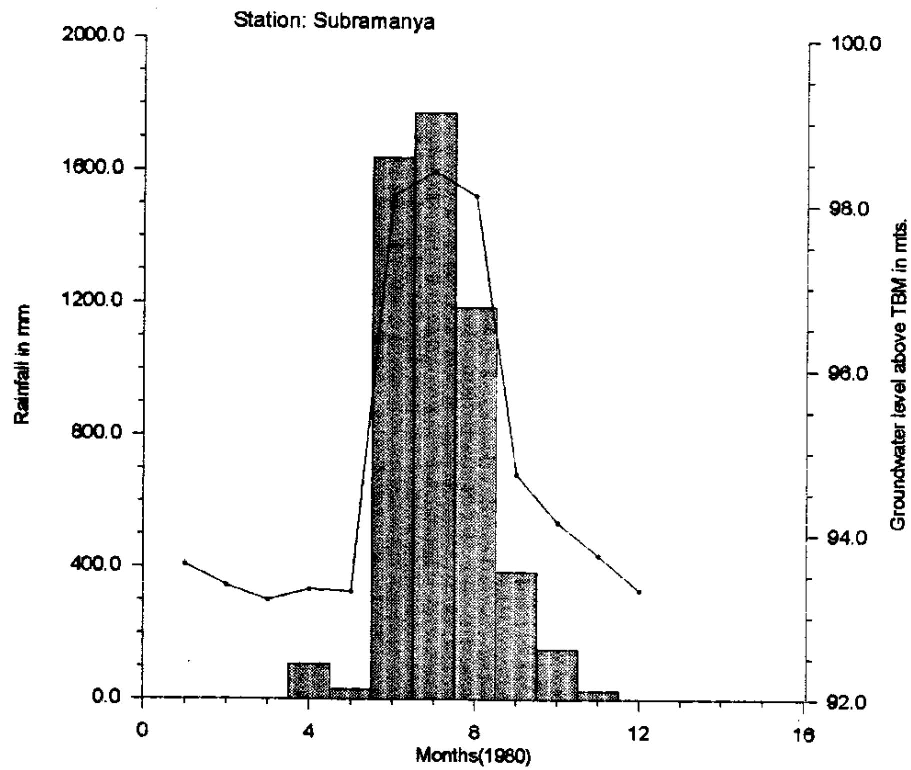


Figure 3.2.2.13 Response of Groundwater Level with Monthly Rainfall

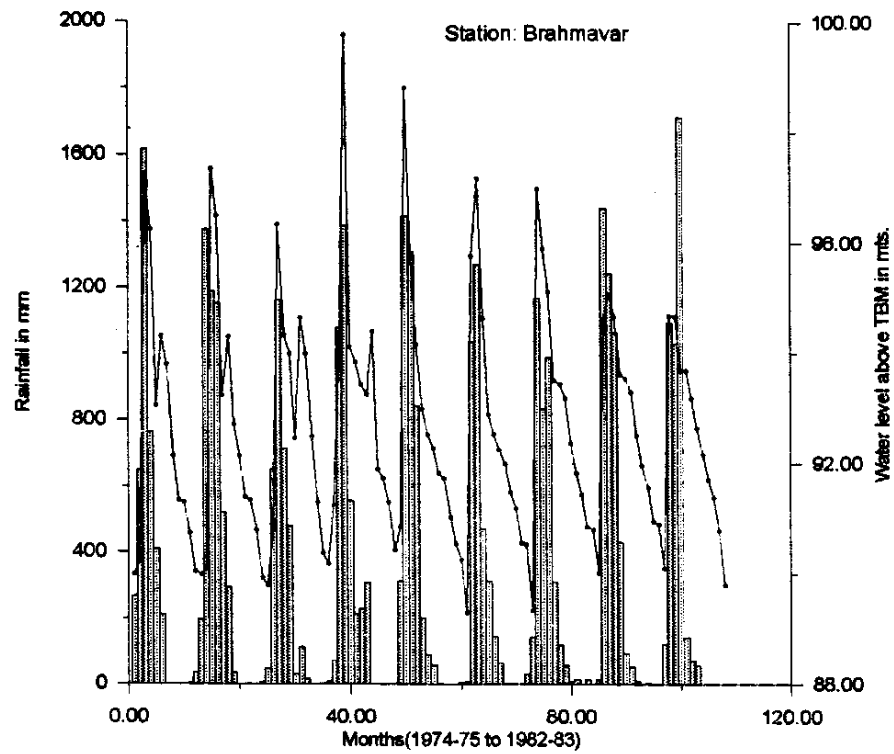


Figure 3.2.2.14 Variation of water level with rainfall

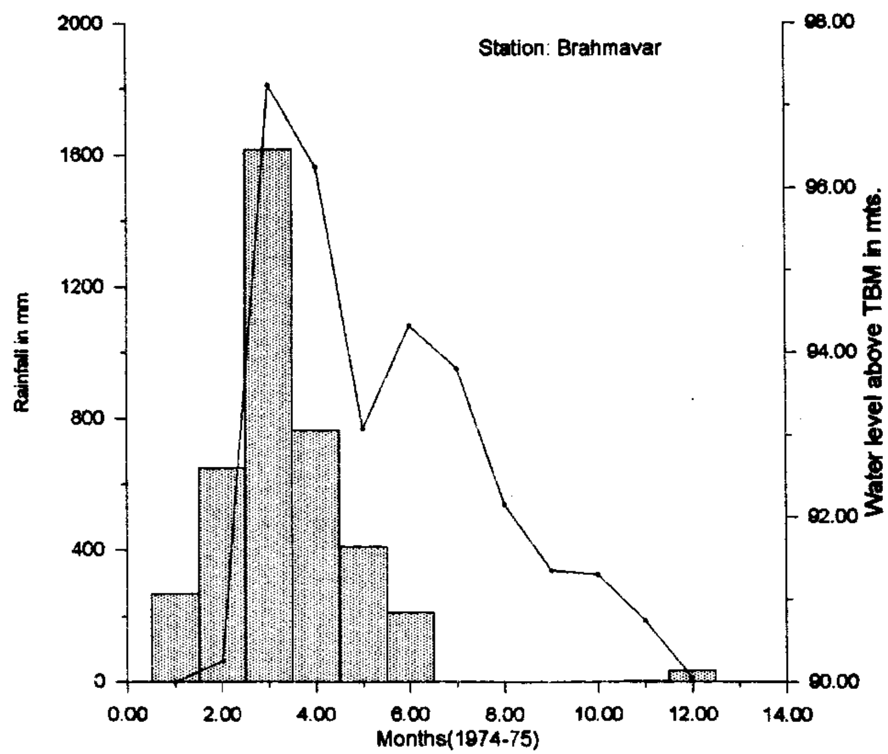


Figure 3.2.2.15 Response of water level with monthly rainfall

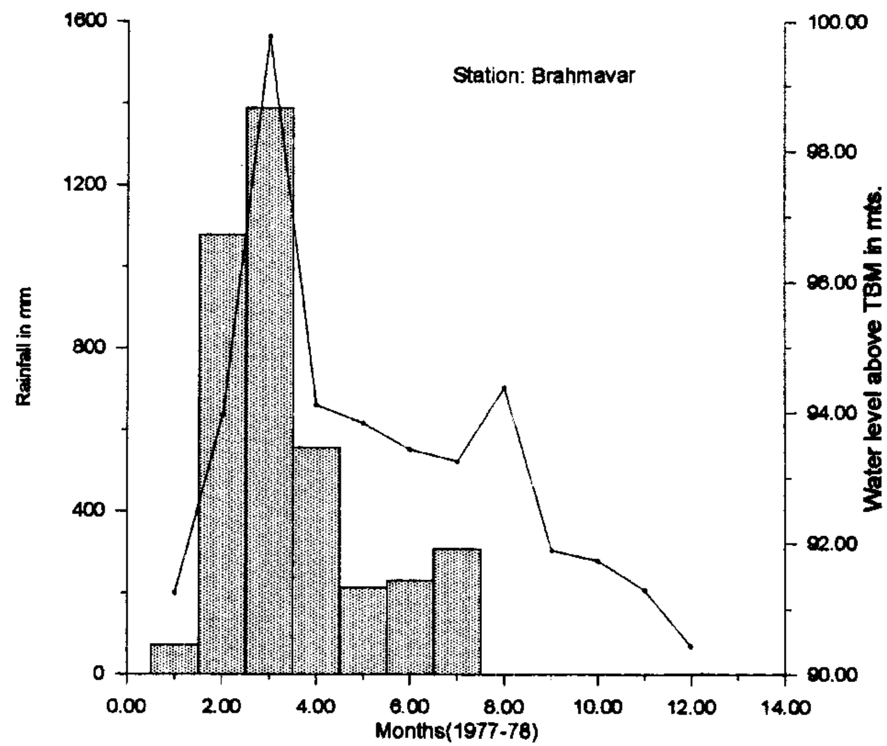


Figure 3.2.2.16 Response of water level with monthly rainfall

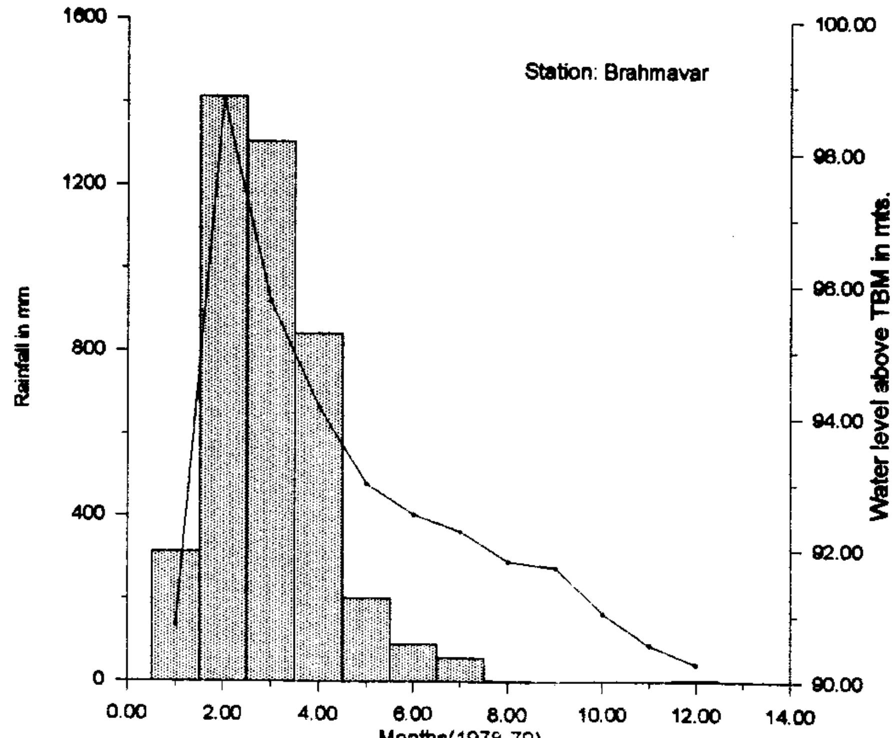


Figure 3.2.2.17 Response of water level with monthly rainfall

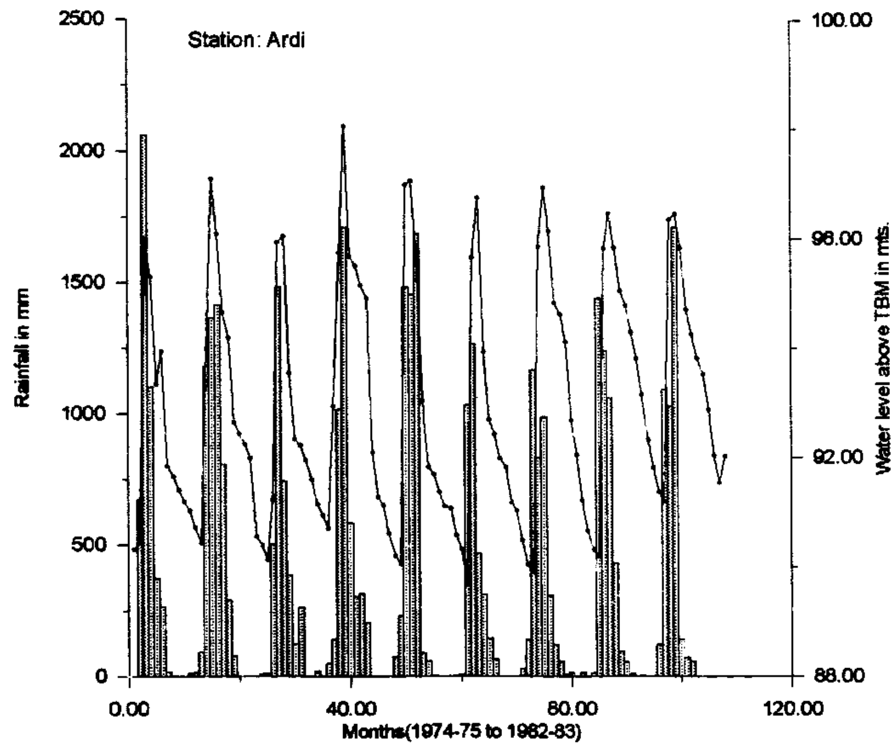


Figure 3.2.2.19 Variation of water level with rainfall

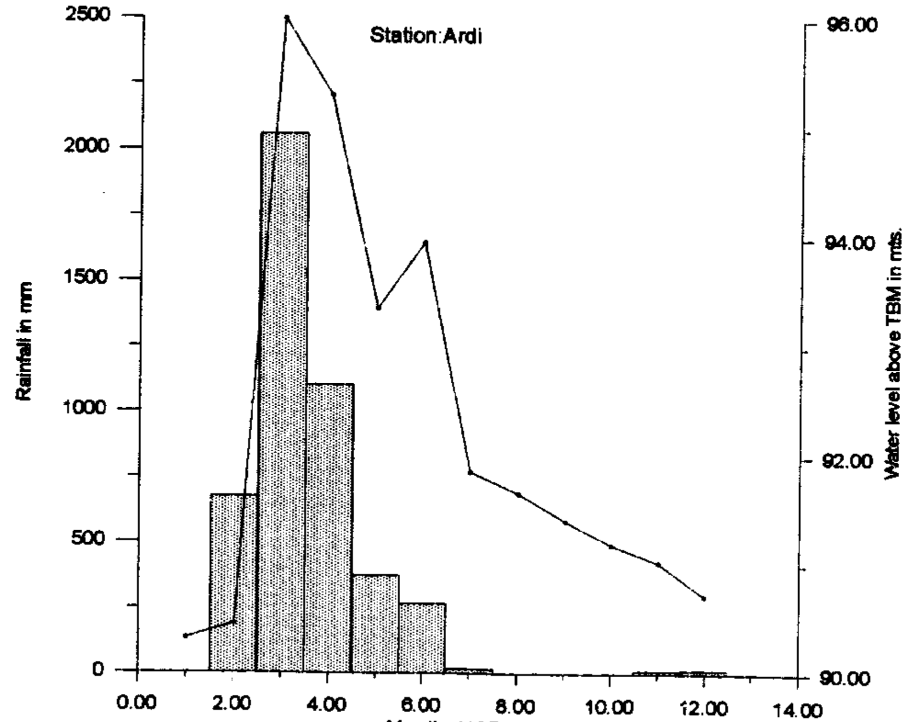


Figure 3.2.2.20 Response of water level with monthly rainfall

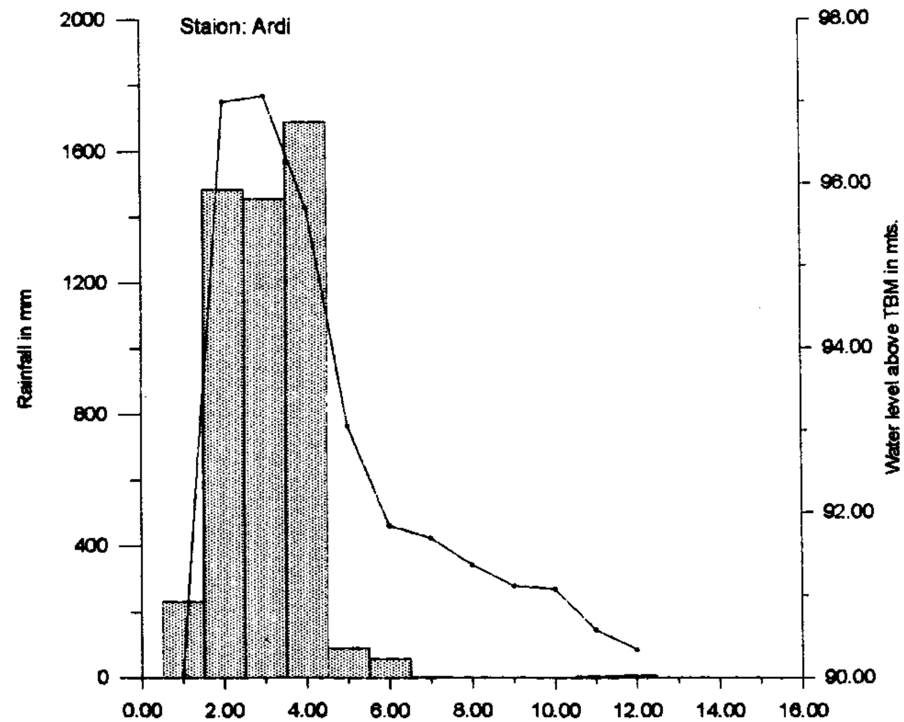


Figure 3.2.2.21 Response of water level with monthly rainfall

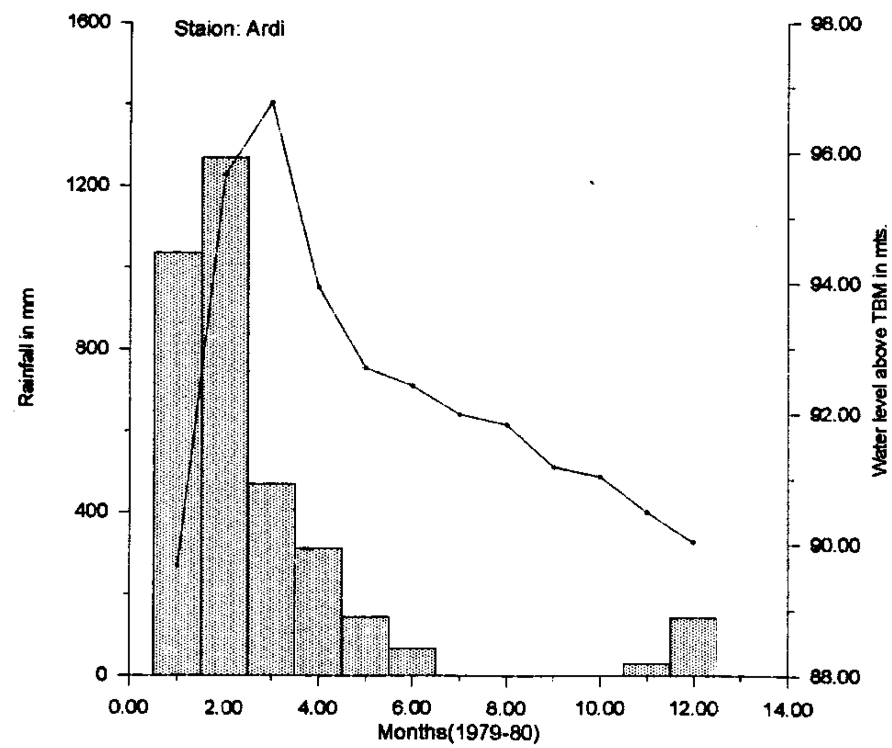


Figure 3.2..2.22 Response of water level with monthly rainfall

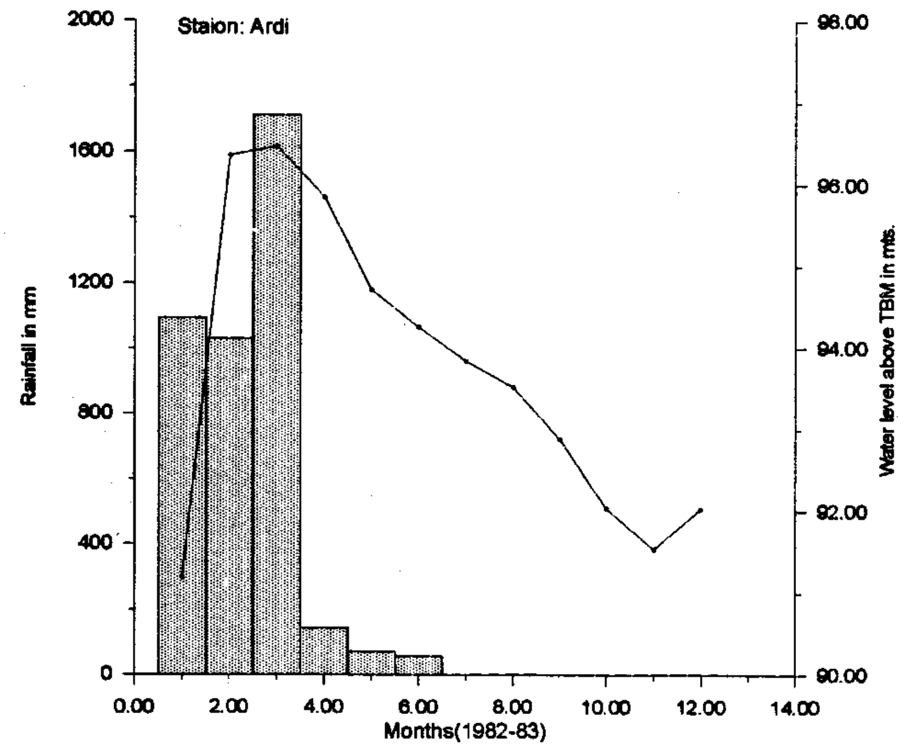


Figure 3.2.2.23 Response of water level with monthly rainfall

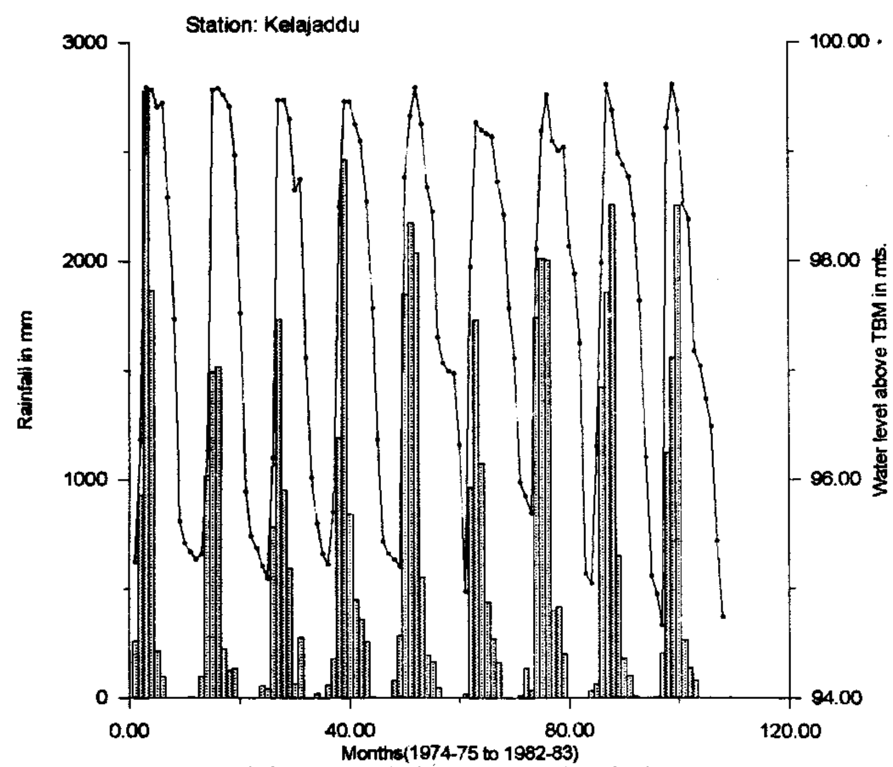


Figure 3.2.2.24 Variation of water level with rainfall

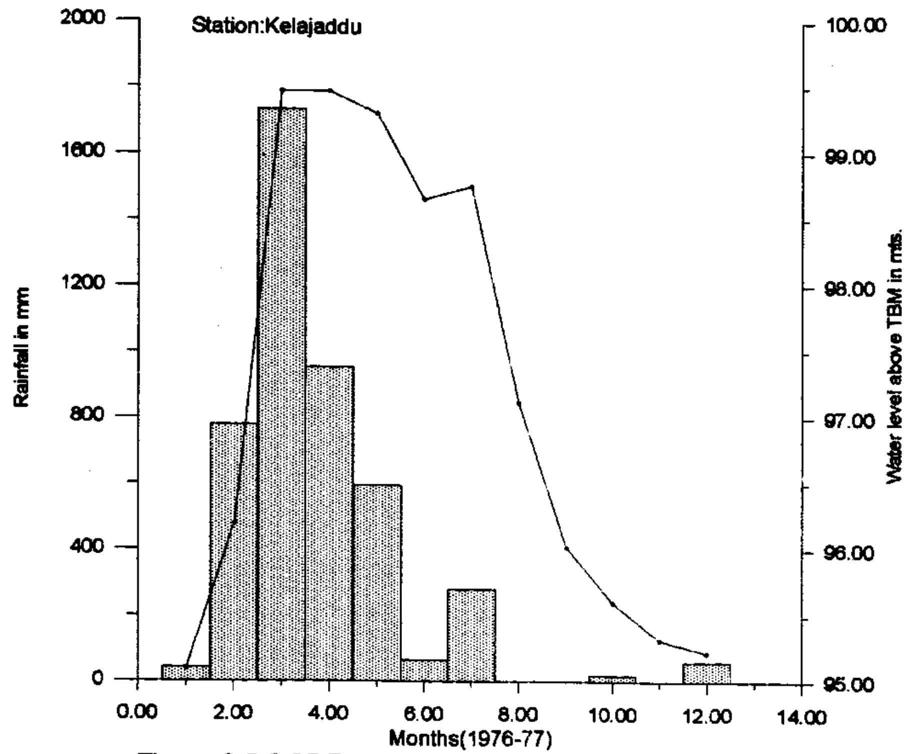


Figure 3.2.2.25 Response of water level with monthly rainfall

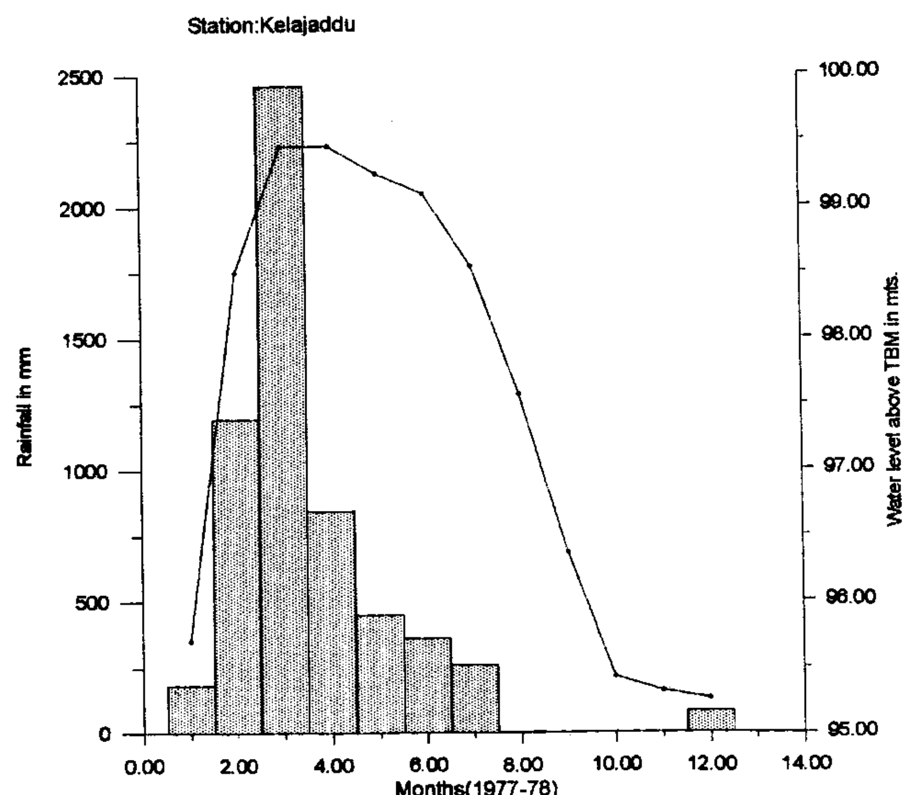


Figure 3.2.2.26 Response of water level with monthly rainfall

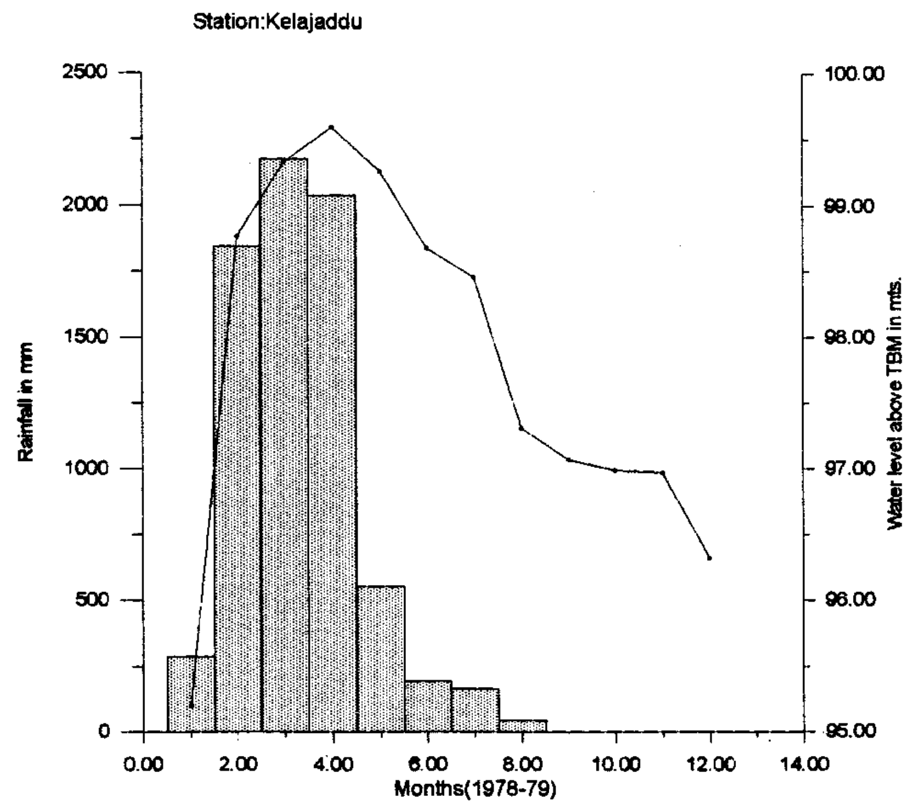


Figure 3.2.2.27 Response of water level with monthly rainfall

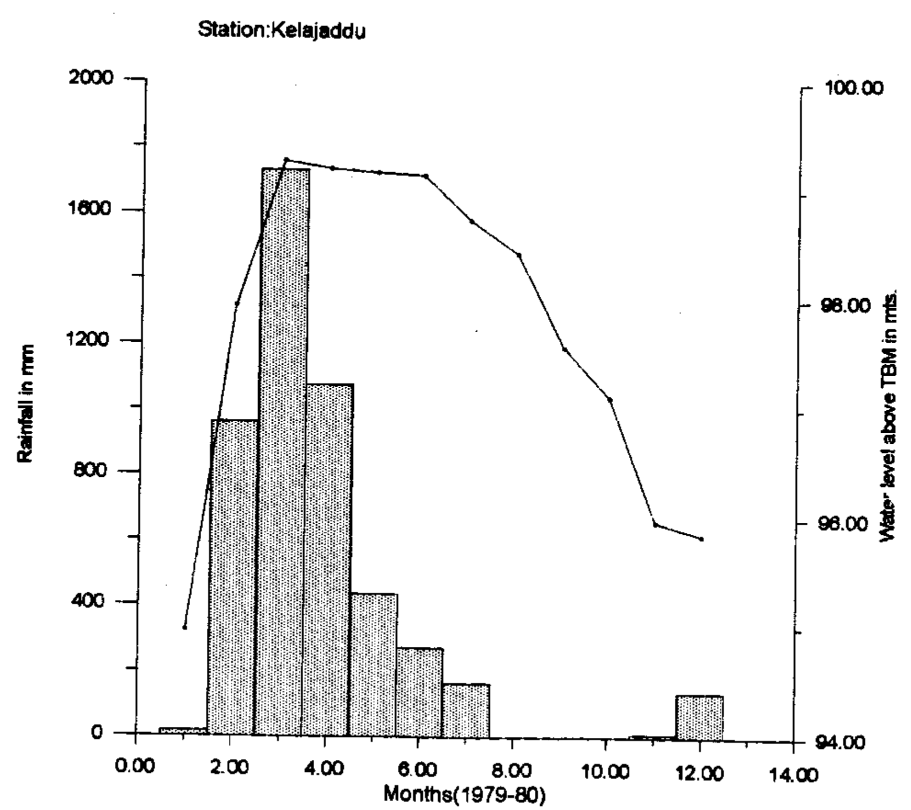


Figure 3.2.2.28 Response of water level with monthly rainfall

and baseflow. The model parameters were determined using measured weighted monthly rainfall for Sithanadi and Nethravathi and daily discharge at Kokkarne for Sithanadi(1973 to 1989) and at Panemangalore for Nethravathi(1973 to 1986). Yearly runoff has been calculated by integrating the daily hydrograph over a year.

The daily hydrograph is drawn based on the daily discharge data obtained at gauging sites. The baseflow separation line has been drawn and the area under these curves has been integrated to find out the volume of the baseflow. Consequently, surface runoff, wetting and vaporization have been calculated using catchment water balance equations.

The proportional curve has been fitted for (1) precipitation and surface runoff, and (2) wetting and baseflow based on the observed data as shown in Figures 3.3.1 to 3.3.2. A set of paired values of surface runoff and precipitation, and wetting and baseflow has been obtained from the fitted proportional curve for the calibration of the model parameters.

3.3.1 Calibration of the model

In order to calibrate the initial abstraction coefficient of surface flow λ_s and baseflow λ_u, and potentials of wetting W_p and vaporization V_p of the study area, the observed data has been used to fit the proportional curves for precipitation and surface runoff, and wetting and baseflow. A set of paired values of precipitation and surface runoff, and wetting and baseflow has been derived from the fitted proportional curves respectively to calibrate the parameters.

Step 1: Initially λ_s is chosen as zero for the set of paired values of precipitation and surface runoff.

Step 2: Use the equation $W_p = (P/S)(P-S)$ to find out the wetting potential values.

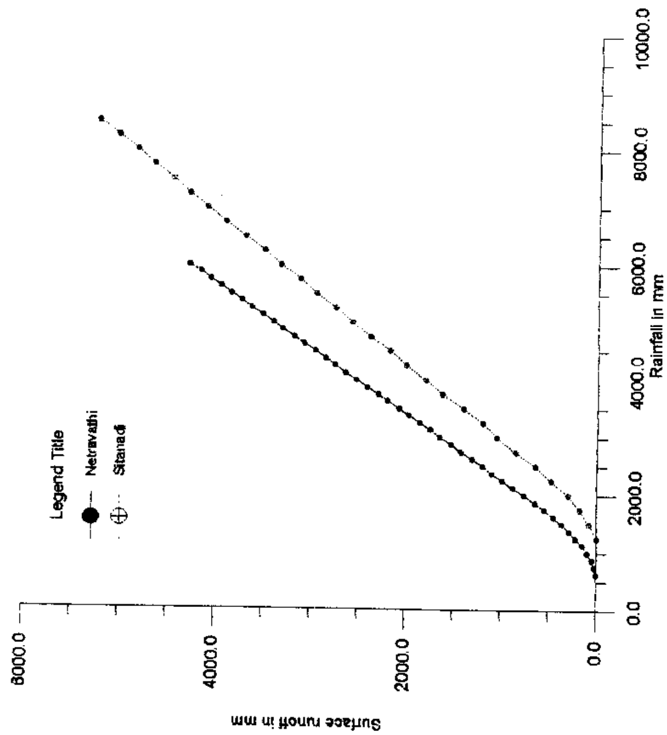


Figure 3.3.1 Fitted Proportional Curve for P and S

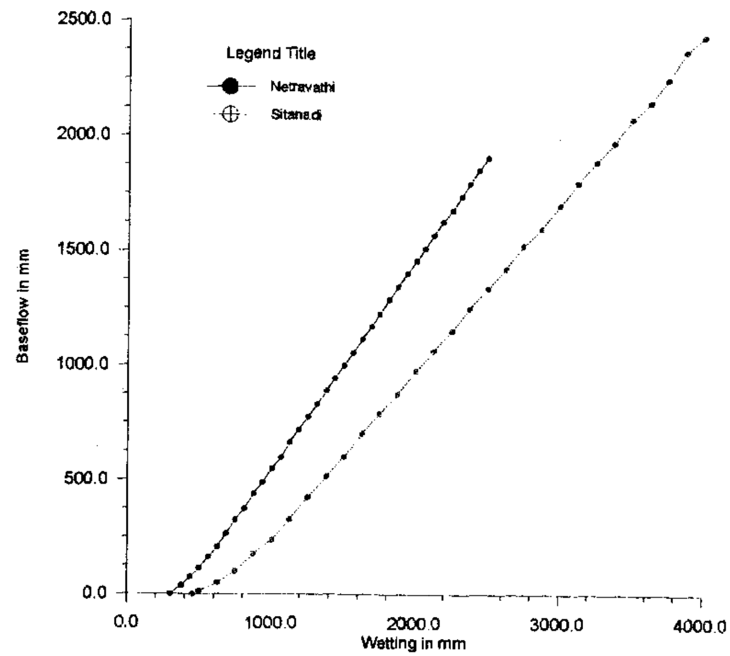


Figure 3.3.2 Fitted proportional line W and U

Step 3: Increase λ_s by 0.01 and calculate array of wetting potential using the equation:

$$Wp = 1/\lambda_s(\{P+[(1/2\lambda_s)][(1-2\lambda_s)^2 S^2 + 4\lambda_s(1-\lambda_s)PS]^{1/2}\})$$ and

Step 4: Calculate the mean, standard deviation, and coefficient of variation of the estimated array of wetting potential values.

Step 5: Go back to step 3, repeat the computation for the new value of λ_s until the coefficient of variation of the array of wetting potential is a minimum. The original fitted proportional curve may be readjusted to get a minimum standard deviation of the calculated array of wetting potential.

Step 6: Choose parameter values W_p and λ_s. W_p is the mean value of the calculated wetting potential with value of λ_s for which coefficient of variation and standard deviation is a minimum.

The same steps are followed to calibrate the vaporization potential and baseflow initial abstraction coefficient. The calibrated model parameters such as Wetting potentials, vaporization potentials, initial abstraction coefficients for surface runoff and baseflow given in the table 3.3.1.

Table 3.3.1. Model Parameters

Sl. No.	Name of the basin	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	3448	0.3	1823	0.15
2	Netravathi	1838	0.33	601	0.36

The water balance components such as wetting, vaporization, surface runoff, total runoff, and baseflow has been separated for Sithanadi and Nethravathi basins and is presented in the table 3.3.2 and 3.3.3. The runoff and baseflow coefficients for both of the basins with annual rainfall is also presented in the table 3.3.4.

Table 3.3.2. Simulated water balance components(Netravathi)

P in mm	S in mm	U in mm	V in mm	W in mm	R in mm
1000	97.8	438.8	463.4	902.2	536.6
1250	224.6	547.7	477.7	1025.4	772.3
1500	380.5	632.8	486.7	1119.5	1013.3
1750	556.2	700.8	493.0	1193.8	1257.0
2000	746.0	756.3	497.6	1254.0	1502.4
2250	946.4	802.4	501.2	1303.6	1748.8
2500	1154.7	841.4	503.9	1345.3	1996.1
2750	1369.2	874.6	506.2	1380.8	2243.8
3000	1588.6	903.4	508.0	1411.4	2492.0
3250	1812.0	928.4	509.6	1438.0	2740.4
3500	2038.6	950.5	510.9	1461.4	2989.1
3750	2267.8	970.1	512.1	1482.2	3237.9
4000	2499.3	987.6	513.1	1500.7	3486.9
4250	2732.7	1003.3	513.9	1517.3	3736.1
4500	2967.8	1017.5	514.7	1532.2	3985.3
4750	3204.2	1030.4	515.4	1545.8	4234.6
5000	3441.8	1042.2	516.0	1558.2	4484.0
5250	3680.5	1052.9	516.6	1569.5	4733.4
5500	3920.1	1062.8	517.1	1579.9	4982.9
5750	4160.5	1071.9	517.5	1589.5	5232.5
6000	4401.7	1080.3	518.0	1598.3	5482.0
6250	4643.5	1088.2	518.4	1606.5	5731.6
6500	4885.8	1095.4	518.7	1614.2	5981.3
6750	5128.7	1102.2	519.0	1621.3	6231.0
7000	5372.1	1108.6	519.4	1627.9	6480.6
7250	5615.9	1114.5	519.6	1634.1	6730.4
7500	5860.0	1120.1	519.9	1640.0	6980.1
7750	6104.5	1125.3	520.2	1645.5	7229.8

Table 3.3.3. Simulated water balance components (Sithanadi)

P in mm	S in mm	U in mm	V in mm	W in mm	R in mm
1000	0.5	231.5	768.0	999.5	232.0
1250	17.6	366.4	865.9	1232.4	384.0
1500	75.2	490.6	934.2	1424.8	565.8
1750	163.5	602.1	984.4	1586.5	765.6
2000	275.7	701.3	1022.9	1724.3	977.1
2250	407.0	789.6	1053.4	1843.0	1196.6
2500	553.5	868.4	1078.2	1946.5	1421.8
2750	712.5	938.8	1098.6	2037.5	1651.4
3000	882.0	1002.2	1115.8	2118.0	1884.2
3250	1060.1	1059.4	1130.5	2189.9	2119.5
3500	1245.6	1111.2	1143.2	2254.4	2356.8
3750	1437.4	1158.4	1154.2	2312.6	2595.8
4000	1634.6	1201.5	1163.9	2365.4	2836.1
4250	1836.5	1241.0	1172.5	2413.5	3077.5
4500	2042.4	1277.4	1180.2	2457.6	3319.8
4750	2252.0	1310.9	1187.1	2498.0	3562.9
5000	2464.8	1341.9	1193.3	2535.2	3806.7
5250	2680.3	1370.7	1199.0	2569.7	4051.0
5500	2898.4	1397.5	1204.1	2601.6	4295.9
5750	3118.6	1422.5	1208.8	2631.4	4541.2
6000	3341.0	1445.9	1213.1	2659.0	4786.9
6250	3565.1	1467.8	1217.1	2684.9	5032.9
6500	3790.8	1488.3	1220.8	2709.2	5279.2
6750	4018.0	1507.3	1224.2	2731.9	5525.8
7000	4246.7	1525.9	1227.4	2753.3	5772.6
7250	4476.6	1543.1	1230.4	2773.4	6019.6
7500	4707.5	1559.3	1233.2	2792.5	6266.8
7750	4939.6	1574.7	1235.8	2810.4	6514.2

Table 3.3.4. Simulated runoff and baseflow coefficients

P in mm	NETRAVATHI		SITHANADI	
	K_u	K_T	K_u	K_T
1000	0.486	0.537	0.232	0.232
1250	0.534	0.618	0.297	0.307
1500	0.565	0.676	0.344	0.377
1750	0.587	0.718	0.380	0.437
2000	0.603	0.751	0.407	0.489
2250	0.616	0.777	0.428	0.532
2500	0.625	0.798	0.446	0.569
2750	0.633	0.816	0.461	0.601
3000	0.640	0.831	0.473	0.628
3250	0.646	0.843	0.484	0.652
3500	0.650	0.854	0.493	0.673
3750	0.655	0.863	0.501	0.692
4000	0.658	0.872	0.508	0.702
4250	0.661	0.879	0.514	0.724
4500	0.664	0.886	0.520	0.738
4750	0.667	0.891	0.525	0.750
5000	0.669	0.897	0.529	0.761
5250	0.671	0.902	0.533	0.772
5500	0.673	0.906	0.537	0.781
5750	0.674	0.910	0.541	0.790
6000	0.676	0.914	0.544	0.798
6250	0.677	0.917	0.547	0.805
6500	0.679	0.920	0.549	0.812
6750	0.680	0.923	0.552	0.819
7000	0.681	0.926	0.554	0.825
7250	0.682	0.928	0.556	0.830
7500	0.683	0.931	0.558	0.836
7750	0.684	0.933	0.560	0.841

3.4.0 Geomorphology

Qualitative geomorphic methods have been developed to provide means of measuring size and form properties of drainage basins. The composition of the stream system of a drainage basin can be expressed qualitatively in terms of stream order, drainage density, bifurcation ratio and stream-length ratio .

Quantitative studies of drainage characteristics in a given catchment help in understanding the physical and hydrological characteristics. To quantify the geometry of the, fundamental dimension of length, time and mass are used. Many drainage basin features which are important to hydrologists, that can be quantified in terms of depth, square of length or cube of length. Such as elevation, stream length, basin parameter, drainage area and volume. The concept of geometric similarity can be applied to drainage basin just as it is to many other systems. Perfect similarity will never be realised if natural drainage systems are compared, but striking similarities have been observed which can often be put to practical use.

Morphometry is the measurement of the slope or geometry of any natural form. It is the systematic description of the geometry of a drainage basin and its stream channel system which requires measurements of linear aspects, areal aspects and relief aspects of channel network and contributing ground slopes. While the linear aspects of the drainage basin are planimetric, the relief aspects of channel network and contributing ground slopes treat the vertical inequalities of the drainage basin forms. It is possible to establish correlation between various geometric characteristics of a basin with its runoff and other hydrological characteristics(Marisawa, 1959; Vorst and Bell, 1977).

In the present study, geomhorpological parameters which are influencing on movement of water and thereby the effect on volume of runoff is studied and presented in the table 3.4.1.

Table 3.4.1. Geomorphological Parameters

Sl. No.	Parameter	Unit	Nethravathi	Sithanadi
1	Area of basin (A_u)	Km^2	3180	650.0
2	Length of Basin(L_b)	Km	92.00	49.5
3	Width of Basin(B_r)	Km	64.00	18.5
4	Basin Perimeter(P)	Km	332.50	165.5
5	Form factor(R_f)	(A_u/L_b^2)	0.38	0.26
6	Shape Factor	(L_b^2/A_u)	2.66	3.79
7	Total Stream Lenth	(L_u)Km	6546.0	1158
8	Total no of Streams	(N_u)	9887	1621
9	Drainage Density(D_a)	(L_u/A_u)	2.06	1.79
10	Stream frequency	(N_u/A_u)	3.11	2.49
11	Hieght of Basin mouth	(z)m	0.0	0.0
12	Hieght of highest point on the basin	(Z)m	1680.0	1150
13	Basin relief	(H)m	1680.0	1150
14	Relief ratio(R_h)	(H/L_b)	0.018	0.02
15	Relative relief(Rhp)	(H/P)	5.05	6.97

3.5.0 Land use and Geology

The spatial information on land use and geology, and their pattern of changes are essential for planning, management and utilization of land for utilization of land for agriculture, forestry, urban industries, environmental studies etc.. However in the present case, land use and geology considered for the effect on runoff process of the basin as the variation.

Distribution of land use type is uneven in the study area. The agricultural land is distributed through out the study areas and it is well confined to western portion only. Forest is distributed through out the study areas. Eastern part of fully covered with thick forest vegetation. Barren land areas in patches can be noticed all over the areas(Table 3.5.1).

Table. 3.5.1: Land Use Details.

Land Use	Sithanadi (Km^2)	Nethravathi (Km^2)
Forest(Dense,Open,Scrub)	350.11	1071.96
Waste(barren land)	188.48	381.40
Pasture	1.18	235.69
Cultivable waste	10.78	353.79
Orchards	16.95	568.20
Cultivated Land	84.8	1046.32

From the above data it may be inferred that three different geographic provinces in the area have different land utilization patterns. The eastern most is mostly covered by forests with no agriculture, while the midland region is supports agriculture in patches depending upon the availability of of water and soil suitability, the agricultural activity and density of population increase towards western portion and reaches its maximum in the coastal low land region.

Geological features of Sitanadi catchment is presented in the figure 3.5.1.1 The major lithological units of Sitanadi catchment area are banded granitic gneiss and laterites and some parts are covered by chlorite schists. Some intrusive bodies like dolerite dykes and pegmatite veins are also noticed. This layer of coastal sediments is also noticed in the western part of the catchment. The rocks of the area belong to different periods like archaean, proterozoic, cretaceous, tertiary and quaternary.

Geological features of Nethravathi is presented in the figure 3.5.1.2 Nethravathi basin consists of recent and sub-recent which includes alluvial formation, clays red and dark clay soils and lateroid formation. Intrusive includes dolerite, basic and ultra basic rocks, charnockity and granitic gneiss.

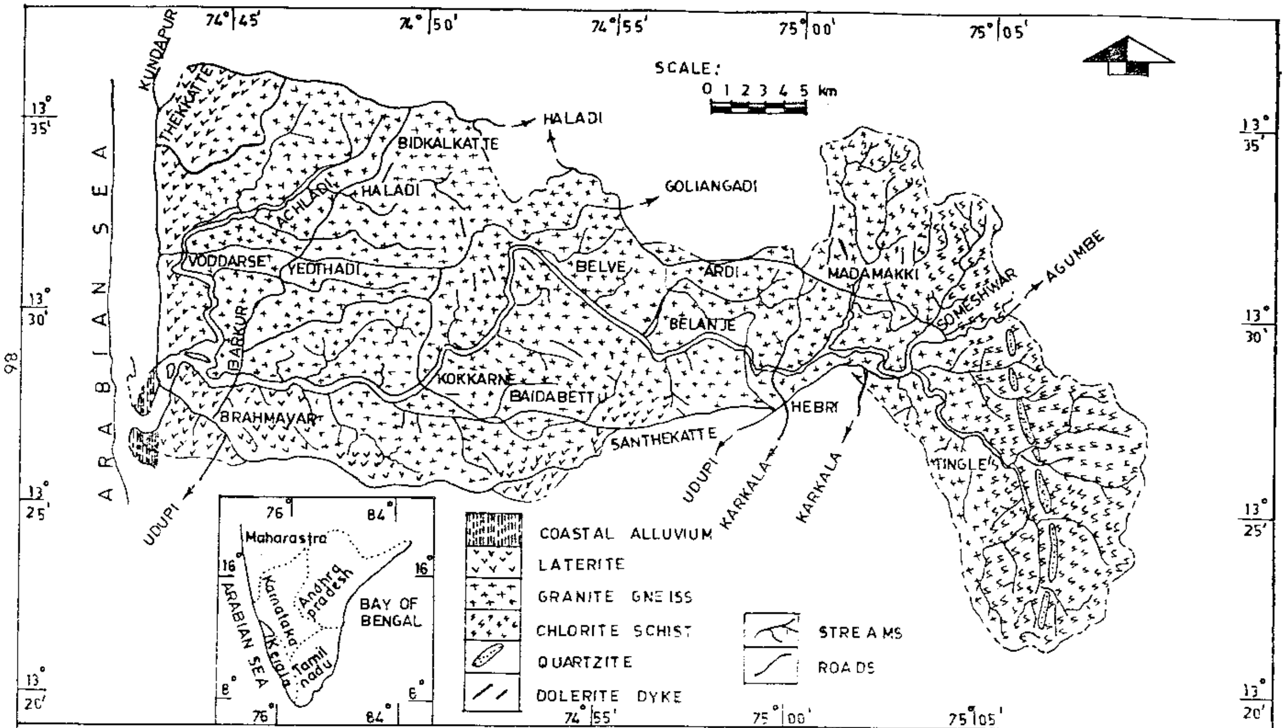


FIG. 3.5.1.1 GEOLOGICAL MAP OF SITANADI BASIN

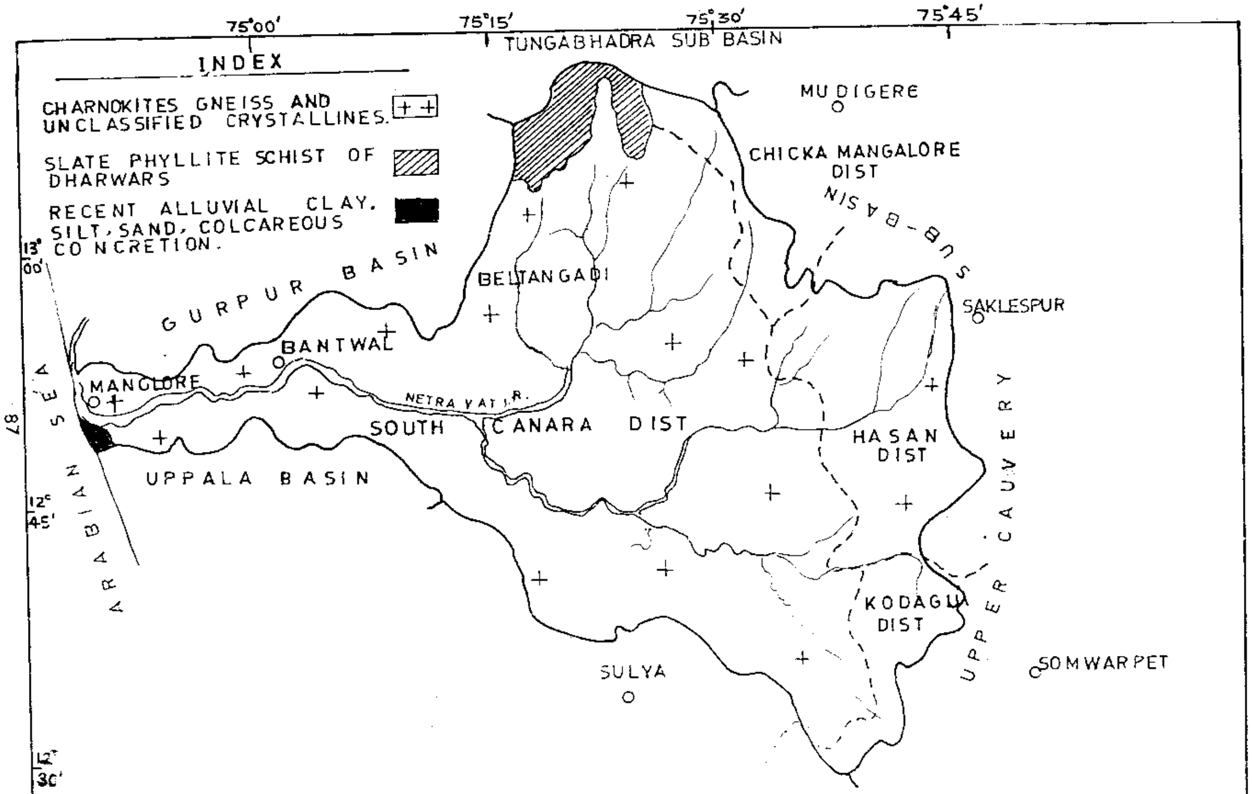


FIG. 3.5.1.2 Geolgical Map of Netravati Basin

Dharwars includes older metamorphic rocks, graniteferrous quartz, sillimanite, talc-schists, hornblende schists, chlorite schists and banded haematite quartzite. These soils generated from the formations are mostly permeable.

3.6.0 Infiltration

Thirteen field values of infiltration has been collected from the report on Integrated study of water balance and management of river catchment of Dakshina Kannada District, Karnataka State and presented in the table 3.6.1. However, for Nethravathi basin only seven sites value are available that is 5.96, 7.04, 7.14, 3.14cm/hr in Belthangadi taluk, 3.46, 8.16, 4.12 cm/hr in Mangalore taluk (Chandrakanth.G.1987).

Table 3.6.1 Infiltration rate of Sithanadi basin

Sl. No.	Place	Location	Soil Type	Infiltration rate cm/hr
1	Matapadi	Stream bed	Clay	7.20
2	Kokkarne	Stream bed	Laterite	19.20
3	Hebri	Cultivated	Laterite	27.52
4	Belve	Uncultivated	Clay	5.16
5	Achaladi	Stream bed	Laterite	19.52
6	Tekkatte	Cultivated	Sandy	9.60
7	Pandaeshwara	Uncultivated	clay with sand	4.11
8	Hunsemakki	Uncultivated	Sandy clay	9.08
9	Januvarkatte	Cultivated	Sandy clay	7.64
10	Baidebettu	Stream bed	Clay	2.88
11	Albadi	Uncultivated	Sandy Clay	5.70
12	Hebri	Uncultivated	Clay	0.9
13	Haluvalli	Cultivated	Sandy	10.32

(Source: Integrated Study of Water Balance and Management of River Catchment of D. K District, Karnataka State)

4.0 RESULTS AND DISCUSSIONS

Rainfall over the years ranges from 3700mm to 6900mm with standard deviation 834.32mm. The symmetry of the rainfall pattern is +0.302 with variability +0.151. The distribution of rainfall based on coefficient of variation uniform as it is within 0.25. The normal annual rainfall is estimated to be 5533.0mm for Sithanadi basin. For Netharavathi basin, rainfall over the years ranges from 3000mm to 5700mm with standard deviation 670.00mm. The symmetry of the rainfall pattern is +0.331 with variability +0.166. The normal annual rainfall is estimated to be 4046.0mm.

The departure from the normal expressed in percentage from 1957 to 1986 for Nethravathi basin and for Sithanadi from 1972 to 1992. The Sithanadi basin recorded annual rainfall deficit in the order of 30 % in the year 1972. Nethravathi basin has recorded annual rainfall deficit of 25 per cent in the year 1966.

Probability of getting rainfall of 75% or more is about 4981.0mm for Sithanadi and for Nethravathi 3612.00mm. Probability of occurrence of rainfall equivalent to 75% of normal rainfall for both basins is only 95 per cent.

The general pattern of rainfall clearly indicates that the eastern part of the basins receives more rainfall as compared the western part of the basins. This may be attributed to the fact that the area lies at the foot hills of the Western Ghat which arrest the rain bearing clouds of south-west monsoon. This wide variation in distribution of rainfall over the basin is due to its physiographic features and wind direction(winaward) which carries the monsoon cloud of the area. In this regard close network of rain gauges will help in estimating the mean rain fall over the study areas. The spatial variation of rainfall remarkably very high, however departure and distribution of the annual rainfall is uniform and highly dependable.

The trend analyses of seasonal groundwater levels over the periods of analysis shows that some wells having declining trend of water table some of other wells have the increase in water table over the years. In Nethravathi basin, Mangalore Farangipet observation wells showing the depletion trend of water table. However, Bantwal, Sulya and Subramanya shows the building up of water table. The water level fluctuation in the area is about 10m.

In order to know the relationship between rainfall an water table fluctuation, monthly water level and corresponding rainfall has been analysed. The water level fluctuations exhibit a uniform rise and fall. It is also noticed that water level will rise to the maximum during the months of June-July and minimum during April or May. Water level response to the rainfall is established by plotting monthly rainfall and water level for the study areas. The annual rainfall and the status of the water table regime is compared over number of years.

As per the rainfall magnitude and groundwater level, it is indicating that the residence time and response time of rainfall to groundwater recharge is very small which is attributed to the fast recharge of aquifer in the area. Otherwise effect of rainfall on groundwater regime is very high. It is of higher side of permeability or low specific yield. The drop in groundwater regime for a short dry spell of rainfall shows the higher rate of conductivity and low soil water retention capacity and also some extent of steep topography. It is also could not be ruled out the possibility of impermeable layer below the water table aquifer which is in shallow depth.

Analysis shows that the magnitude of rainfall has a little effect on the groundwater level status during dry season or over all regime of the groundwater table. Only the distribution of rainfall has an effective role on the regime of groundwater level in the dry season. In conclusion, we can say that as quickly as it recharges, it will drain out as interflow or baseflow from the region. The analyses of rainfall and groundwater table of the study area shows that it has very weak aquifer from the point of view of stability and sustainability of the aquifer.

The question is how to arrest the baseflow. Base flow is a function of rainfall, hydraulic conductivity, permeability, specific yield, soil moisture retention capacity and vaporization. Apart from rainfall and vaporization all other parameters are natural physical characteristics of soil and geology. However, baseflow should be contained by technical measures.

The annual rainfall at 1500mm, 75mm will appear as surface runoff, 491mm as baseflow, 934mm as vaporization, 1425mm as wetting and 566mm as total runoff for the Sithanadi basin. Nethravathi basin which produces 381mm of surface runoff, 633mm of baseflow, 487mm of vaporization, 1120mm of wetting and 1013mm as total runoff. The above said results clearly shows that Nethravathi basin has better yielding capacity than Sithanadi basin. There is also a possibility of better recharge of groundwater aquifer in Sithanadi basin when compared to Nethravathi basin with respect to the higher wetting and infiltration rate. Sithanadi is having more vaporization potential when compared to Nethravathi basin which will indicate the higher rate of evapotranspiration capacity due to the large cover of forest. Runoff and baseflow coefficients are higher in the case of Nethravathi basin which will be attributed to the higher surface and sub-surface drainage capacity of the basin. The higher baseflow coefficient implies that lower capacity of recharge of groundwater aquifer. Finally one can say that Sithanadi basin is better in groundwater resources and Nethravathi basin is better in surface water yield.

The calibrated model parameters of catchment water balance model has been compared with basin area, drainage density, basin relief, basin slope, infiltration rate, vegetation cover and normal rainfall of the basin and is presented in the table 4.1.0 to 4.6.0. It is noticed that the basin area is not having any correlation with model parameters. However, the drainage density and stream frequency of the basin clearly indicates that the higher the density, lower the wetting potential. It shows that the higher drainage density basin will be able to drain out the higher magnitude of surface flow and there by lower possibility wetting. Sithanadi is having lower basin relief than the Netravathi which is also a indication of higher wetting and infiltration rate in the Sithanadi basin. Infiltration rate of Sithandi is more than the Netravathi which will contribute in the higher wetting potential of the basin. The vegetation cover in the Sithanadi basin is 69.2 per cent and in Nethravathi is 30.0 per cent. The higher percentage of vegetation cover may increase the wetting capacity of the area and increase the vaporization potential. From the results it shows that the higher the annual rainfall higher in wetting potential.

Table 4.1.0. Relationship of Basin Area and CWB Model Parameters

Sl. No.	Name of the Basin	Basin Area (Km^2)	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	338	3448	0.30	1823	0.15
2	Netravathi	3180	1838	0.33	601	0.36

Table 4.2.0. Relationship of Drainage Density and CWB Model Parameters

Sl. No.	Name of the Basin	Drainage Density	W_p (mm)	λ_s	V_p (mm)	λ_s
1	Sithanadi	1.79	3448	0.30	1823	0.15
2	Netravathi	2.06	1838	0.33	601	0.36

Table 4.3.0. Relationship of Total Basin Relief and CWB Model Parameters

Sl. No.	Name of the Basin	Total Basin Relief	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	1150	3448	0.30	1823	0.15
2	Netravathi	1680	1838	0.33	601	0.36

Table 4.4.0. Relationship of Infiltration and CWB Model Parameters

Sl. No.	Name of the Basin	Infiltration	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	9.9	3448	0.30	1823	0.15
2	Netravathi	4.4	1838	0.33	601	0.36

Table 4.5.0. Relationship of Vegetation Cover(in per cent) and CWB Model Parameters

Sl. No.	Name of the Basin	Vegetation cover	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	69.2	3448	0.30	1823	0.15
2	Netravathi	30.0	1838	0.33	601	0.36

Table 4.6.0. Relationship of Annual Rainfall and CWB Model Parameters

Sl. No.	Name of the Basin	Total Rainfall	W_p (mm)	λ_s	V_p (mm)	λ_u
1	Sithanadi	5533	3448	0.30	1823	0.15
2	Netravathi	4046	1838	0.33	601	0.36

The runoff coefficients of Sitanadi basin varies from 0.23 to 0.84 which is also a indication that the higher side of total runoff from the basin. Nethravathi basin is having runoff coefficients from 0.54 to .93 which is higher than the Sithandi basin. This is a clear inference that about 90 per cent of the precipitation will drain out from the basin at the higher annual rainfall(8000mm).

Geomorphological parameters for both the basins have been analysed for the movement of water and thereby the effect on volume of runoff is studied. The drainage density of Sithanadi is 1.79 where as in case of Nethravathi is 2.06. Likewise, stream frequency of Nethravathi is higher than Sithanadi basin. The higher the stream frequency and drainage density will facilitate better surface drainage capability. It has been reflected in the observed hydrograph as well as in the simulated water balance components by the catchment water balance model. Basin relief of Sithanadi is lower than Netravathi basin which may be attributed to lower surface runoff from the basin. Relief ratio and relative relief are in the same order for both of the catchments.

The land use pattern of the study area from the data indicating that three different geomorphic provinces in the area have different land utilisation patterns. The eastern most region is mostly covered by forest and no agriculture, while the mid land region supports agriculture in patches depending upon the availability of water and soil suitability. The agricultural activity and density of population increase towards western portion and reaches its maximum in the coastal alluvial region.

The lateritic soils occur on gently undulating to hilly topography. The laterite mass is compact to vesicular honey combed structure. These soils are well drained with high permeability.

Red loamy soils occur on hilly to undulating land scape of granite and gneisses. The soils are moderately deep to very deep. These soils are well drained with moderate permeability.

Coastal alluvial soils are constituted of washed down materials from the western ghat and and by the action of Arabian sea(NWDA, 1993)These soils are deep to very deep and sandy loam in texture. The soils of the the area which indicates that infiltration rate and permeability are moderate to high in nature.

From the result of infiltration tests, it is observed that highest infiltration rates are observed in cultivated lateritic bed soils and also in sandy soils. Infiltration rates varies from 0.9cm/hr to 27.57cm/hr. Hence the most of the area is covered by red and lateritic soil in which infiltration rate is very high. It is also noticed that Sithanadi basin has higher infiltration rate as a whole when compared to Nethravathi basin. The higher infiltration rate may attribute to higher wetting and lower surface runoff.

Suggestions

The investigations carried out for one southern most basin of Dakshina Kannada district and one more from northern part of the district. The study revealed that most of the the study area has crystalline as basement rock which are overlaid by laterite and coastal alluvium beds. In addition to this, study area consists of lofty hills and ridges. Due to this uneven terrain, steep gradients, porous nature of lateritic soil and high evaporation loss due longer period of sunshine hours, surface reservoirs are not feasible for storing water. The higher permeability rate of lateritic soil and lower soil retention capacity and steep gradient of water table influencing in higher baseflow condition of the area.

It is also noticed from the study that land use pattern has influenced the hydrological regime through high surface runoff during the monsoon season and decline in groundwater level during non-monsoon season.

In conclusion, both the study areas in align with biogeographical hydrolgical features which influencing the almost same pattern of surface and subsurface flow process in the study areas.

To improve the recharge condition, structures like vented dams, temporary bunds and surface dykes may be adopted, which will arrest surface water flow and recharge will take place during the dry period.

Sub-surface dykes are recommended to arrest the subsurface flow and improve the groundwater regime for longer period. However, the feasible location has to be investigated for the implementation of above said measures for the effective use of the structures.

To reduce the systematic error in estimation of mean precipitation, the close network of rain gauges recommended as there is a large variation in the spatial distribution of the rainfall.

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