

**TECHNOFEASIBILITY OF ON FARM RESERVOIRS IN  
BHILWARA DISTRICT**

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By

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**THESIS**

**MASTER OF ENGINEERING**

**IN**

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This is to certify that this thesis entitled “**Techonofeasibility of on farm reservoirs in Bhilwara district**” submitted for the degree of **Master of Engineering** in the subject of **Irrigation and Water Management Engineering**, embodies bonafide research work carried out by **Ms. Punam Mhetre**, under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on / /2012.

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## ABSTRACT

Water is an essential resource, to feed the rapid growing population and improving living standards. The pressure on available water resources is increasing and per capita availability is reducing day by day. Water harvesting is a traditional water management technology to insure recurrent droughts and future water scarcity in many arid and semi arid regions of world. Though farmers of the Bhilwara region are using Nadi system for water harvesting, but no scientific study was conducted earlier in this region on Nadi system. Therefore an attempt has been made to conduct study on 'Techno feasibility of on farm reservoirs in Bhilwara district'.

Daily rainfall data for period of 30 years (1981-2010) for Suwana, Shahapura and Baneda Panchayat Samitis was used to analyze the probability distribution using Webull's technique and annual rainfall was recorded for Suwana (69.92 mm) and Baneda (59.97 mm) at 80 per cent probability and Shahapura (147 mm) at 70 per cent probability. The runoff generating capacity of the watershed was estimated by SCS curve number method and found to be 78807.50 m<sup>3</sup> (Suwana), 52095 m<sup>3</sup> (Shahapura) and 55929 m<sup>3</sup> (Baneda).

For Suwana and Baneda Panchayat Samiti polynomial model was found to be good and for Shahapura Panchayat Samiti Logarithmic model was found to be good. Efforts was also made to estimate the capacity of Nadi by topographic survey and following results were obtained; 43247.83 m<sup>3</sup> (Suwana), 15468.26 m<sup>3</sup> (Shahapura) and 15468.26 m<sup>3</sup> (Baneda). In west weir designing crest length of Sidadiyas Nadi should be 0.92 and height should be 0.4 m, length Chalaniya Nadi should be 1.070 m and height should be 0.3 m and length Baran Nadi should be 0.89 m and height should be 0.3 m. Results revealed that at the three selected Nadis are under designed. Thus capacity of traditional Nadis can be increased to store available runoff in the Nadis. In embankment designing required height of embankment for Sidadiyas, Chalaniya and Baran should be 4.25 m, 5.50 m and 3.67 m respectively. Benefit cost ratio was found to be 2.51:1 (Suwana Panchayat Samiti), 2.40:1 (Shahapura Panchayat Samiti) and 2.51:1 (Baneda Panchayat Samiti).

*Key words: Rainfall, Runoff, Benefit cost ratio*

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# I- INTRODUCTION

## 1.1 GENERAL

“Water is life”. Good quality of potable water is global issue, particularly in the developing world. With rapid growing population and improving living standards, the pressure on available water resources is increasing and per capita availability of water resources is reducing day by day. Although risk and uncertainty dominate the lives of most rural inhabitants in the semi-arid regions of the world due to low and erratic distribution of rainfall. Many farmers have been able to make of innovative soil and water management systems, locally adapted crop species, and traditional rainwater harvesting systems. Nadi is traditional technique to collect the rain water in the local conditions of the semi-arid environment. This technique is enabling farmers to generate sustained yields meeting their subsistence needs, despite harsh conditions and low use of external inputs. Part of this performance is linked to the indigenous soil and water conservation systems, but also to the high levels of agro-biodiversity exhibited by traditional agro-ecosystems, which in turn positively influences agro-ecosystem function. Rain water management aimed at assisting rainfed resource-poor farmers in the development of a variety of practical techniques and strategies to enhance production and resiliency in the midst of resource constraints typical of semi-arid environments have also discussed. Many of these efforts used elements of modern science but that build upon traditional knowledge by including farmers in the development process.

The overall national availability of water may not pose a problem in the near future, but there would be a severe shortage of water in many regions of India particularly in the state like Rajasthan. Rajasthan is the largest State in Indian union but it is the driest state in terms of availability of water resources. The annual per capita availability of water in the state is much below ( $857 \text{ m}^3$ ) than the threshold value of  $1700 \text{ m}^3$  considered for water stress conditions. The annual rainfall in the state varies significantly. There is a very rapid and marked decrease in rainfall in west of the Aravlli range, making Western Rajasthan, in the most arid part of India. (Goyal and Kumar,2004)

Surface water resources in arid part of Rajasthan are very poor and majority of population depends on groundwater extraction to meet their essential water requirements. The source of drinking municipal water supply in most part of the arid Rajasthan is mostly

groundwater or borehole based. With frequent droughts and chronic water shortages in many areas, most people pay increasingly high price for water and for the lack of water.

Rainfall exhibits a wide variation in the time and space. The under dependable and erratic rainfall introduces an element of risk which results into uncertainty and instability in crop production in the region. Mid-season and late season, droughts are common features of this region. Therefore, increasing yields and its stability, rainwater harvesting is essential to generate other means to provide small amounts of water at critical stages as life saving irrigation.

In the absence of adequate surface and groundwater resources, rain water plays an important role in the survival and livelihood in arid regions. Rain water appropriately harvested, can be a reliable resource of potable water for domestic purposes. Rain water harvesting is an ancient practice and has been practiced for more than 4000 yrs in many parts of the world. Rain water harvesting is the collection and storage of rain from runoff areas such as fields and other surfaces. It is necessary in areas lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. If collection and storage are designed carefully, it is possible for a family to live for a year in areas with rainfall of 100 mm per year.

## **1.2 RAINWATER HARVESTING**

Rainwater harvesting is broadly defined as the collection and concentration of runoff for productive purposes such as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions (Fentaw et al., 2002; Gould, 1999; Scott, et al; 2001). For agriculture purposes, it is defined as a method for inducing, collecting, storing and conserving local surface runoff in arid and semi-arid regions (Prinz and Singh, 2001). It is an ancient practice and still forms an integral part of many farming systems in the worldwide. The first use of such techniques is believed to have originated in Iraq over 5000 years ago, in the Fertile Crescent, where agriculture once started some 8000BC (Hardan, 1975).

Rain water harvesting systems have the characteristics viz; it is practiced in Arid and Semi-arid regions, where surface runoff often has an intermittent character; it is based on the utilization of runoff and requires a runoff producing area and a runoff receiving area; because of the intermittent nature of runoff events, water storage is an integral part of

the system and it can be done directly in the soil profile or in small reservoirs, tanks and aquifers (Oweis et al., 1999). The aim of the rainwater harvesting is to mitigate the effects of temporal shortages of rain to cover both household needs as well as for productive use. It has been used to improve access to water and sanitation, improve agricultural production and health care thus contributing to poverty alleviation, reverse environmental degradation through reforestation and improved agriculture practice, aid groundwater recharge, empower women in the management of water and other natural resources and address floods and droughts by storing excess water (Oweis et al, 1999 and TWDB, 2006).

Rainwater harvesting means locally collection and storage of rainfall through different technologies, for future use to meet the demands of human consumption or human activities. The art of rainwater harvesting has been practised since the first human settlements. It has been a key entry point in local water management ever since, buffering supplies of rainfall to service the human demand of freshwater. To many water managers, rainwater harvesting is a technique to collect drinking water from rooftops, or to collect irrigation water in rural water tanks. However, rainwater harvesting has much wider perspectives, in particular if it is considered in relation to its role in supporting ecosystem goods and services.

Rainwater harvesting is a way of increasing the provisioning capacity at a specific location. Rainwater harvesting is an ancient technique enjoying a revival in popularity due to the inherent quality of rainwater and interest in reducing consumption of treated water. Rainwater is valued for its purity and softness. It has a nearly neutral pH, and is free from disinfection by-products, salts, minerals, and other natural and man-made contaminants. Plants thrive under irrigation with stored rainwater. Appliances last longer when free from the corrosive or scale effects of hard water. Users with potable systems prefer the superior taste and cleansing properties of rainwater.

Rainwater harvesting is practical only when the volume and frequency of rainfall and size of the catchment surface can generate sufficient water for the intended purpose. Rainwater harvesting is the capturing, diversion, and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and storm water abatement.

Advantages and benefits of rainwater harvesting are numerous (Krishan, 2011). The rain water is free and cost is only for collection and use. The end use of harvested

water is located close to the source, eliminating the need for complex and costly distribution systems. Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies. Rainwater harvesting can reduce the volume of storm water, thereby lessening the impact on erosion and decreasing the load on storm sewers. Decreasing storm water volume also helps keep potential storm water pollutants, such as pesticides, fertilizers, and petroleum products, out of rivers and groundwater.

### **1.3 TRADITIONAL RAIN WATER HARVESTING**

India is a country with very deep historical roots and strong cultural traditions. These are reflected in our social fabric and institutions of community life. Rainwater harvesting has been practiced in India for centuries and traditional system of rain water harvesting proved more successful. Water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of world.

The problem of water shortage in arid and semi-arid regions is due to low rainfall and uneven distribution throughout the season, which makes rainfed agriculture a risky enterprise. Therefore new interest came up in recent decades to evaluate traditional water management techniques (Prinz and Singh, 1999) most of them being simple, sure to implement and of low capital investment. The classical sources of irrigation water are often at the break of overuse and therefore untapped sources of (irrigation) water have to be sought for increasing agricultural productivity and providing sustained economic base. Water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of world.

Farmers in this region using traditional method (Nadi) for rain water harvesting. Nadis are village ponds used for storing water from an adjoining natural catchment during the rainy season. A Nadi is essentially a natural surface depression. Some have stone walls built for extra storage and for water retention. Most villages in Rajasthan have their own Nadi and the site of Nadi is selected by the villagers based on the available natural catchment and its water yield potential. Water availability from a Nadi would range from two months to a year after the rains. The location of a Nadi had a strong bearing on its storage capacity due to the related catchment and runoff characteristics. Nadis were heavily relied on for human and livestock needs.

## **1.4 JUSTIFICATION**

The present day world is increasingly turning into a water scarce world. It has been estimated that 1.4 billion people in the world will face absolute water scarcity and another 1.3 billion people will face water scarcity due to economic disabilities or sectoral imbalances by the year 2025.

As 80 percent of global and 86 percent of developing country water consumption is in agriculture. Thus, water availability will have enormous effect on world food production. By 2025, global population will increase to 79 billion, out of which 80 percent population will live in the present developing countries. Projected increase in cereal food demand between 1995 and 2025 would be 46 percent globally, and 65 percent for developing countries. Agricultural development rests heavily on the management of natural resources, which have to be utilized optimally to obtain food, nutrition and environmental security for the future generation. India receives adequate amount of rainfall annually through four different types of weather phenomena- southwest monsoon (74%), northeast monsoon (3%), pre-monsoon (13%) and post monsoon (10%). The distribution in time and space is erratic thus limiting the length of crop growing periods or the occurrence of floods. Rainfall is one of the most important natural resources for human beings. According to National commission on Agriculture (1971) irrigation could not be provided to more than 40% of cultivable land area in India even with utilization of all available water resources in the form of major and medium irrigation projects/ schemes. The remaining 60% of cultivable land area shall remain dependent on available monsoon rains as source of water for crops. Therefore, water has to be used and recycled most efficiently to produce adequate quantity of food, fodder, fruits, fuel and fiber to meet the ever increasing demand of nation and to bring stability in agriculture production.

India has about 47 million ha of dry lands out of 108 million ha of total rainfed area. Dry land contributes 42% of total food grain production of country. These areas produce 75% of pulses and more than 90% of sorghum, millet, groundnut and pulses from arid and semiarid regions. Thus dry lands and rainfed will continue to play a dominant role in Indian agriculture.

Rajasthan is the largest state in India covering an area of 34.22 million hectares, i.e., 10.5 percent of the country's geographical area, but sharing only 1.15 percent of its water resources. In the last 50 years, a threefold increase in the human population and a doubling of the livestock populations have put tremendous pressure on the fragile water

and land resources of Rajasthan. Recurring and prolonged droughts, particularly in the western arid part of the state, is a common climatic feature leading water shortages. The estimated annual, per capita water availability in the state during 2001 was 840 m<sup>3</sup> and it is expected to be 439 m<sup>3</sup> by the year 2050, against the national average of 1,140 m<sup>3</sup> by 2050. Groundwater is overexploited in many districts of the state. The mean annual rainfall of the state is 490 mm with the local averages ranging from 100 mm in the north-western part of Jaisalmer to over 1,000 mm in Jhalawar. Arid or semi-arid areas occupy 60-75 percent of the state. Droughts of varying intensity, particularly in the western part, are a recurring phenomenon. During 1901-2003, Western Rajasthan experienced 20 moderate droughts (with 50% to 75% of the normal annual rainfall) and 10 severe droughts (rainfall below 50% of the normal) compared to 14 moderate and 5 severe droughts in eastern Rajasthan.

Bhilwara district is lying under the South Western part of Rajasthan. Average rainfall of Bhilwara district is 610 mm with 29 rainy days in the last 10 years. The minimum(295.8 mm) and maximum rainfall(1051.0 mm) is received in the year 2002 and 1994, respectively. In Bhilwara, agriculture is primarily rain dependent. Every year its fate oscillates with the quantity, onset, progress and spatial distribution of rainfall. A small deviation from the normal rainfall promote drought like conditions. As a result, rainfed crops subjected often-optimal moisture availability stress. Thus, failure of monsoon in an area, where more than two-third of the area under cultivation is rainfed and where irrigation system is largely poor and insufficient, often leads critical fall in employment, food, fodder and drinking water for both human and cattle. Drought is an inevitable phenomenon in rainfed farming and the latest drought in 2009 was an eye opener for scientists, planners and administration on the urgent need to evolve both short and long term strategies for drought mitigation in the state as well as in the country.

Recent studies have shown that the crop production can be increased substantially by providing one or two life saving irrigation during dry spells by harvesting surplus water flowing out as runoff during monsoon periods. This calls for water harvesting and recycling techniques.

Though the farmers of the region using Nadi system for water harvesting, but no scientific study was conducted earlier in this region on Nadi system. Therefore, study on water harvesting and recycling through Nadi is planned with the following specific reasons:

- The yield is unstable due to erratic nature of rainfall and dry spell.

- Recurrent drought in the region as well as in the state.
- There is no feasibility of deep tube wells in the region due to hard rock area, only open dug wells feasible but due to the recurrent drought, the water table is lowered and quality of groundwater is deteriorated.
- The rainfall area is mono cropped in the region.
- Farmers construct Nadi with their own wisdom and without any technical skills and its design is based on experience.
- It is low cost technique of water harvesting, recycling system in which water is recycled when dry spells occur and water storage area may be used for Nadi bed cultivation when it is emptied. It also helps in recharge groundwater which improves ground water quality.

Dry lands are areas with limited water resources. Rainfall is scarce, unreliable and concentrated during a short rainy season with the remaining period tending to be relatively or absolutely dry. High temperatures during the rainy season cause much of the rainfall to be lost through evaporation, and the intensity of storms ensures that much of it runs off in floods. Aridity and variability are two dominant characteristics of dry land climate and several classifications based on aridity have been developed. It is apparent that the FAO and UNEP approaches and classifications produce divergent assessments of the range and extent of dry lands throughout the world.

Dry lands pose great constraints to crop production. Yields vary enormously from year to year, and crops frequently fail. Soil fertility, weed infestation and pest incidence fluctuate from place to place. Generally, efforts towards improving dry land farming have focused on the following aspects; (i) Soil and water management through conservation tillage; (ii) Water harvesting and storage for domestic use, livestock, and crop farming; (iii) Micro-management of soil fertility through manuring, composting, mulching; and, (iv) Production of high value market crops under irrigation where the potential exists.

With prevailing monsoon type of rainfall in the region. Water harvesting and recycling seems to be the ideal solution to exploit full production potential and regional imbalance in agricultural production as well as for artificial groundwater recharge.

### **1.5 OBJECTIVES:**

The present study was planned with the following objectives:

- (i) Probability analysis of rainfall data & determine design capacity of on farm reservoir (Nadi) under different rainfall situations,

- (ii) Validation of the existing on farm reservoirs (Nadies) with technically design capacity and dimension, and
- (iii) To determine the benefit cost ratio of on farm reservoirs (Nadies) under different practice for use of harvested water.

## **II- REVIEW OF LITERATURE**

Traditional water harvesting structure (Nadi) is an important on farm water resource management technique in the drought prone area of Rajasthan. It has been used to harvest the runoff water during rainy season may be recycled during the dry spell period in kharif season or to raise Rabi crops in the region. The Nadi bed may also be used to raise Rabi crops on conserved moisture after emptying the Nadi. However this water harvesting structure was constructed by the farmers with experience and knowledge. In order to design a Nadi, rainfall analysis, extent of use of Nadi in drought prone area, is presented in subsequent section of this chapter.

### **2.1 PROBABILITY ANALYSIS**

Rainfall is an important factor that decides the severity of drought in a particular region. The schedule of irrigation of a crop in rainfed farming region is decided by the intermittent drought period during the monsoon season. Water conservation techniques such as rainfall harvesting, runoff agriculture, rainfall cistern system are rainfall dependent. Hence in order to use these techniques, it is necessary to have detailed information on rainfall amount, duration and intensity for drought. Past records of rainfall can be used to predict future trends of rainfall occurrence in rainfed farming areas. This will help in planning various other measures for water conservation. The amount of recharge due to rainfall will help in estimating groundwater resources and their development prospects. The runoff relationship will be important for implying techniques like water harvesting and runoff agriculture.

Sharma *et al.* (1979) studied on probability analysis of rainfall for crop planning. The rainfall data of 17 years (1961-77) of Pantanagar located in Nainital Tarai region, has been statistically analysed. Weekly data of rainfall was found to be more useful for planning of cropping programme as well water management practices than monthly, seasonal or annual data, 80%, 50% and 10% chance rainfall in a week, normal, drought and abnormal months and yearly drought estimation have been presented.

Senapati and Sharma (1979) conducted research on probability analysis of annual rainfall data at Bhubaneswar, Orissa. The annual maximum daily total rainfall data of 30 years (from 1949-1978) for the station, Bhubaneswar, Orissa have been collected and analysed. The frequency curves of annual maximum rainfall data have been plotted using two different theoretical probability distributions.

Bhattacharya and Sarkar (1982) studied analysis of rainfall data for agricultural land drainage design. Daily rainfall data for period of forty years (1931-1970) were collected from hoshangabad weather station in Madhya Pradesh. Rainfall for the month of June, July, August and September were analyzed to determine 1, 2, 3, 4 and 5 consecutive days rainfall at 5 years recurrence interval and the number of years of data required to be analyzed such that the predicted 5 years value can be expected to be within a pre-selected range of deviation from the true mean. It was observed that a length of record varying between 15 to 30 years will be required to have a reasonable confidence on the predicted 5- year rainfall value. The deviations of the true mean were between  $\pm 10$  and  $\pm 5$  for 15 years of record, respectively.

Agarwal *et al.* (1984) studied probability of sequences of wet and dry days in NainitalTari region. Probability of various sequences of wet and dry days may be used to

determine the probable economic gains or losses for many agricultural and non-agricultural activities. Rainfall data for the years 1960-1981; were analyzed by using Markov chain probability model and sequences of wet and dry days are presented for condition of Nainital Tari region.

Agarwal *et al.* (1988) studied probability analysis of annual maximum daily rainfall of U. P. Himalaya. Design Engineers and hydrologist require maximum daily rainfall of different return periods for economic planning and design of small and medium hydraulic structures such as dams, bridges and culverts etc. To fulfil their need PA of one day maximum rainfall data have been done using 60 years rainfall records of 25 stations comprising of six hill districts of U. P. Himalayas. The three probability distribution functions, which are widely used in hydrology viz. Gumbel distribution, Log normal distributions and Log Pearson type III distribution have been compared with observed data. Log Pearson type III distribution gave the closet fit to the observed data Pearson type III distribution is used to worked out one day maximum rainfall for various return periods for all the 25 stations.

Weerasinghe (1989) studied rainfall probability analysis of mapalana and its application to agricultural production of the area. Daily rainfall of mapalana metrological station for 35 consecutive years were analysed for the Markov chain probabilities for weekly rainfall and the rainfall availability of the location is assessed in relation to rice agronomy for both Yala and Maha seasons. It was revealed that rainfall probability of greater than 10 mm at 75 % probability level and the moisture availability index of greater than 0.5 as good indicators to select the cropping cycles of both seasons.

Singh *et al.* (1992) studied consecutive day rainfall prediction from one day rainfall. Consecutive day rainfall totals are required for the estimation of design drainage coefficient for crops of tolerance against excess water condition of more than a day. In the present study, long-term monsoon season daily rainfall data of 16 rain gauge station in Karia district of Gujrat were used to investigated the predictability of various consecutive day rainfall from one day rainfall of 1-20 years recurrence interval (RI). Appropriate statistical tests were performed to test the agreement between the predicted and observed rainfall of various consecutive days. The study indicated that the rainfall totals of 2-6 consecutive days can be predicted with a reasonable accuracy from the known values of 1-day rainfall.

Kumar (1995) analyzed runoff estimation using Antecedent Rainfall probability. The daily rainfall data of 28 years recorded at Pantanagar were analyzed to calculate 5

days antecedent rainfall preceding the storm. The observed value of 5 days antecedent rainfall calculated by Weibull's formula and expected values computed by different distributions were compared at 1.25, 5, 10, 100 and 1000 years recurrence intervals. The chi-square test resulted that fit to of all the distributions were good at 1 and 5 % levels of significance. The average percentage deviation of computed values from of observed ones was found to be minimum in case of pearson type I distribution and therefore, it was used to calculate the days antecedent rainfall required for the estimation of runoff using Curve Number Method.

Chakraborty (1998) analyzed rainfall data of 10 years (1983-1992) at regional research station, Kakdwip (West Bengal). He used Weibull's method for analysis of rainfall data and worked out computed rainfall amounts at different return periods.

Singh (1998) analyzed rainfall data of 25 years (1971-1995) on probability basis for Udaipur, Bhilwara and Banswara district of Rajasthan to find out the functional utility of Anicut. Results revealed that 75 percent dependable rainfall for normal curve for Udaipur, Bhilwara and Banswara are 75 mm, 145 mm and 180 mm respectively while for fitted curve these are 80 mm, 150 mm, respectively. These results showed that 75 percent dependable rainfall for Banswara is much greater than that for Udaipur.

Updhayaya and Singh (1998) analyzed consecutive days maximum rainfall by various methods and their comparison. Two to six consecutive days maximum rainfall corresponding to return period varying from 2 to 20 years and crop tolerance period, help in determination of drainage coefficient for agricultural fields. Various probability distributions and transformations can be applied to estimate the one day as well as consecutive days maximum rainfall of various return periods. In this paper, relative performance of seven probability distributions. And one step power transmission technique with respect to Gringorten's plotting position method applied to estimate 1 day as well as 2 to 6 consecutive days maximum rainfall at Bhubaneswar has been studied; to understand the behaviour of these distributions and transformation; and to assess the reliability of design rainfall corresponding to various return periods. Analysis shows that for 1 day maximum rainfall, one step power transmission gives the best coefficient of determination and can predict values closer to the values obtained by Gringoren's plotting position method, while for 2 to 6 consecutive days maximum rainfall, log extreme value 1 shows the best coefficient of determination and predicts the values closer to the values given by Gringgorten's plotting position method. Results also show that in most of the cases, for a return period of 2 to 10 years Gringgorten's plotting position method gives the

lowest values of 1 day and consecutive days maximum rainfall, whereas for the return periods of 15 and 20 years it gives the highest values of 1 day and consecutive day maximum rainfall.

Vishwakarma *et al.* (1999) studied probability analysis of rainfall at chhindwara (M.P.) Daily rainfall data for period of 24 years (1975-98) were collected from the Regional Research Station, Chandangaon chhindwara, campus of JNKVV, Jabalpur and analyzed to estimate the expected rainfall at different probability levels. The data was divided into three seasons, i.e. from mid of the June to mid of the October, mid of October to mid of March and mid of March to mid of June. Weibull method was used to work out the rainfall at different probabilities for levels daily, monthly and seasonal and annual rainfall.

Kumar *et al.* (2000) analyzed daily rainfall data (1977-1985) of Rani Chauri, on using Weibull's formula, log Pearson type III distribution and log normal distribution at different probability levels. He used Chi-square test of goodness of fit and found that log-normal distribution gave closet fit to the observed values.

Rizvi (2001) analyzed probability of annual maximum daily rainfall for Bundelkhand region Of uttarpradesh, India. Daily rainfall data of Jhansi was collected from 1961-1996 one day maximum rainfall was taken for the purpose of study. Log-Pearson type III, Log normal, Gumbeldistribution were used for analysis. Comparison of the probability distribution to find out the goodness of fit to observed values has been done by using chi-square test of goodness fit.

Panighari and Panda (2001) studied analysis of rainfall for crop planning in rain fed region. Probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning in rain fed regions. In the personal study, power transformation is used to normalize the weekly rainfall data and then normal distribution is used to predict the minimum assured rainfall at different probability of exceedance in all weeks of the whole year. In addition, probability of occurrence of different amount of rainfall in various weeks has been estimated. The study reveals that chances of drought and there is a scope for in-situ moisture conservation and runoff collection in tanks for supplemental irrigation.

Kumar (2003) analyzed frequency analysis of consecutive days maximum rainfall at Sainagar (J & K). Daily rainfall data recorded at Serinagar station are used in this analysis. The daily data in particular year, is converted in this analysis. The daily data in particular year is converted 2 to 5 days consecutive days rainfall by summing up the

rainfall of corresponding previous day. The maximum amount of 1 day and 2-5 days consecutive days rainfall for each year was then taken for analysis. Following statistical distribution were used in the analysis.(1) normal (2) Log-Normal(3) Pearson Type III(4) Log-Pearson Type III (5)Extreme Value Type I. All five probability distribution functions were compared by chi square Test of goodness of fit. The computed chi square values for three probability distribution i.e. log normal were found to be less than the critical value of chi square at 95 % confidence level for 1 day as well as consecutive days maximum rainfall series. Log normal distribution gave maximum value of  $\chi^2$  for annual 1 day, 4 day and 5 days consecutive maximum rainfall, whereas Pearson type III for 2 and 3 days.

Jat *et al.* (2005) A analysed weekly rainfall data for crop planning in Udaipur region. Results revealed that probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning in rain fed regions. Incomplete gamma distribution is used to predict the minimum assured rainfall at different probability of exceedence in all weeks of the whole year. The study revealed that chances of drought are more at critical stages of maize and there is a scope for in-situ moisture conservation and runoff collection in tanks for supplemental irrigation. Rabi crops are found to be grown under moisture stress.

Dingre and Atre (2005) conducted research on probability analysis for prediction of annual maximum daily rainfall of Shrinagar region. Probability analysis can be used for predicting the occurrence of rainfall events from the available data with the help of statistical methods (Kumar and Kumar 1989). An attempt has been made to find out annual maximum one day rainfall values using log Pearson type III, log normal and Gumbel distribution for various return periods for Shrinagar district of Jammu and Kashmir. The study reveals that log normal distribution is best distribution for predicting the maximum daily rainfall of Shrinagar. Hence appropriate planning and hydrologic design of oil conservation and drainage structures in Shrinagar region of Kashmir valley can be effectively carried out on the basis of predicted valued of annual maximum rainfall using log normal distribution.

Sethy *et al.* (2005) studied frequency analysis for one day to five consecutive days annual maximum rainfall for South-Eastern Rajasthan. Design engineers and hydrologist require annual one day and two to five consecutive days maximum rainfall data corresponding to return period varying from 2 to 100 years and crop tolerance period that help in economic planning, design of small and medium hydraulic structures and determination of drainage coefficient for agricultural fields. Various probability

distribution and transformations can be applied to estimate the one-day as well as consecutive days-annual maximum rainfall of various return periods. Five commonly used probability distribution functions (viz. Normal, Log-normal, Extreme value type-I, Pearson Type-III and Log Pearson Type-III) were tested by comparing the chi-square values. 2 parameters log normal distribution was found to be the best fit frequency distribution function for the region. Simple regression models were developed for one day as well as 2 to 5- consecutive days annual maximum rainfall for the region. Their's U-static indicated that consecutive days annual maximum rainfall model estimate was not statistically different from a 2-parameters lognormal estimate.

Dinghare and Sahi (2006) analyzed consecutive days maximum rainfall to predict 1 day maximum rainfall for Shrinagar in Kashmir Vally. The rainfall data of Shrinagar region were procured to investigate the predictability of various consecutive days rainfall from 1 day rainfall of 1-20 years return period. The Chi-square test was performed to test the agreement between the predicted and observed rainfall of various consecutive days. The analysis showed that 2 to 6 consecutive days maximum rainfall of 2 to 20 years return period can be predicted with a reasonable accuracy with the help of 1 day maximum rainfall to the same return period at Srinagar region of Kashmir Vally.

Babu *et al.* (2006) studied probability Analysis of rainfall of Bankura for design of soil and water conservation structures. Daily rainfall data of 21 years (from 1983-2003) for Bankura district of west Bengal were analyzed to ascertain their fit to several probability distributions. The series generated by Weibull's plotting position formula was treated as the observed series. The expected values were estimated by Gumbel, Log Pearson type III and Log Normal probability distribution functions. The goodness of fit was determined by  $\chi^2$  test. Linear probability model was also developed using the parameter frequency factor for the best distribution. The analysis indicated that Log Pearson type III gave the closest fit to the observed data and it is recommended to forecast the annual maximum I-day day rainfall for the design return period. The theoretical annual maximum day rainfall values using log Pearson type III for 5,10,15, 25 and 50 years return period were 116,155,165,185 and 207 mm respectively. The expected 1-day maximum rainfall values for the desired return period could be used for hydrological design of different soil and water conservation structures in watershed development projects being implemented under different programme in Bankura district. In this paper, the usefulness of predicted annual maximum 1-day rainfall for the desired return period has been verified

in the design of a masonry check dam in Kashibedia micro-watershed, which is located at Bankura district.

Machiwal *et al.* (2006) analyzed consecutive day's maximum rainfall of Kharagpur, India using probabilistic approach. In this paper, one-day maximum rainfall and consecutive 2,3,4,5 and 6 day maximum rainfalls of Kharagpur, West Bengal, India forecasted probabilistically for selected return periods. These maximum rainfall series were subjected to preliminary hydrologic analyses using box plots and normal probability plots. Thereafter, one-day maximum rainfall was correlated with the consecutive day's maximum rainfalls using four types of regression models. Furthermore, nine probability distributions were fitted to each of the above mentioned maximum rainfall series, and the Chi-square and Kolmogorov-Smirnov tests were employed for selecting a best-fit distribution for each maximum rainfall series. Based on the estimated parameters of the best-fit distributions, the maximum rainfalls of different periods were forecasted for the return periods of 1.33, 2,3, 4,5,10,15,20 and 30 years, and the forecasted results were verified for some return periods. The preliminary hydrologic analyses revealed that the maximum rainfall time series becomes more uniform in distribution by increasing the number of consecutive days. The result of the regression analyses indicated that any one of the four types of regression models could be used for estimating consecutive days maximum rainfall from the one-day maximum rainfall of Kharagpur. However, the linear regression model was selected as best-fit in this study and a general linear relationship for the Karagpur region was developed to compute/ predict different consecutive days maximum rainfalls from one-day maximum rainfall. The results of the goodness-of-fit tests indicated that Pearson type V is the overall best-fit probability distribution for the one-day maximum rainfall and consecutive 2,3,4,5 and 6 day maximum rainfall series of Kharagpur. The forecasted maximum rainfalls for the selected return periods were found to be reliable.

Mishra *et al.* (2006) studied application of probability analysis of rainfall for design of continuous contour trenches, contour trenches, contour bunds and west weirs in Bankura. Continuous contour trenches (CCTs) along with pasture/ afforestation on barrain bunding along with a forestation as land use in west lands or the most popular soil and water conservation measures adopted in different watershed development project implement in Bank district of west Bengal. The results of probability analysis of rainfall of Bankura can be effectively applied for the better design of these measures. In the present study, the predicted 1 day maximum rainfall for the desired return period using best fit

Log Pearson type-III probability distribution for better design of CCTs on a barren hillock, covering an area of about 10 ha and contour bund and west weir system in water land covering.

Patel (2008) studied probability analysis of consecutive days annual rainfall for the design of surface drains in semi arid areas of Maharashtra. Daily rainfall data of 25 years (1974-19998) were analysed to ascertain one to four consecutive days maximum rainfall of Akola(M.S). The observed value estimated by Webull's plotting position and expected values estimated by three well known probability distribution functions viz Gumbel, Lognormal and log Pearson type III. The expected values calculated out by three probability distributions were compared with observed values worked out by Webull's method and goodness of fit were determined by Chi-square test. The frequency analysis indicated that Lognormal distribution gives the closet fit to the observed data to forecast 1-day annual maximum rainfall. Study further revealed that incase of two, three and four consecutive days maximum rainfall for different return periods, Lognormal distribution gave the closest fit to the observed data. The probability analysis of one to four consecutive days maximum rainfall for different return periods will useful for design of surface drains and other hydraulic structure of semi arid region of the district having predominantly clayey soils.

Jakhar *et al.* (2011) studied probability analysis of rainfall characteristics of semiliguda in Karaput, Orissa. The knowledge of probable period of onset of rainfall and its distribution over the cropping season are important for finely seedbed preparation, selection of crop varieties and choice of cropping pattern. The probability analysis of rainfall data revealed that the onset of monsoon is on 11<sup>th</sup> June. The probability distribution of seasonal rainfall indicated that the occurrence of 75% probable rainfall in Kharif, summer and rabi season are 1095.5 mm, 19.4 mm and 83 mm respectively whereas 1274.5 mm is the annual rainfall. It was forecasted that the occurrence of rainy days (72.5 mm rainfall per day) is 70 days per annum.

Machiwal *et al.* (2011) conducted research on modeling daily runoff and probabilistic estimation of design maximum daily runoff from selected watersheds of Udaipur, Rajasthan. In this study, one-day maximum and consecutive 2 and 3- day maximum runoff were computed for eight watersheds of udaipur, Rajasthan. Of the eight watersheds, six are interconnected and two are independent. Daily runoff was estimated for 30-year period by using soil Conservation Service Curve Number(SCS-CN) model. The SCS-CN model was validated for one-day maximum runoff from Bari, Chhota Madar,

Lakhawali, Fatehsagar and Udaisagar watershed is log Pearson type III. Whereas, Gumbel is the best-fit distribution for rest of the watersheds. For 2 and 3- day maximum runoff, either Gumbel or log Pearson type III distributions were the best-fit except log normal for 3-days maximum runoff from Lakhawali. Finally, 1, 2 and 3-day maximum runoff was estimated at return periods of 1.05, 1.11, 1.25, 2.5, 10, 15, and 30 years.

Pradeep *et al.* (2012) conducted research on probability models for prediction of rainfall at Solapur, Maharashtra. The analysis indicated that the normal (0.17), log normal (0.19) and log Pearson type III (0.19) distributions were best fitted for the maximum one day rainfall with minimum D-Index values. Pearson type III distribution was best fit for the maximum weekly, monthly, seasonal (kharif) and annual rainfall but the distribution was unfit for the seasons of rabi and zaid. From the result, it is concluded that exponential distribution is not fit for the study area.

## **2.2 DESIGN OF WATER HARVESTING STRUCTURE**

The meaning of the term “water harvesting” is clear and well defined but perhaps its origin is not so well known. Probably it was first used in 1963 by Geddes of the University of Sydney in Australia. Geddes (1963) defined water harvesting as the collection and storage of any farm water, either runoff or crack flows for irrigation use (Singh and Chauhan, 1980). Later on several modifications of the definition have broadened its meaning which includes the process of collecting natural Precipitation from prepared watersheds. The potential of water harvesting may be estimated by pointing out that 1 mm of rain equals 10000 litres of water per hectare. It becomes apparent a small area of impermeable surface can collect a relatively large volume of water.

The infrequent rain in semi-arid region if harvested over a large area, can yield considerable amount of water. Rain water harvesting is particularly suited to supply water for small villages, schools, households, small gardens, livestock, wild life and runoff agriculture.

Generally, rain water harvesting is possible in areas with as little as 50-80 mm average annual rainfall. However, in Israel, a water harvesting catchment receiving only 24 mm of rain annually yielded an usable runoff (Anonymus, 1974).

Water harvesting practices in different forms were prevalent in India during ancient times. A lot of references of such systems are available in *Vedas* and other ancient scriptures. These systems have undergone continuous refinements and modifications over

a period of time on the basis of location, specific objectives and requirements of the people. *Rigveda* mentioned a lot regarding the judicious and rational use of water from wells, tanks and canals for irrigation, domestic and other purposes. In *Arthashastra*, Kutilaya entrusted the responsibility for construction of dams, reservoirs, wells and ponds to the kings. Bywas regarding orientation of tanks to store and conserve water and protecting them from possible damage have been described in *vraht Sanhita* during 550 A.D.

Kolkar *et al.* (1980) described in brief about water harvesting practices (Khadin and relay cultivation) in arid region of western Rajasthan. They also determined catchment to command area ratio at different locations.

Chittaranjan *et al.* (1981) found that the storing of excess runoff into dug out farm ponds and utilizing the same to overcome moisture stress during the crop growth period help in elevating and stabilizing the crop yield. They also found that the high intensities of rainfall (5-7.5 cm /hr.) Coupled with low intake rate of the soil (0.8 mm/hr.) initiate surface runoff.

Hedge *et al.* (1981) analyzed water harvesting at dry-land research station, Bangalore for water harvesting revealed that about 20- 30 per cent of the annual rainfall as available from the cultivated land for harvesting. The average runoff varied from 7.5 per cent in ridge and furrow methods of cultivation to 33.3 per cent in fallow lands.

Verma *et al.* (1984) conducted study on feasibility of storage runoff in dugout ponds and its use for supplemental irrigation in submantane Punjab. It is possible to collect at least 8-10 cm of runoff.

Gupta *et al.* (1991) reported that chickpea proved the most suitable crop for growing under tank bed situation in Bhilwara.

Pandy and Hiran (1992) earthen embankment reservoir planning for water harvesting- A case study of Vagpura water shed. The paper results that benefit cost ratio of earthen embankment reservoir was 1.38. Hence it can be taken up with government assistance development.

Sasrty and Singh (1993) studied water harvesting, storage and recycling at Debra Doon Results revealed that 16.19 percent of the total monsoon rainfall can be harvested from treated agriculture watershed into pond. The catchment area pond size relationship worked out to be 1.0 ha in lined and unlined farm pond, respectively in Doon valley. Supplement irrigation of 5 cm at pre sowing and CR 1 stage to wheat could be effected to

80, 50 and 25 percent catchment area resulting in grain yield of 3.14, 2.16 ton per ha respectively, compared to control yield of 1.9 ton per ha.

Sharda and Simali (1994) reviewed that water harvesting techniques being adopted under different situations in the northern hilly region with special emphasis on their design, rainfall-runoff relationship and catchment area storage.

Vanghani (1994) analysed small earthen embankment ponds called Nadis which are the principal drinking water sources in the Indian desert. The structure and functioning of this ancient practice is studied in relation with geomorphologic units to design for storage and better utilization of runoff water. The inter relationship between runoff volume and catchment area in different landforms have been explained by regression equation. It is revealed that in buried pediments, the Nadis should be constructed under catchment slope of less than 1 per cent.

Maliwal *et al.* (1995) concluded that under tank bed conditions sowing of wheat in lines with 25 % higher seed rate gave maximum yield and return in climatic situation of Bhilwara. The study was carried out at three study site viz. Dasuya, Indore and kanas for the assumed watershed area of 5 ha to 100 ha at different probability levels of estimated runoff in multiple regression models were developed for the design of water harvesting pond capacities.

Prinz and Singh (1999) studied technological- potential for improvements of water harvesting. The problem of water shortage in arid and semi-arid regions is due to low and uneven distribution of rainfall throughout the season, which makes rain fed agriculture a risky enterprise. Therefore new interest came up in recent decades to evaluate traditional water management techniques most of them being simple, sure to implement and of low capital investment. The classical sources of irrigation water are often at the break of overuse and therefore untapped sources of (irrigation) water have to be sought for increasing agricultural productivity and providing sustained economic base. Water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of world.

Katiyar *et al.*(1999) evaluated impact of water harvesting and recycling in south eastern Rajasthan. In their study three village ponds of South-Eastern Rajasthan were observed and it was found that pond capacity has reduced due to siltation. Recently desilted ponds to be economically viable. One irrigation to wheat, mustard, gram and coriander increased the yield by 64.9, 118.1, 85.8 and 117.5 per cent respectively, over no

irrigation. While two irrigation increased the yield by 130,141.4, 93.3 and 2008.8 per cent respectively, over no irrigation.

Abu-Zreig *et al.* (2000) conducted research on rainfall harvesting using sand ditches in Jordan. Rainfall harvesting in rain-fed agricultural areas increases water availability for plants during the growing season, thus increasing crop production. Rainfall can be stored directly in the soil for crop production using terraces, rippers, contour ridges, and other types of water collection methods. However, the efficiency of these methods is limited by the infiltration characteristics of soil and climatic conditions. In the rain-fed agricultural areas of Northern Jordan soils are predominantly clay having very low infiltration rates. In such cases the depth of water infiltration is very small and water may remain in the upper layer of the soil profile. With high evaporation rates, collected water is lost to the atmosphere very rapidly and is therefore, unavailable for plants.

El-Awar *et al.* (2000) developed a hydro-spatial hierarchical method for siting water harvesting reservoirs in dry areas. Water availability is the main limiting factor in dry-land agriculture throughout arid and semi-arid regions, due to low annual rainfall depth and its non-uniform temporal and spatial distribution. Water harvesting has been used for thousands of years to supplement scarce water resources in dry areas. Surface reservoirs are used to collect and store precipitation surface runoff so that stored water can be used for supplemental irrigation during long dry seasons. Results also shows the flexibility of the method with respect to the criteria used for ranking the candidate sites.

Srivastava (2001) studied the water harvesting on small scale at W.T.C. for eastern region. The tank capacity was 1750 m<sup>3</sup> per ha command area can serve a crop rotation of farm planted rice-groundnut rotation. The benefit cost ratio of this system is around 2.0. The catchment command area ratio should be 3.0 or more.

Shah and Vengama Raju (2001) rethought about rehabilitation: socio-ecology of tanks and water harvesting in Rajasthan, North-West India. In the arid and semi-arid Indian state of Rajasthan, tanks and ponds have been a mainstay of rural communities for centuries. There are over 4600 large minor irrigation tanks, plus numerous johads, bandh sand pals (small water harvesting structures). This paper assesses a strategy proposed for rehabilitating 1200 of the larger tanks. It argues that treating tanks only as flow irrigation systems—which lies at the centre of the main stream thinking on rehabilitating surface irrigation systems—is very likely to resulting a flawed strategy when applied to tanks. Instead, reviewing the successful experience of NGOs like PRADAN and Tarun Bharat Sangh in reviving and rehabilitating clusters of small traditional water harvesting

structures at a watershed level, it posits that Rajasthan's tanks belong more to the watershed development domain than to the irrigation domain and that a strategy that views tanks as multi-use socio-ecological constructs, and which recognizes varied stakeholder groups is more likely to enhance the social value of tanks.

Kanupriya and Mathews (2003) studied application of bottom up participatory strategies and traditional methods of water harvesting in the desert Rajasthan. With the increasing evidence on climate change policy- makers and researchers are searching for ways to cope up with its impacts and consequences. Adaptation is particularly important for developing countries as impacts of climate change will deeply affect the geographical locations of developing countries. They are most vulnerable due to their limited economic capacity as: "the people who will be exposed to the worst of the impacts are the ones least able to cope with the associated risks". The management of water resources will be most troublesome due to the unpredictability of the climate, thereby seriously affecting not only the availability of drinking water but also other sectors such as agriculture, sanitation and health. The vulnerability of the water sector is much worse for most developing countries as their policy frameworks are "less mature, with weaker institutions, and less capable of providing for adaptation to climate change"

Goel and Kumar (2004) studied economic analysis of water harvesting for the catchment at a mountainous watershed in India. Results recreated that benefit/cost ratios varies from 0.41 to 1.33 are obtained for water harvesting structures of different sizes with estimated life of 25 and 40 years respectively, by taking into account different crop return from maize and wheat.

Sharma and Bhattacharya (2005) developed a procedure for the design of water harvesting pond. It is based on rainfall analysis. Runoff estimation by CN method. They worked out design of pond capacity, calculation of expected available water in ponds at various point of time and economic analysis of pond construction and irrigation activities using stored water.

Oweis and Hachum (2005) studied water harvesting and supplemental irrigation for improving water productivity of dry farming systems in west Asia and North Africa. In the dry areas, water, not land, is the most limiting resource for improved agricultural production. Maximizing water productivity, and not yield per unit of land, is therefore a better strategy for dry farming systems. Under such conditions, more efficient water management techniques must be adopted. Supplemental irrigation (SI) is a highly efficient

practice with great potential for increasing agricultural production and improving livelihoods in the dry rain fed areas.

Mahajan *et al.* (2006) studied Rain Water Harvesting: A Viable Solution to Conserve Water. The problem of water shortage in arid and semi-arid regions is one due to low rainfall and uneven distribution throughout the season, which makes rain fed agriculture a risky enterprise. Rain water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of world. The paper discusses the use of water harvesting as an effective tool for water management. The various forms of water harvesting have been elucidated. The common goal of all forms is to secure water supply for annual crops, pastures, trees and animals in dry areas without tapping groundwater or river-water sources. As the appropriate choice of technique depends on the amount of rainfall and its distribution, land topography, soil type and soil depth and local socio-economic factors, these systems tend to be very site specific. The water harvesting methods applied strongly depend on local conditions and include such widely differing practices as bunding, pitting, micro catchments water harvesting, flood water and ground water harvesting.

Bhavsar and Bhalge (2006) studied roof top rain water harvest- a long lasting solution to drive away the need of water tankers. Water has been harvested in India since antiquity. Roof top water harvesting techniques are not new for Indians. Numerous documentary and filed evidences about the water harvesting techniques used by the ancestors exist in India. For general, Maharashtra receives a good amount of annual rainfall. But the Government has to supply drinking water by the water tankers to numerous villages and wadies. Many of the wadies or tandas are situated in remote places. In such cases drinking water cannot be supplied to the thirsty people by tankers or by any other means. The water supplied by the Tankers may not be either pure or sufficient. There is a need to think; 'Is it necessary to supply the drinking water by Tankers?' The answer is 'not in all the cases'. Roof top rainwater is the best solution to solve all the problems discussed above.

Ghani (2006) conducted research on water harvesting and management for increasing agricultural production and household water supply in Bangladesh. Results revealed that, water harvesting has been selected in place of rainwater harvesting intentionally as under Bangladesh context it is not possible to separate water volumes received from these two sources during June to September when the country receives about 90% of total annual water.

Sekar and Randhir (2006) developed a spatially explicit method to evaluate costs of harvesting and potential benefits in water harvesting in the Taunton River Watershed in Eastern Massachusetts, USA. A spatial analysis is used to assess surface storage and groundwater recharge potentials in developed and undeveloped regions of the watershed. Prioritization maps were developed to characterize conjunctive harvesting potential that is based on benefits and costs. The potential harvest areas were clustered in specific locations that satisfy feasibility and economic criteria the model has potential for further extension into complex situations of biophysical and socioeconomic conditions at watershed level.

Patil and Patil (2006) studied rainwater harvesting techniques. Water is our most precious natural resource and something that most of us take for granted. We are now increasingly becoming aware of the importance of water to our survival and its limited supply. The human beings require water for various purposes. The most part of the earth surface i.e. about 71 % is covered by water. Out of total volume of water available on the surface of the earth 97 % is saline water, 2 % water is in the form of ice and glaciers and only 1 % is fresh and potable water. India is well endowed nations in the world in terms of average annual rainfall. It is unbelievable but it is true that Cherapunji which gets 11000 mm annual rainfall still suffers from serious drinking water shortage. Though India's average annual rainfall is 1170 mm; in the deserts of western India it is as low as about 100 mm. Hence, it is necessary to opt for rainwater harvesting measures for fulfilment of water requirement.

Nagaraj *et al.* (2006) studied the impact of water harvesting on groundwater recharge, Productivity and net returns with integrated farming systems approach In Eastern Dry Zone Of Karnataka, results revealed that water harvesting structures have facilitated the rejuvenation of failed wells and enhanced the water yield. About 75% of the failed bore wells were rejuvenated as against 66% in the non-watershed. The yield of bore wells was increased by 21% in the watershed whereas in non-watershed area the water yield has reduced by 11%. Investment analysis of water harvesting structures indicated that for every rupee of present investment on water harvesting structure there is a return of Rs. 2.79 in farm pond and Rs. 2.19 in recharge pits. Further, productivity of crops has enhanced through protective irrigation given at critical stages of crop growth and moisture conservation, which in turn increased the net returns of the farmer.

Frot *et al.* (2008) conducted research on water harvesting potential in function of hill slope characteristics: A case study from the Sierra de Gador. Surface water in

limestone and dolomite mountain ranges in semi-arid regions is very rare. Therefore, water harvesting systems, collecting the runoff from hill slopes, can be found at regular distances to supply water points for grazing animals. Multiple logistic regressions showed that the rainfall depth per event and the antecedent precipitation index over 20 days (API20) are the main parameters to explain the occurrence of runoff in the reservoirs connected to the four catchments. The hill slopes show a systematic pattern of rock outcrops on the crest and shoulders to a colluvial mantle at the foot slopes, where the cisterns are dug out. The rainfall and API threshold of the four catchments, required to produce runoff in the reservoirs, are lowest for hill slopes with a short distance from the rock outcrops to the reservoirs and a low vegetation cover. It was demonstrated that (i) re-infiltration of runoff frequently occurs (56 events not reaching the reservoirs against 14 events with continuous runoff) even within the unlined channel connecting the cistern to the hill slope, and that (ii) the 80% probability of runoff occurrence, calculated using the logistic regression, can be used as a proxy for the total annual runoff to be collected.

Samuel and Satapathy (2008) studied rainwater harvesting for irrigation and drinking water requirement in hilly terrains of N-E India. The mainstay of economy of India's North East region is agriculture, which is currently exhibiting trends of increasing un sustainability. Much of the enormous water resources in the region remain unutilized due to the absence of proper water recourse planning and scientific management. Storing of water can be done in two ways (1) Storing in an artificial storage and (2) In soil media as ground water.

Kumar *et al.* (2008) analyzed water harvesting and artificial recharge in naturally water-scarce regions. Results revealed that in water-scarce regions of India, run-off harvesting does not offer any potential for groundwater recharge or improving water supplies at the basin scale. The issues are many: (1) Water harvesting in the "closed" basins have downstream negative hydrological impacts. (2) Due to high inter-annual variability in rainfall and therefore run-off, during drought years the water harvesting structures have become highly unreliable, whereas an attempt to capture run-off during wet years would remarkably increase the unit cost of harvesting water. (3) In closed basins, intensive water harvesting would lead to negative welfare outcomes due to high negative externalities at higher degrees of basin development. (4) Even at the local level, physical efficiency of water harvesting is likely to be poor, mainly due to groundwater-surface water interactions and the poor storage capacity of hard rock aquifers underlying most of the water-scarce regions.

Borthakur (2008) conducted a study on traditional rain water harvesting and its applicability at department of economics, barely Baptist College, Wokha. Result revealed that watershed management in India has been defined as rational utilization of land and water, and water resources for optimum, and sustained production with minimum hazards to natural resources. It is essentially related to soil and water conservation.

Kumta *et al.* (2010) conducted study to identify the prevailing indigenous soil and water conservation practices among the tribal farmers of Mizoram. Out of eight agricultural districts in Mizoram, seven agriculturally important districts have been selected. The data were collected by executing PRA tools. One community development block from each district and two villages per block were selected randomly. The sample size comprised of 70 key informants and 420 farmers. Surface seeding, no till or pot holing and mulching were major indigenous agronomic soil conservation practices followed by the farmers in every part of Mizoram. However, some other practices like adjustment of sowing time in such a manner that when the maximum amount of rainfall occurs, there is enough ground cover. Mixed cropping, inclusion of fast growing legumes and use of maize stalk to make trash lines were also practiced by them. Popular mechanical indigenous practices followed for soil and water conservation were stone bunding, pit digging, earthen bunds, traditional ditches, ridges and indigenous method of terrace making. Further, they store water at the farm for lean season in the traditionally made water reservoir.

Rao *et al.* (2010) reported national workshop cum- brain storming on rainwater harvesting and reuse through farm ponds: Experiences, Issues and Strategies. Research by ICAR and State Agricultural Universities has resulted in designing of efficient water harvesting structures for different rainfall regions and soil types, effective storage of harvested water and methods of its efficient use. Outside the main stream research system also, several non-governmental organizations (NGOs) have come up with models of simple and low cost water harvesting structures, evolved water sharing methods, community regulation of water use, which helped in up-scaling the models to certain extent. Different state governments have initiated special programs on farm ponds/small storage structures in order to ensure the sustainability and to improve the livelihoods of people. Despite these experiences, the adoption of farm ponds at the individual farm level has been very low, particularly for drought proofing through life saving irrigation of Kharif crops. A number of technological and socio-economic constraints are cited for this poor adoption and up-scaling.

Agarwal *et al.* (2010) Studied Impact of Rooftop Rainwater Harvesting for Groundwater Recharge. A rooftop rainwater harvesting structure was constructed and the design of filtration unit for ground water recharge evaluated for four years. The other structure constructed at the university library recorded an average of 0.3 million litres groundwater recharge. The success led to construction of six more structures at different places, and currently 20 structures have been established at different places in Punjab under the technical guidance of the university. In the year 2007, eleven structures were evaluated and found that they contributed about 2.01 million litres of rainwater as groundwater recharge. The study revealed that there was a need to adopt this technique at mass level to get significant results. This would be possible only with the help of people, participation. The possibilities to motivate the people for adoption of the technique at mass level have been reviewed.

Krishan (2011) studied water harvesting traditions and the social milieu in India: a second look. India has a variety of local community traditions of water harvesting. There are a number of scholars and activists who tend to valorize premodern wisdoms without critically evaluating their socio cultural context and realizing how deeply they were embedded in the social hierarchy of their times. There has been, of course, a great deal of stress lately on a kind of “eco-golden age”. Seen from such a perspective, all pre-industrial societies would exhibit a kind of harmony with nature. However, most of the times, it was the demographic and technological factors that made these societies less harmful to the environment. It was not that they wished to protect the whole canopy of nature. This reappraisal demonstrates how precepts and rites, culture and customary practices and state policy interact to lay the bases of water harvesting traditions. Social customs are the necessary conditions for sustaining these traditions, while local autonomy in resource management is the critical sufficient condition but it never results in equitable access for all.

### **2.3 BENEFIT COST RATIO**

A benefit-cost ratio (BCR) is an indicator, used in the formal discipline of [cost-benefit analysis](#), that attempts to summarize the overall [value for money](#) of a project or proposal. A BCR is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs should be expressed in discounted [present values](#). Benefit cost ratio (BCR) takes into account the amount of monetary gain realized by performing a project versus the amount it

costs to execute the project. The higher the BCR the better the investment. General rule of thumb is that if the benefit is higher than the cost the project is a good investment.

Goyal *et al.* (1995) made the economic evaluation of water harvesting pond under arid conditions, at Jhanwar watershed during 1988-1994 results revealed that water harvesting by means of farm pond of 271 m<sup>3</sup> capacity coupled with ber in the adjoining area could sustain the system in very low rainfall situations. The B: C ratio of the system worked out to be 1.672 which indicates that in order to impart stability to agriculture production on rainfall lands in arid and semi-arid areas, farm ponds seems to hold the key.

Katiya *et al.* (1999) studied impact of water harvesting and recycling in South Eastern Rajasthan. In a study of three village ponds of south eastern-Rajasthan. It was found that the pond capacity has reduced due to siltation, recently distilled ponds were found to be economically viable. One irrigation to wheat, mustard, gram and coriander increased the yield by 64.9, 118.1, 85.8 and 117.5 % over no irrigation, respectively. While two irrigation increased the yield by 130, 141.4, 93.3 and 208.8% over no irrigation. Economic analysis of irrigation with Diara pond shows that benefits cost ratio is 2.5:1.

Bisnoi (2001) studied the planning and designing of water harvesting systems for South-West region of Rajasthan. The ratio of catchment area to submergence area was found to be 10.85 and 34.48 for Khadin and Anicut, respectively. The benefit cost analysis revealed that the B:C ratio of entire water harvesting system was found as 1.788:1 and 1.889:1 on the basis of economical and financial evaluation, respectively.

Machiwal *et al.* (2004) planned and designed a cost-effective water harvesting structures for efficient utilization of scarce water resources in semi-arid regions of Rajasthan, India. Agfe Department, Indian Institute of Technology, Kharagpur, India. In semi-arid regions of Rajasthan, India, existing practice of harvesting rainwater is through anicuts and earthen embankments. In the present paper, the detailed design of some low-cost water-harvesting structures using locally available materials and adaptable to the socio-economic conditions of the beneficiaries is discussed.

Singh *et al.* (2006) studied economics of Rainwater Harvesting and Recycling for Winter Vegetable Production in Mid Hills of Meghalaya. The weekly rainfall during November to mid March being less than the weekly evaporation, irrigation becomes necessary. Four locally grown high-value vegetables viz. Cabbage, cauliflower, pea and lettuce were cultivated during November to mid March. The harvested rainwater was

used through sprinkler system to irrigate the crops. The overall benefit- cost ratio for the whole system for 1 ha vegetable cultivation area was 2.7 over a period of 15 years. A farm of 1 ha area totally under vegetable cultivation can recover the initial investment in two years. The benefit-cost ratio may be further enhanced by utilizing the harvested water for fish production and livestock rearing. Thus efficient utilization and management of rainwater may help transform the subsistence agriculture into a profit earning enterprise in the region.

Rana *et al.* (2006) studied economic evaluation of water harvesting structures in Himachal Pradesh. Between the predicted and observed rainfall of various development project in H.P., revealed that the productivity of crops was increased, and the cropping pattern was changed due to availability of irrigation water. All the projects are found economically viable as the benefit-cost ratio was more than unity both at 10 and 12% discount rates. Net present worth was highest for labour and least for normal. Internal rate of (29.11%) and least for Narowal (25.85%).

### **III MATERIALS AND METHODS**

This chapter includes the methodology adopted in achieving the sets of objectives in light of the basic background data, the location of the study area and its characteristics features and other relevant components of the study.

#### **3.1 LOCATION OF THE STUDY AREA**

Bhilwara district is situated between 25 degree 0 minutes to 27 degree 50 minutes North Latitude and 74 degree 3 minute to 75 degree 25 minute East longitude. The location of study area is shown in Fig 3.1. The district is situated 100 meters above mean sea level. It is bounded in the north by Ajmer District, in the north-west, west and south west by Udaipur and Rajasamand District, in the east and north east by Bundi and Tonk district. The district has geographical area of 10,455 km<sup>2</sup>, and a population of 23,35,611 (2001 census), which increased 26.14% from 1991 to 2001. The district is known for its textile Industries. The total length of the district from west to east is 144 km while the breadth from north to south is 104 km approximately. Rainfall pattern in Bhilwara district is normal (507.58 mm).

The Bhilwara District has a hot dry summer (mean maximum 39°C and mean minimum 27°C) and bracing cold winter (mean maximum 23°C and mean minimum 8°C). The cold season is from December to February and is followed by hot summers from March to the last week of June. The south west Monsoon season which follows, lasts till about mid September. The period from mid September to about the end of November constitutes the post monsoon season. Among the rivers in the district, Banas River is only seasonal river in the district. Its tributaries are Bedach, Kothari and Khari. Other rivers are Mansi, Menali, Chandrabhaga and Nagari. Number of Tehsils in Bhilwara district are 12. Number of blocks are 11 and number of villages are 1745.

Bhilwara district of Rajasthan state is drought prone in southern Rajasthan. This district also falls under the disadvantaged districts identified by the planning commission. The agriculture in this district is characterized by recurrent draught, sloppy lands, dominance of low value and holding, poor irrigation sources, poor livestock productivity, lack of farm employment opportunities, poor market support, and non-availability of credit and high rate of illiteracy. Soil in this region is Loam, Clay loam, Sand Loam pebbly & stony and sandy loam. Major crops of the Kharif season are maize, pulses, sorghum, sesame and cotton while major crops of the Rabi season are wheat, gram and mustard and area under principal crops are shown in Table 3.1 the land use pattern in study area is shown in Table 3.2.

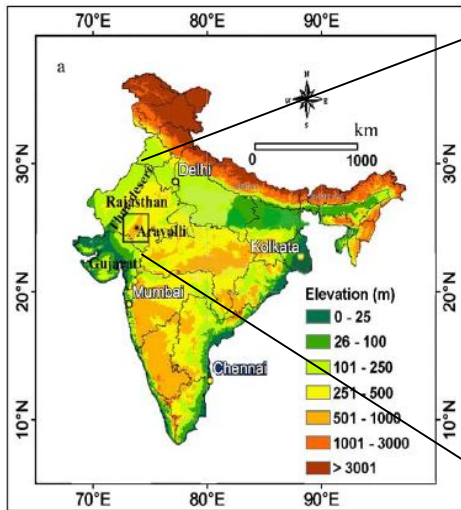
**Table 3.1 Area under principal crops during the year 2004-05**

S. No	Crops	Area (ha)
1	Maize	180927
2	Oil Seeds	122771
3	Wheat	83389
4	Pulses	55217
5	Jowar	38671
6	Barley	10666
7	Spices	7650
8	Bajra	2265

(Source: District Ground Water Brochure, Bhilwara district, Rajasthan, 2008)

**Table 3.2 Land use pattern in the study area**

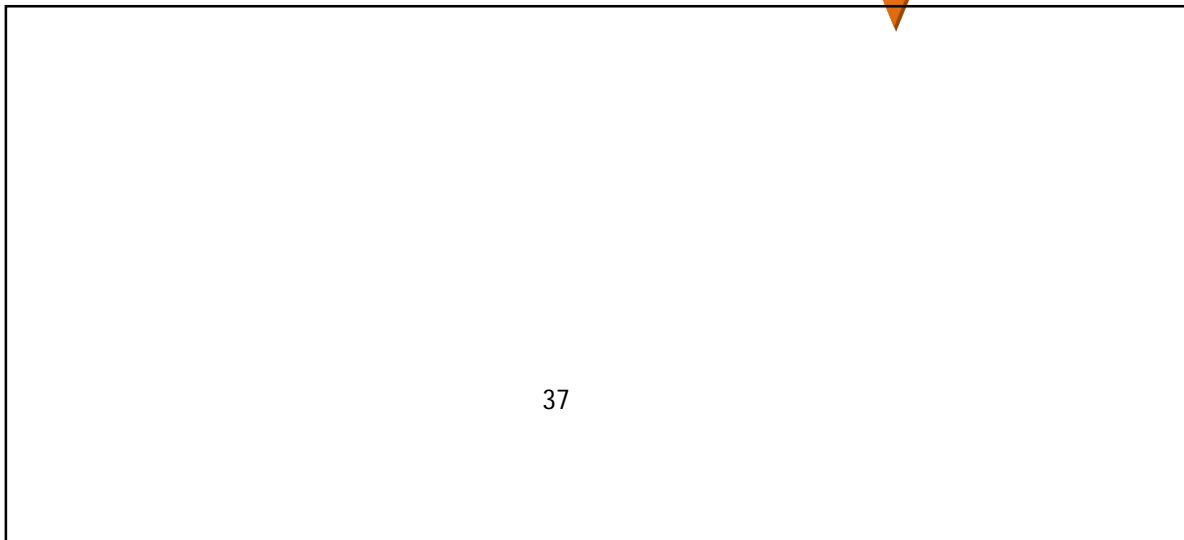
Tehsil	Geographical area (ha)	Cultivated land (ha)	Pasture land (ha)	Non-cultivable land (ha)	Other land uses (ha)
Bhilwara	96495	34155 (35.4)	10591 (11.0)	17409 (18.0)	34340 (35.6)
Baneda	68048	21610 (31.8)	9648 (14.2)	12590 (18.5)	24200 (35.6)
Shahapura	112892	16899 (15.0)	12819 (11.4)	24822 (22.0)	58352 (51.7)



India



Rajasthan





Bhilwara district

Fig 3.1 Location of study area

### 3.2 WORK PLAN

The following work plan was carried out to achieve the objectives of the proposed study:-

- Developed survey questionnaire.
- Randomly three different Panchayat Samitis of the district were selected under different rainfall situations. Therefore 10 Nadis were randomly selected in each Panchayat Samiti. Thus, total 30 nadies were selected in three different selected Panchayat Samitis (Suwana, Shahapura and Baneda).
- Three Nadis were selected for detailed study of Nadi farmers. Therefore, topographic survey of selected three Nadis were conducted and, measured embankment size (Plate 3.1 to 3.3)
- The selected Nadis were situated at Sidadiyas village in Suwana Panchayat Samiti, Baran village in Baneda Panchayat Samiti and Chalaniya village in Shahapura Panchayat Samiti.

- Daily rainfall data for a 30 years period (1981-2010) and meteorological data were collected for all the three selected Nadis from Dryland farming research station, Arjia, Baneda tehsil and Shahapura tehsil.
- Analysed the survey data for different objectives.

### **3.2.1 Survey and Documentation of Nadies**

1. Data was collected according to questionnaires developed for 10 no. of existing Nadies in each selected Panchayat Samiti of Bhilwara district.
2. Detailed Data were collected for 10 Nadies in each Panchayat Samiti. The data collected data were pertaining to area, capacity, submerged, command area and soil characteristics (sediment depth, texture, organic matter, NPK, salinity), size and height of embankment and chemical analysis of sediment. Toposheet of all the three selected villages are shown in Fig 3.2 to 3.4 Sluice of Nadies are shown in Plate 3.4 to 3.8
3. Data collected through survey were analysed for, age of Nadies, command area, scheduling of irrigation, and cost of construction, status of farmers / group of farmers posing the system, operational constraints, and impact and success stories.

### **3.2.2 Detailed Study of One Nadi In Each Randomly Selected Panchayat Samiti and the Following Information as Used For Techno Feasibility of Nadi**

4. 1. Topographic survey of catchment, storage area of Nadies were conducted for selected three Nadies for identification of catchment characteristics, Contour maps of all the three Nadies were shown in Fig 3.5 to Fig 3.7.

2. Estimation of surface runoff from catchment area.

The surface runoff was estimated by following procedure as described bellow:

The SCS (Soil Conservation Services) curve number method was employed to estimate rainfall. Two days consecutive maximum rainfall in a week was used for runoff estimation.

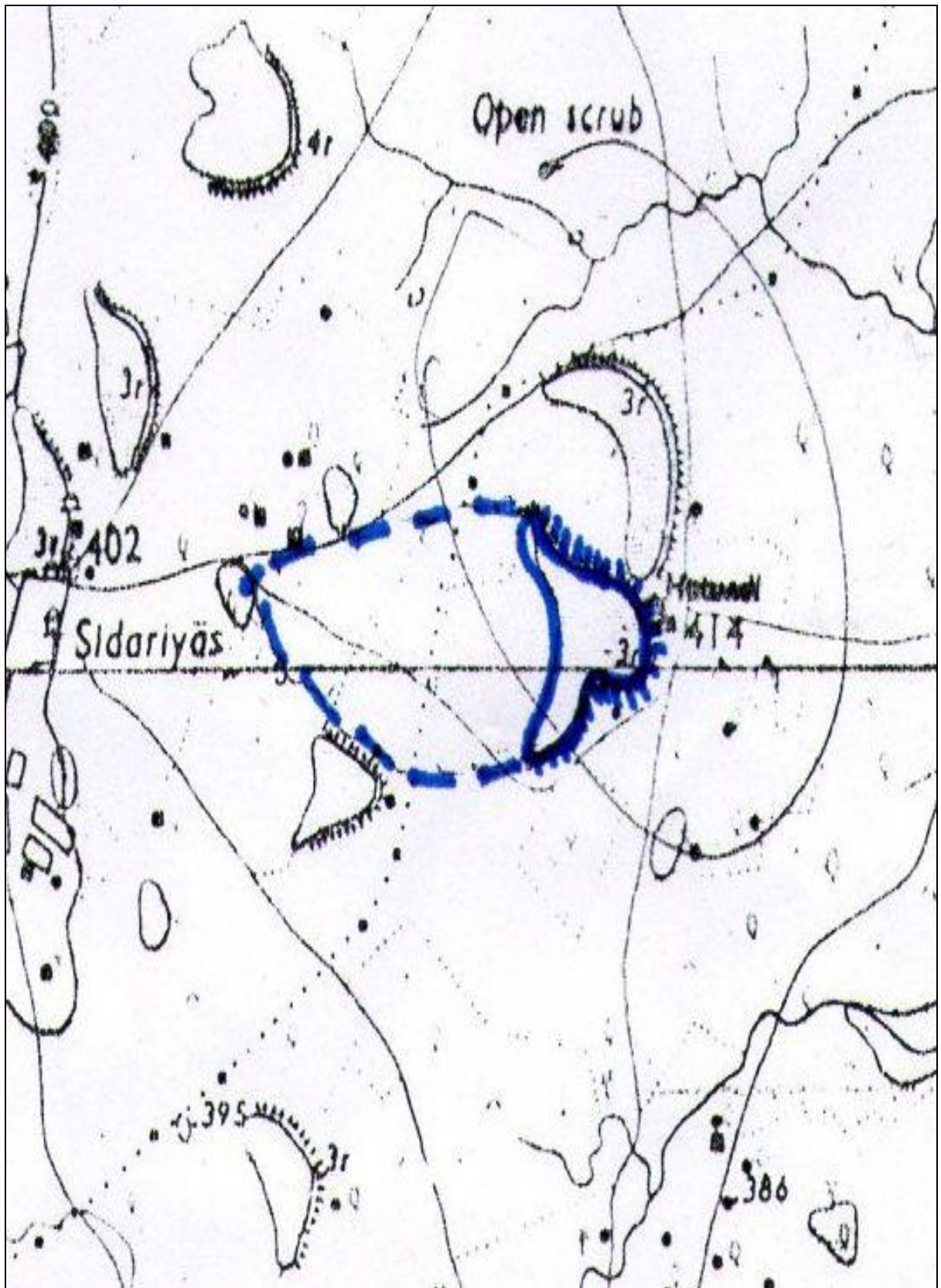


Fig 3.2: Topo sheet of Suwana Panchayat Samiti

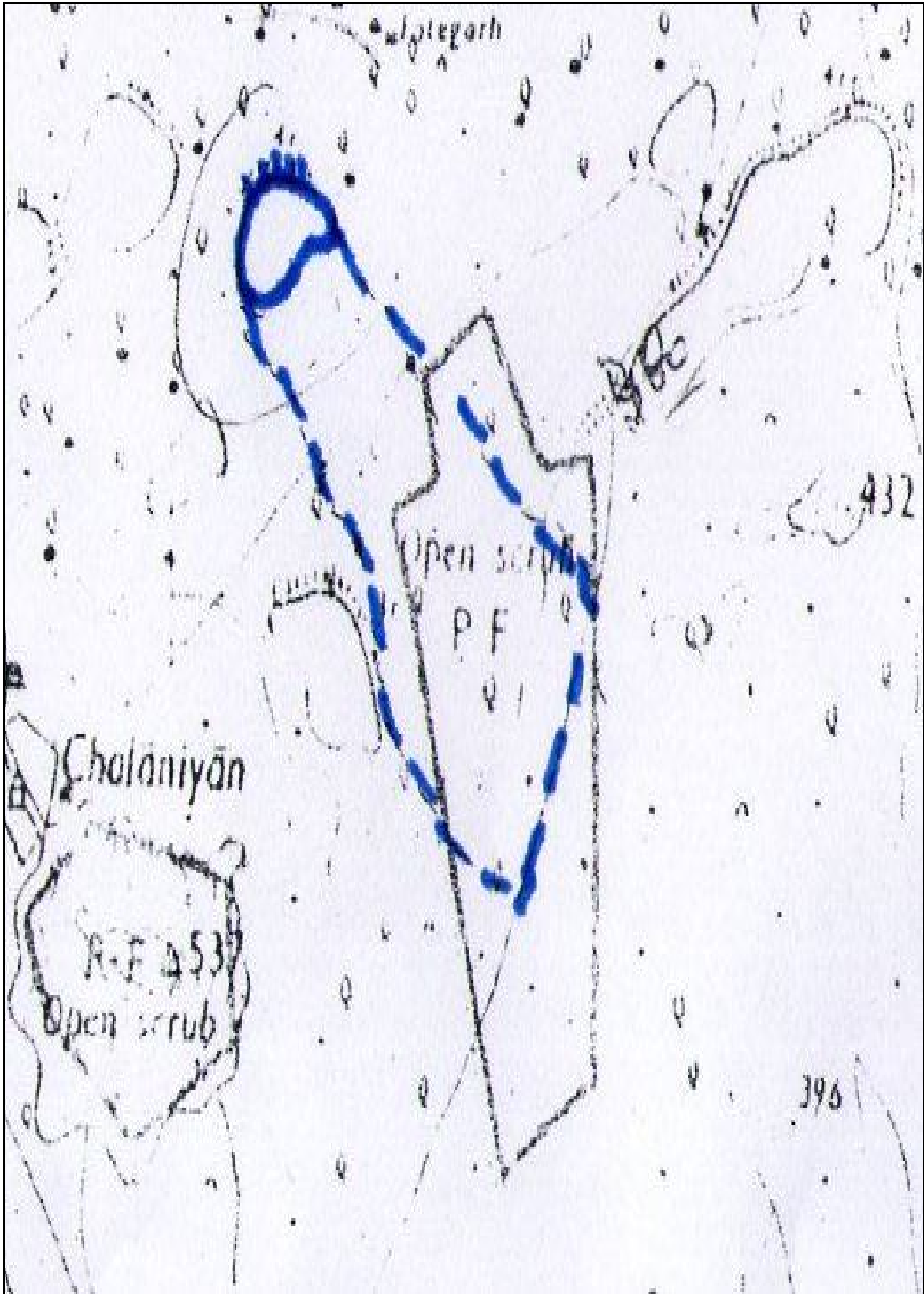
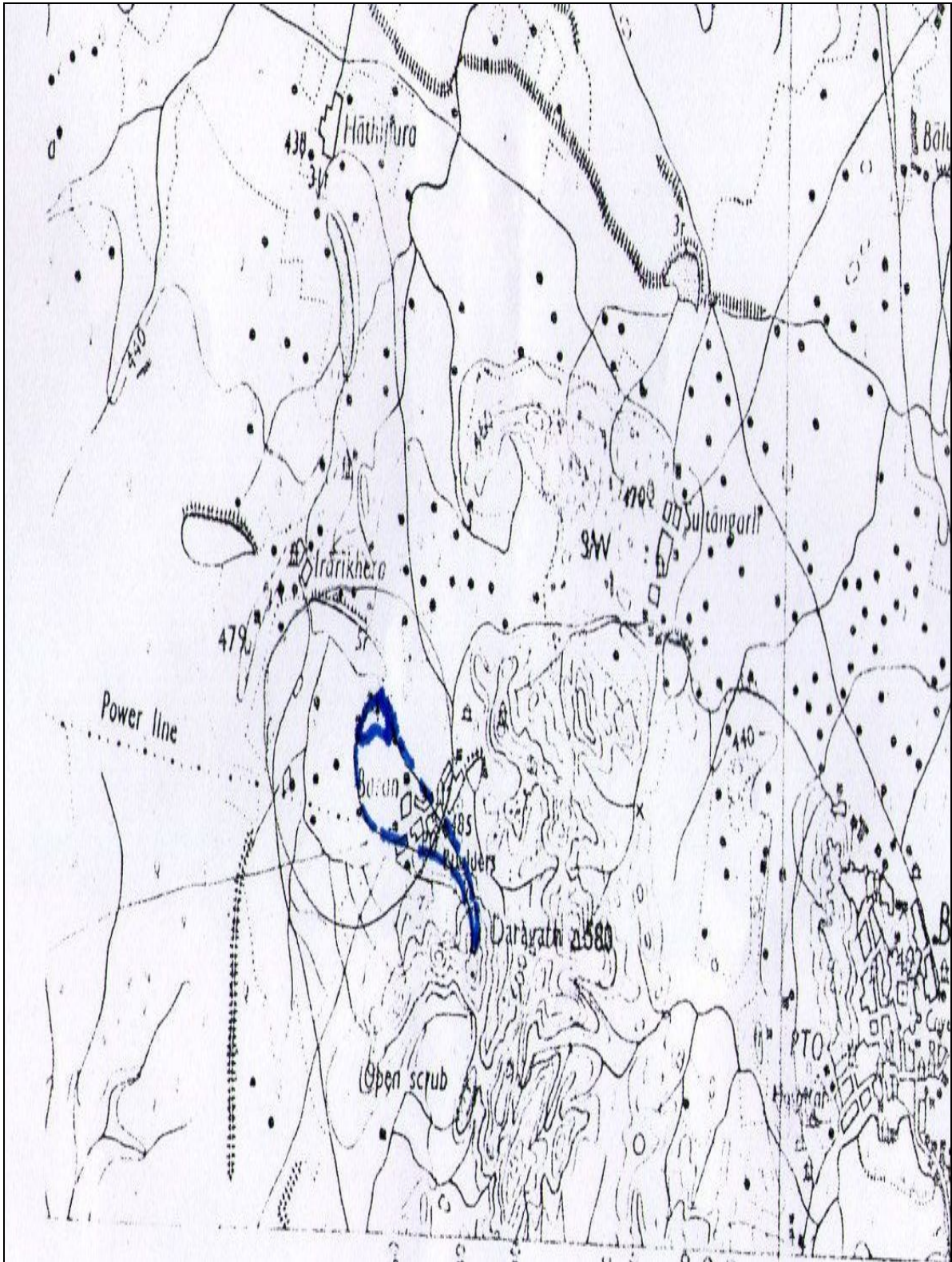
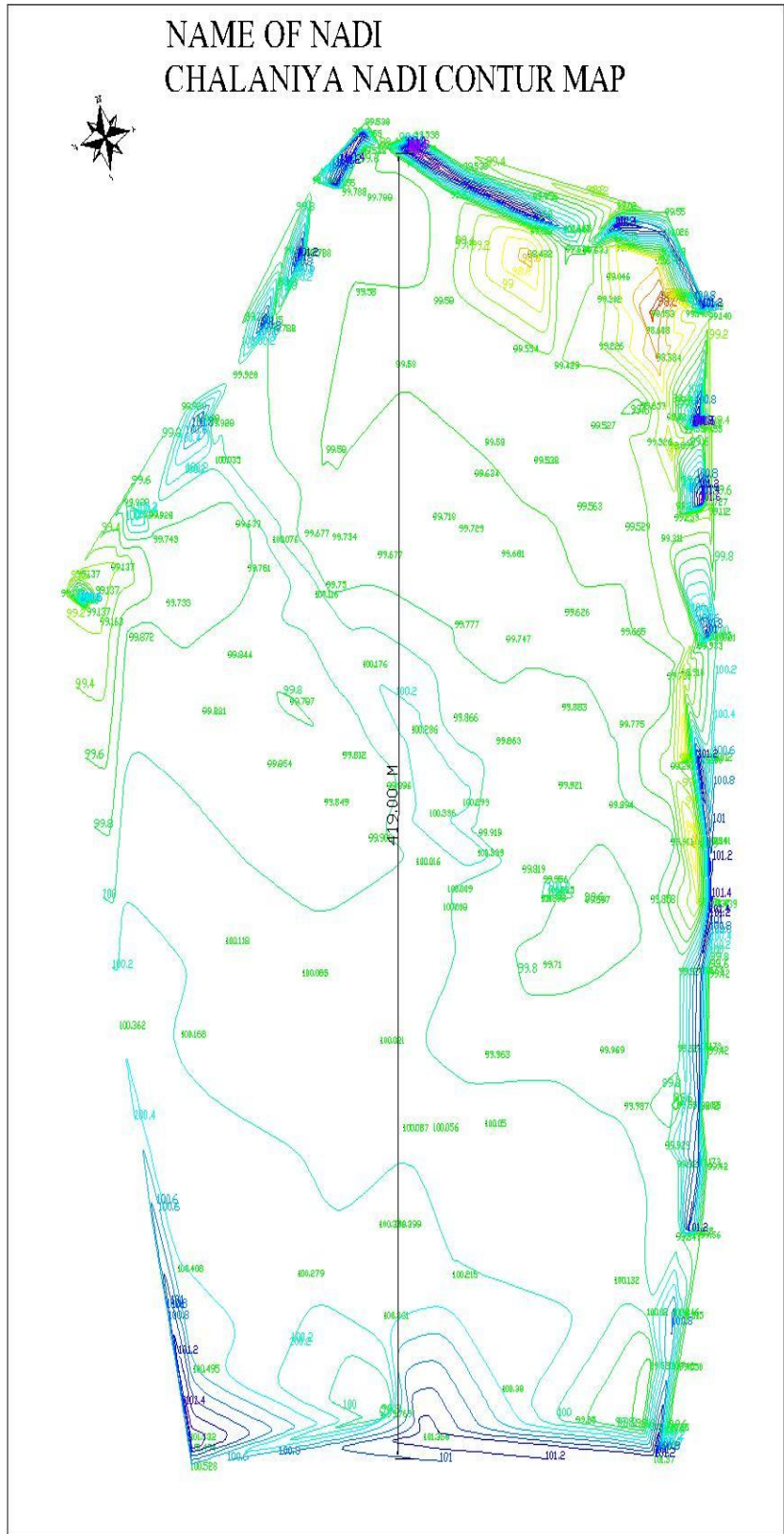


Fig 3.3: Topo sheet of Shahapura Panchayat Samiti



**Fig 3.4: Topo sheet of Baneda Panchayat Samiti**





**Fig 3.6: Contour map for Chalaniya Nadi**

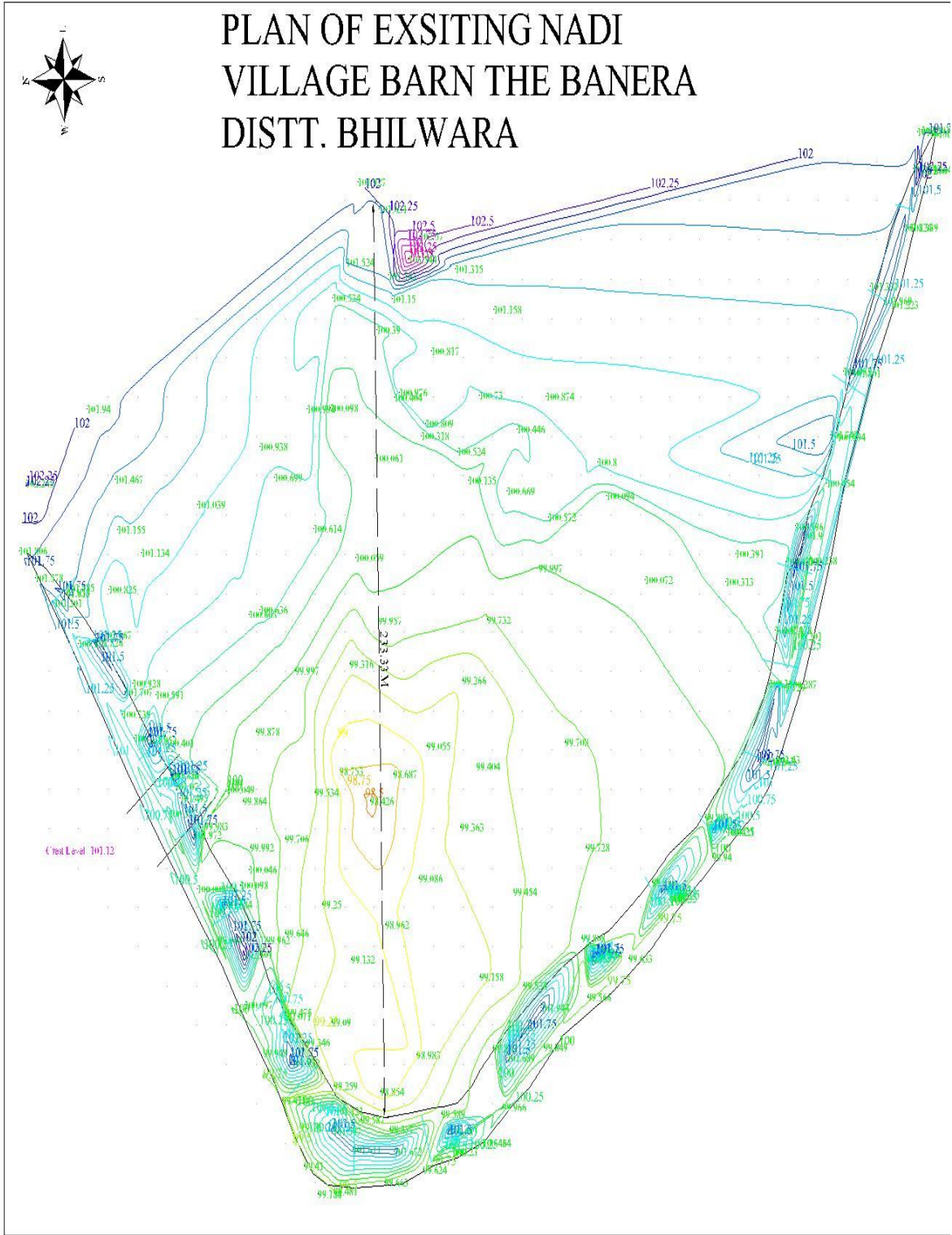


Fig 3.7: Contour map for Baran Nadi



**Plate 3.1: Topographic survey of Chalaniya Nadi (Shahapura)**



**Plate 3.2: Measurement of embankment size of Nadi at Chalaniya, village (Shahapura)**



**Plate 3.3: Survey of Nadi farmers at Chalaniya, villages (Shahapura)**

### 3.2.3 CRITERIA USED FOR CLASSIFICATION OF NADI

Different criteria were used for classification of Nadis and Nadi farmers and are designed as under

#### 3.2.3.1 Nadi farmers were categorised based on the following criteria;

Marginal land holding = <1.0 ha

Small land holding = 1-2 ha

Semi- medium land holding = 2-4 ha

Medium land holding = 4-10 ha

Large land holding = >10

### 3.3 PROBABILITY ANALYSIS OF RAINFALL

Considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources in drought prone areas results in frequent crop failure and shortage of fodder and drinking water. Knowledge of rainfall is very useful to estimate the water availability periods for deciding the cropping pattern; water management and water harvesting practices and in estimating sensitivity to droughts. Determination of rainfall amount expected at various probability levels for different periods e.g. annual, monthly, weekly etc. plays an important role in estimating water deficit/ surplus periods and their amounts at various probabilities.

A probability analysis of maximum weekly runoff of 30 years was done using Weibull formula. The estimated weekly runoff at probability levels ranging from 10 to 90 per cent were selected for designing the WHP. The number of drought, normal and surplus months and weeks in a year were listed in descending order of magnitude and probability analysis has been carried out using Weibull's formula:

Where,

$$P = \frac{M}{N + 1} \dots (3.1)$$

Rainfall data for the period of 1981-2010 were collected for Bhilwara from agro-metrological observatory, Arjia, Bhilwara and for Shahapura and Baneda from Tehsil headquarters of Sahapura and Baneda respectively. This daily data was processed in to weekly, monthly and annual rainfall by simple mathematical means. From daily rainfall

maximum rainfall in one day per year was recorded, Similarly maximum rainfall for two days and weekly rainfall was calculated.

The rainfall of the months of respective season has summed up to calculate mean seasonal rainfall that was divided by the number of month for the respective seasons. The early total rainfall was calculated by dividing the yearly total by number of year.

Jena & Senapati (1981) found that Weibulls equation approximates closely the linear relationship between the rainfall and plotting positions than the other equations.

### 3.3.1 Standard Deviation

In [statistics](#) and [probability theory](#), standard deviation (represented by the symbol  $\sigma$ ) shows how much variation or "[dispersion](#)" exists from the average ([mean](#), or expected value). A low standard deviation indicates that the data points tend to be very close to the [mean](#), whereas high standard deviation indicates that the data points are spread out over a large range of values.

The standard deviation of a [random variable](#), [statistical population](#), data set, or [probability distribution](#) is the [square root](#) of its [variance](#). It is [algebraically](#) simpler though practically less [robust](#) than the [average absolute deviation](#). A useful property of standard deviation is that, unlike variance, it is expressed in the same units as the data.

With sample standard deviation

The sample standard deviation, denoted by  $\sigma$  and defined as follows:

$$\sigma = \sqrt{\frac{1}{N-1} \sum_{i=0}^N (X_i - \bar{x})^2} \quad \dots(3.2)$$

Where  $x_1, x_2, x_3$  are the observed values of the sample items and  $\bar{x}$  is the mean value of these observations. This correction (the use of  $N - 1$  instead of  $N$ ) is known as Bessel's correction. The reason for this correction is that  $s^2$  is an unbiased estimator for the variance  $\sigma^2$  of the underlying population, if that variance exists and the sample values are drawn independently with replacement. Additionally, if  $N = 1$ , then there is no indication of deviation from the mean, and standard deviation should therefore be defined. However,  $s$  is not an unbiased estimator for the standard deviation  $\sigma$ ; it tends to underestimate the population standard deviation.

The term standard deviation of the sample is used for the uncorrected estimator (using  $N$ ) while the term sample standard deviation is used for the corrected estimator

(using  $N - 1$ ). The denominator  $N - 1$  is the number of degrees of freedom in the vector of residuals,  $(x_1 - \bar{x}, \dots, x_n - \bar{x})$ .

In [probability theory](#) and [statistics](#), the coefficient of variation ( $C_V$ ) is a [normalized](#) measure of [dispersion](#) of a [probability distribution](#). It is also known as unitized risk or the variation coefficient. The absolute value of the  $C_V$  is sometimes known as [relative standard deviation](#) (RSD), which is expressed as a %.  $C_V$  should not be used interchangeably with RSD (i.e. one term should be used consistently).

The coefficient of variation ( $C_V$ ) is defined as the ratio of the standard deviation  $\sigma$  to the mean  $\mu$ :

$$C_V = \frac{\sigma}{\mu} \quad \dots \quad .(3.3)$$

### 3.4 COMPOUND AMOUNT FORMULA

Future worth ( $S_a$ ) of the investment made in the present ( $P_a$ ) is at the interest rate ( $r$ ) is worked out using the following equation;

$$S_a = P_a (1+r)^{np} \quad \dots \quad .(3.4)$$

Where,  $S_a$ = Future worth,  
 $P_a$ = Present worth,  
 $r$ = interest rate, and  
 $np$ = number of years

### 3.5 COMPUTATION OF SURFACE RUNOFF

#### 3.5.1 Estimation of Runoff by Using SCS Curve Number Method

The SCS curve number method is developed by SCS, USDA (1964). This method requires individual storm rainfall, land use type, hydrologic soil group and antecedent soil moisture condition as input. Curve number is dimensionless and its value varies from 0 to 100.

#### 3.5.2 Computation of Runoff Curve Number

A curve number is an index that represents the combination of hydrologic soil group and land use and treatment classes. Empirical analysis suggested that the curve number was a function of three factors; soil group, the cover complex and antecedent moisture conditions.

The composite or weighted curve number for a watershed under antecedent moisture conditions (AMC) has three methods which are as follows;

Antecedent Moisture Condition I :- This condition is for initially dry soil

$$CN_I = \frac{4.2 CN_{II}}{10 - 0.058 CN_{II}} \quad \dots (3.5)$$

1) Antecedent Moisture Condition II:- This condition is for average soil moisture

$$CN_{II} = \frac{\sum_{i=1}^n (A_i \times CN_i)}{A_w} \quad \dots (3.6)$$

2) Antecedent Moisture Condition III :- This condition is for initially wet soil.

$$CN_{III} = \frac{23.0 CN_{II}}{10 - 0.13 CN_{II}} \quad \dots (3.7)$$

### 3.5.3 SCS Curve Number Method

Daily runoff from rainfall can be estimated by using SCS-CN model (SCS, 1964)

The relation between rainfall, runoff and retention in which rainfall and runoff begin simultaneously,

$$\frac{F}{S'} = \frac{Q}{P} \quad \dots (3.8)$$

The parameter S" in Equation does not contain the initial abstraction. The retention S" is a constant for a particular storm because it is the maximum retention. In above formula the retention (F) varies between the difference between P and Q at any point on the mass curve, i.e.

$$F = P - Q \quad \dots (3.9)$$

Therefore,

$$\frac{P - Q}{S'} = \frac{Q}{P} \quad \dots (3.10)$$

Solving for Q,

$$Q = \frac{P^2}{P + S'} \quad \dots (3.11)$$

It represents the rainfall runoff relation in which the initial abstraction is ignored. Taking initial abstraction into account and replacing retention parameter S by S the equation (3.11) becomes

$$= \frac{Q}{P - I_a} \quad \frac{F}{S} \quad \dots (3.12)$$

Where,

$I_a$ =initial abstraction  $F \geq S$  and  $Q \leq (P - I_a) I_a$

The parameter S includes  $I_a$  i.e.  $S = S_{\square} + I_a$

$$F = (P - I_a) - Q \quad \dots (3.13)$$

Equation 3.10 reduces to

$$\frac{(P - I_a) - Q}{S} = \frac{Q}{P - I_a} \quad \dots (3.14)$$

Solving for Q gives

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad \dots (3.15)$$

The initial abstraction consists mainly of interception, infiltration and surface storage. The relation between  $I_a$  and S was developed by using rainfall and runoff data is as follows

$$I_a = 0.2 S \quad \dots (3.16)$$

Therefore the equation for runoff estimation becomes

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \dots (3.17)$$

Vandersypen *et al.*(1972) has presented following formula for different regions of India.

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \quad \dots (3.18)$$

The retention parameter S is determined based on antecedent moisture condition (AMC) and is given by the following relation (USDA,SCS, 1972),

$$S_r = \frac{25400}{CN} - 254 \quad \dots (3.19)$$



**Plate 3.4: Sluice at Chalaniya Nadi**



**Plate 3.5: Sluice at Sidadiyas Nadi**



**Plate 3.6: Different types of sluice at Sidadiyas Nadi**

**3.5.4 Determination of Peak Runoff Rate by SCS Method**

Ogrosky and Mockus (1957) developed the method to determine the peak runoff rate by using the curve number method. They suggested to employ the following formula to determine the peak rate of runoff using the 6-hour rainfall at the design frequency.

$$Q_p = \frac{0.0208 * A_c * Q_d}{T_p} \quad \dots (3.20)$$

$$T_p = 0.6T_c + \sqrt{T_c}$$

### 3.6 EMBANKMENT DESIGN

The water stored will be in the shape of right angled triangle (Fig 3.8) with water surface being base (as the water level will always be horizontal). Embankment being perpendicular and gully bed being hypotenuse. It has been assumed that the width is same for the submergence area in case of this not being so, average width can be taken. The mathematical formulation for estimation of volume at maximum depth 'H'.

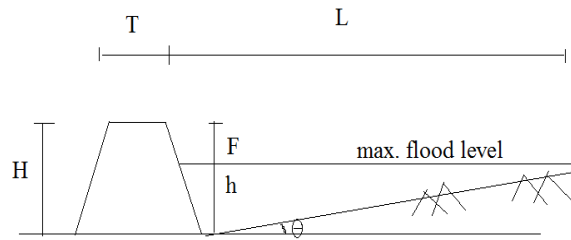


Fig 3.8: Side view of Nadi embankment

$$\text{Max storage capacity} = \frac{H^2 \cdot \cot\theta W}{2} \quad \dots (3.21)$$

$$S\eta = \frac{H^2 \cdot \cot\theta W}{2} \quad \dots (3.18)$$

Or

$$h\eta = \frac{\sqrt{2S\eta}}{W \cdot \cot\theta} \quad \dots (3.19)$$

$$WSA\eta - W \cdot h\eta \cdot \cot\theta \quad \dots (3.20)$$

And

$$VT = \frac{h^2 \cot\theta W}{2} \quad \dots (3.21)$$

Total amount of earthwork for construction of the embankment  $V_t$  will be

$$V_t = \frac{1}{2} \{2T + [(h + F)(S_u + S_d)]\}(h + F)W \quad \dots(3.22)$$

The height required for creating required storage capacity is determined as suggested by Shrivastava (2001) with the following relationship

$$h_r = \frac{2(VT - V_t)}{\cot \theta W} \quad \dots(3.23)$$

Embankment must be designed to make optimum use of the materials of construction including the excavated foundation material so as to minimize cost. The feasibility of using excavated material when this constitutes an appreciable proportion of the embankment material would depend on the sequence of operation of construction operation. For instance, since a large placing area must be available in order to use material excavated from the spillway in embankment without stock piling, the excavation of the spillway could be delayed till the availability of the requisite space rather than wasting large quantities of these materials.

Hydrologic design involves the estimation of peak rate of runoff to be passed safely through pond and runoff volume from catchment of pond. Formula for rainfall intensity,

$$I = \frac{kTt^a}{(t + a)^b} \quad \dots(3.24)$$

The peak rate of runoff was determined as suggested by Schwab *et al.* (1993) as;

$$Q = \frac{CIAc}{360} \quad \dots(3.25)$$

The discharge passing over the standard weir is determined by the following relationship,

$$Q = CLcHw^{\frac{3}{2}} \quad \dots(3.26)$$



**Plate 3.7: West weir at Baran Nadi**



**Plate 3.8: Sluice at Baran Nadi**

### **3.7 BENEFIT COST RATIO**

A benefit-cost (B:C) ratio simply compares the present value of benefits to the present value of costs and is given by the following equation:

$$B:C \text{ ratio} = \frac{\sum_{t=1}^n [B_t / (1+r)^t]}{\sum_{t=1}^n [C_t / (1+r)^t]} \dots (3.27)$$

If the B:C ratio is greater than one, the present value of benefits is greater than the present value of costs and the structure is considered economically viable.

### **3.8 COST OF EXPENDITURE OF STRUCTURES AT THREE SELECTED NADIS**

In purpose to calculate cost of construction of Nadi embankment and other structures measurements were taken in different sections. Volume for each section were calculated and is shown in Appendix L to Appendix V . Total cost of earthwork was found to be Rs. 131734.8, Total construction cost for sluice with foundation was found to be Rs.8659.18 for Sidadiyas Nadi. Total cost of earthwork was found to be Rs. 151904.4, Total construction cost for sluice with foundation was found to be Rs.2465.37 for Chalaniya Nadi. Total cost of earthwork was found to be Rs. 151621.5, Total construction cost for sluice with foundation was found to be Rs.5007.15 and total cost for west weir was found to be Rs. 1304.6 for Sidadiyas Nadi.

## **IV RESULTS AND DISCUSSION**

### **4.1 GENERAL**

The study was conducted to check the feasibility of on-farm reservoirs in Bhilwara, Baneda and Sahapura. The design of Nadi has been done considering all features like command area, storage and catchment area.

The present study reported in this dissertation consists of three parts. In first objective, the rainfall data was analysed and runoff was estimated by using SCS curve number method. In second objective validation of the existing on farm reservoirs (nadies) with technically

design capacity and dimension were done. In third objective Benefit cost ratio (B:C) was calculated.

The results along with discussion are presented under the following major headings:

- i) Results of survey of Nadi Farmers
- ii) Probability analysis of rainfall
- iii) Estimation of runoff
- iv) Validation of on-farm reservoirs (Nadi)
- v) Benefit cost ratio

#### 4.1.1 Education of Farmers

Bhilwara district possessed more than 24,10,459 people as per 2011 census. Males and has constituted about 53% and 47% of the total population. 15% of the population was under 6 years of age. Rural contributes 78.71% and urban area contributes 21.29%. The district has a population density of 230 inhabitants per square kilometre. Its [population growth rate](#) over the decade 2001-2011 was 19.7 %, and a [literacy rate](#) of 62.71%. Female literacy rate was 47.93% whereas male literacy was almost double at 77.16 %. There are 8 sub divisions in the district. Bhilwara, Banera, Shahapura, Gangapur, Gulabpura, Mandal, Mandalgarh and Jahajpura. Under these sub-divisions there are 12 Tehsils; Bhilwara, Banera, Mandal, Mandalgarh, Beejoliya, Kotri, Shahapura, Jahazpur, Sahada, Raipur, Asind, Hurda. There are four Sub Tehsils also named Kareda (Mandal), Badnor (Asind), Hamirghar (Bhilwara) and Puliakalan (Shahapura). Similarly there are 1783 villages as per census of 2001

**Table 4.1: Socio economic indicators of selected Panchayat Samitis**

S. No.	Particulars	Suwana	Shahapura	Baneda
1	Total population	1,64,004	1,48,955	1,06,222
2	Literacy rate	51%	61%	49.99%
3	Male literacy	71%	72%	67.49%
4	Female literacy	48%	50%	32.11%
5	SC	17.95%	17.33%	17.06%
6	ST	5.27%	6.61%	6.67%

(Source: [www.indiamapped.com/rajasthan/bhilwara/banera/](http://www.indiamapped.com/rajasthan/bhilwara/banera/))

Suwana Panchayat Samiti possessed more than 1,64,004 total population as per 2011 census. Suwana is one of the oldest and biggest Panchayat Samiti Head quarter of Bhilwara District (Table 4.1). As of 2011 India [census](#), Shahapura Panchayat Samiti had a total population of 1,48,955. Males constitute 51% of the population and females 49%. Shahapura Panchayat Samiti had higher average literacy rate an (61%) as compared to national average of 59.5%: whereas male and female literacy was 72 and 50 % respectively. In Shahapura, 16% of the population is under 6 years of age. Banera is a Tehsil of Bhilwara district in the Indian state of Rajasthan. The total population of Banera, was 106222. Of this, 6830 are Scheduled Tribes (STs) and 16393 are Scheduled Caste (SC). The literacy rate was 49.99 %, 67.49 % for males and 32.11 % for females in Baneda Panchayat Samiti.

In Suwana Panchayat Samiti, survey of five villages was done which were as follows; Kochria, Sidadiyas, Pipli, Fagnoka Khana, Bada Mahuva. In Shahapura Panchayat Samiti, survey of five villages was done, which were as follows; Mundetee, Phalsa, Nasard, sola kakheda, Phuliya khurd, Chalaniya. Similarly, survey of five villages was done in Baneda Panchayat Samiti. The villages were Sardarnagar, Lamba, Kamalpura, Bamniya, umkarpura in Baneda.

#### 4.1.2 Agrarian Structure of Nadi Farmers

Nadi holders farmers were categorised into five groups based on their land holding i.e. Marginal (< 1.0 ha) Small (1.0-2.0 ha), semi medium (2.0-4.0 ha), Medium (4.0-10 ha) and large (>10 ha) for logical interpretation. Results revealed that average land holding of farmers was 5.5 ha, 12.5 ha and 3 ha in Suwana, Shahapura and Baneda Panchayat Samiti, respectively.

Maize was the dominant crop in the Bhilwara district followed by Black gram, Green gram, Sesame, cotton in kharif season. Whereas Wheat and Mustard were major crops in rabi season followed by chick pea, Taramira. Major soils were yellow, brown and black soils. Soil texture varies from sandy loam to clay loam. Available water holding capacity is low to medium. Overall dominance of brown colour with variation.

**Table 4.2: Classification based on age of Nadi**

S. No	Particular	Number of Nadis
-------	------------	-----------------

1	Earliest	11
2	Medium	12
3	Oldest	7

#### 4.1.3 Classification of Nadis

Survey of 30 Nadis were done in three selected Panchayat Samitis viz. Bhilwara, Shahapura, & Baneda. It was found from this that there are 11 numbers of Nadis which are constructed between five to forty years (Table 4.2). 12 Nadis were constructed between 40 to 90 years and 7 Nadis which are oldest and constructed between 90-200 years. Age of the Nadi was observed in Suwana, Shahapura and Baneda Panchayat Samitis is 50 years, 90 years and 45 years, respectively.

Similarly cost of construction for these Nadis were 10,680/-, 13000/- and 7030/- in Suwana, Shahapura and Baneda Panchayat Samitis respectively. Average command area for these Nadis is 3.5 ha, 7.5 ha and 2.75 ha for respective Panchayat Samitis. Capacity of Nadi was 2.1 ha-cm, 6 ha-cm and 2 ha-cm for respective Panchayat Samitis. Catchment area for Suwana was 7.5 ha out of which 2.3 ha was cultivated and 12.5 ha was uncultivated. Catchment area for Shahapura was 12.5 ha out of which 10 ha was cultivated and 2.5 ha was uncultivated. Catchment area for Baran Nadi (Baneda) was observed to be 5 ha out of which 3.0 ha is cultivated and 2 ha was uncultivated. Shahapura has maximum storage capacity with respect to maximum catchment area.

**Table4.3: Earliest Nadi according to age of Nadi construction**

S. No	Total land holding (ha)	Age of Nadi (years)	Cost (Rs)	Command (ha)	Capacity(m <sup>3</sup> )
1	25	40	15000	5	4125
2	2.625	30	15000	8	2750
3	2.5	40	3000	1	110
4	22.5	35	40000	12	7500
5	2	7	20000	5	1650
6	8.75	20	10000	12	2475
7	5	40	15000	6	4950
8	5.25	30	8000	21	3850
9	7.5	30	10000	15	6000
10	4.5	40	10000	2	275
11	1.5	15	200000	1	275

**Table 4.4: Medium Nadi according to the year of construction**

S. No	Total land holding (ha)	Age of Nadi (years)	Cost (Rs)	Command area (ha)	Capacity(m <sup>3</sup> )
1	7.5	60	5000	2.5	4800
2	5	60-70	500	0.625	275
3	4.5	55	200	1	275
4	17.5	60-70	6000	7.5	4125
5	5	80	6000	3.75	11000
6	8.75	60	6000	1.75	1925
7	15	70	35000	5	16500
8	3	70	2000		825
9	7.5	80	15000	3.75	11000
10	6.75	60	2500	1.5	825
11	2	55	5000	0.625	1437.5
12	4.5	50	200	1.75	412.5

**Table 4.5: Oldest Nadi according to the year of construction**

S. No	Total land holding (ha)	Age of Nadi (years)	Cost (Rs)	Command area (ha)	Capacity(m <sup>3</sup> )
1	7.5	200	200	2.5	13750
2	5	100	50000	0.75	1650
3	50	100	6000	3	13200
4	1.5	100	300	0.5	1100
5	3	100	500	7.5	8800
6	4	150	50	8.75	5500
7	6.25	100	600	5	4125

**Table 4.6: Classification of Nadi based on present cost of construction**

Category	Name of Panchayat Samiti			Total
	Suwana	Shahapura	Baneda	
< 1 Lakh	3	5	2	10
1-3 Lakh	5	4	5	14
>3 Lakh	2	1	3	6
Total	10	10	10	30

**Table 4.7: Classification of Nadi according to command area**

Category	Name of Panchayat Samiti			Total
	Suwana	Shahapura	Baneda	
Up to 2	5	4	4	13
2-5	4	5	4	13

>5	1	1	2	4
Total	10	10	10	30

According to age of Nadi, Nadi was classified into three categories viz. earliest Nadi, Medium Nadi and Oldest Nadi. Result revealed that 11 Nadis are constructed earlier, 12 Nadis were Medium and 7 Nadis were oldest out of the 30 Nadies. One of the Nadi was constructed 7 years ago and its cost of construction was Rs.20000 having command area of 5 ha and capacity of 1650 m<sup>3</sup> (Table 4.3). One of the Nadi was constructed 15 years ago requires maximum cost for construction Rs. 200000 having command area of 5 ha and capacity of 275 m<sup>3</sup>. One Nadi was oldest; constructed 200 years ago; required cost of construction was Rs. 200. And command area of 2.5 ha having capacity of 13750 m<sup>3</sup> (Table 4.4 & Table 4.5)

Analysis of results revealed that maximum Nadis were constructed in medium class as well as in earliest class. There were very less number of Nadis under oldest class. The possible reason for this was lack of money or poor economic condition of dryland farmers.

Classification of Nadi according to present cost of construction was done (Table 4.6); results revealed that 10 Nadis required amount more than 1 lakh for construction purpose. 14 Nadis required 1-3 lakh; 6 Nadis required amount greater than 3 lakh for construction purpose.

Average storage capacity of Nadi was 4.17 ha with coefficient of variation of 19.35 % in all the three selected Panchayat Samitis.

Dimensions of Nadi embankment in Suwana were; 3.70 m height, 0.4 m top width and 3.35m bottom width. Nadi embankment dimensions in Shahapura were; 2.56m height, 2.09 m top width and 8.08m bottom width. Nadi embankment dimensions for Suwana are; 3.70 m height, 0.4 m top width and 3.35m bottom width.

Most of the farmers are using gravity flow to irrigate the field from stored water in the Nadi. Whereas some of the farmers were using diesel engine for lifting up water from Nadi. No technical assistance/ consultancy obtained for Nadi construction. Average productive life of Nadi is 25 years for Suwana. For Shahapura it is 30 years and for Baneda it is 20 years. Tank bed cultivation area for Suwana is 1 ha and for Baneda it is 0.93 ha.

Total income per year from Nadi based technology in Suwana, Shahapura and Baneda is 341666, 40000 and 19000/- respectively. Total income from Nadi bed cultivation is 15000/-, 18000/- and 8333/- for respective locations. Average filling of Nadi was once in a year during Normal year whereas two times in a excess rainfall year for all locations.

**Table 4.8: Number of operational holdings of Nadi farmers in three selected Panchayat Samitis**

Category	Name of Panchayat Samiti			Total
	Suwana	Shahapura	Baneda	
Marginal (<1.0 ha)	-	-	-	-
Small (1-2 ha)	-	1 (10 %)	1 (10 %)	2
Semi- medium (2-4 ha)	5 (50 %)	2 (20 %)	-	6
Medium (4-10 ha)	4 (40 %)	4 (40 %)	8 (80 %)	17
Large (>10 ha)	1 (10%)	3 (30 %)	1 (10 %)	5
Total	10	10	10	30

#### 4.1.4 Classification of Nadi Farmers

It is evident from (Table 4.8) that there were large numbers of medium farmers as compared that of semi medium, medium and large farmers. Baneda Panchayat Samiti possessed maximum number of medium farmers. As compared to rest of the selected Panchayat Samitis Shahapura has maximum number of large farmers than Suwana and Baneda. Result revealed that there were maximum number of medium farmers followed by semi medium farmers used Nadi for rain water harvesting and recycling to enhance productivity of crops and rain water.

#### 4.1.5 Income pattern

Income analysis was done for large, medium, semi medium and small farmers separately for all the selected three Panchayat Samitis and results are depicted in Fig 4.1(a), Fig 4.1(b), Fig 4.1(c), Fig 4.2 (a), Fig 4.2 (b),Fig 4.2 (c),Fig 4.2 (d),Fig 4.3 (a),Fig 4.3 (b) and Fig 4.3 (c).

Analysis revealed that agriculture is the major source of livelihood to the farmers. Most of the farmers using Nadi for storage of rain water. Results revealed that large farmers

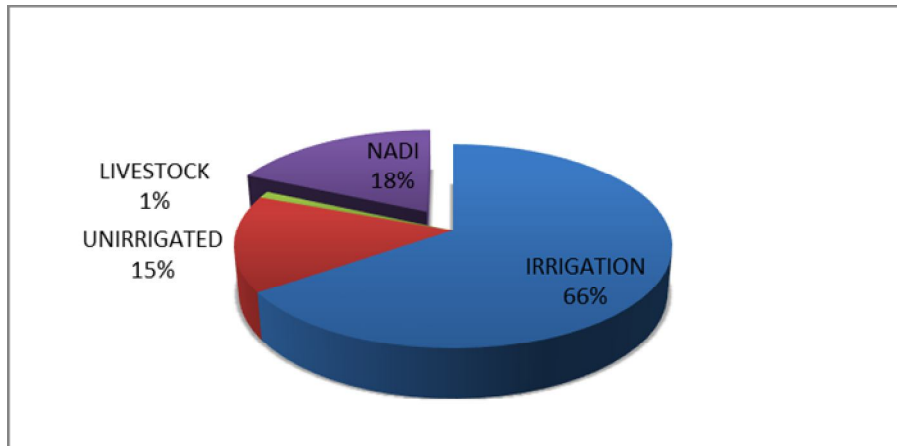
were having 18 per cent annual income was from Nadi in Suwana Panchayat Samiti. Whereas medium and semi-medium farmers annual income was 11 per cent and 23 per cent, respectively from Nadi. However annual income from Nadi was more for large farmers and less for small farmers in Shahapura and Baneda Panchayat Samiti.

Suwana and Shahapura Panchayat Samiti has 4 medium farmers out of 10 farmers survived in each Panchayat Samitis. The maximum medium farmers were observed Baneda Panchayat Samiti. Nadi contributes maximum share of 21% to total income for medium farmers in Shahapura Panchayat Samiti. Whereas it varied from 11 % (Suwana) to 16 % (Shahapura). Medium farmers were obtained maximum share of income from well irrigation in Suwana Panchayat Samiti as compared to Panchayat Samitis. Annual income for semi medium farmers was higher in Suwana Panchayat Samiti as compared to Shahapura Panchayat Samiti. Suwana Panchayat Samiti does not possessed small farmers.

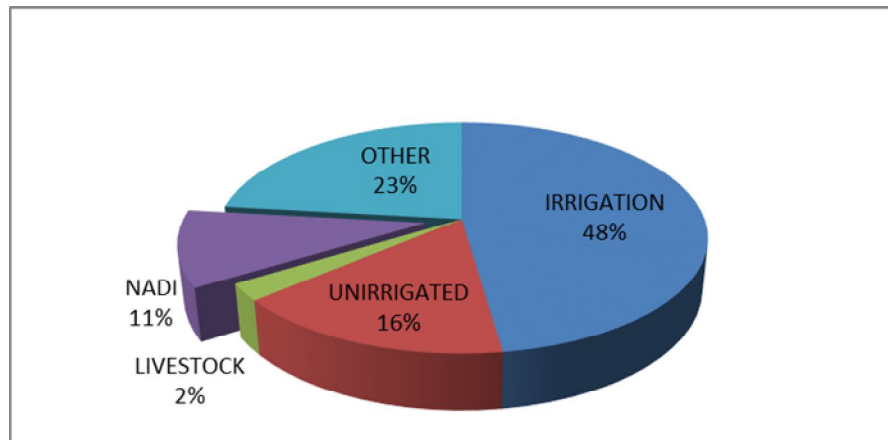
Nadi contributes to maximum share 21-23 % to total income of semi medium farmers in Shahapura and Suwana Panchayat Samitis, respectively. Whereas, in Baneda it contributes only 7 % to total income for small farmers. This may be contributed to grater water losses from Nadi due to light texture soils Thus farmers were generated income from other sources to meet out their needs. Similarly nadi contributes maximum share of 58 % to total income for large farmers in Baneda. This showed that larger farmers were totally depend on agriculture and successful crop production can be taken by providing supplemental irrigation to crops. Whereas reverse trend was observed in Shahapura and Suwana Panchayat Samitis. The possible reason for this was that farmers have the other land besides Nadi command area with well irrigation facilities. Therefore, decrease in land holding of farmers leads to increase income from Nadi and small farmers were having maximum shares of income from Nadi.

Thus, it can be concluded that income from Nadi cannot be over emphasized in the region. Income from Nadi can be increased by adoption of efficient cropping pattern and micro irrigation system to enhance productivity of land and water and also net returns.

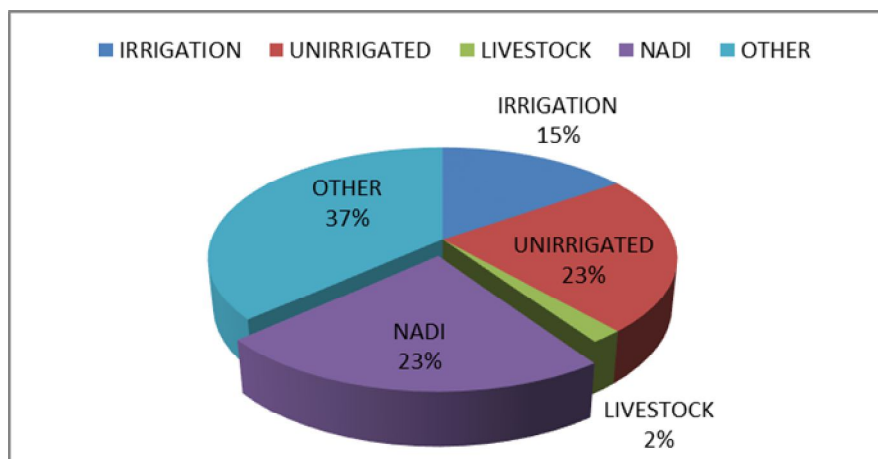




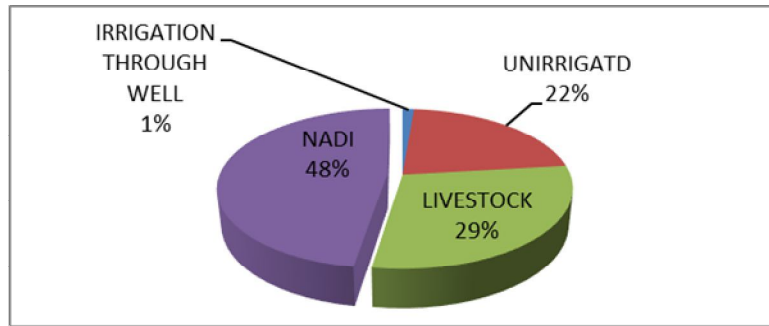
**Fig4.1(a): Annual income for large Farmers**



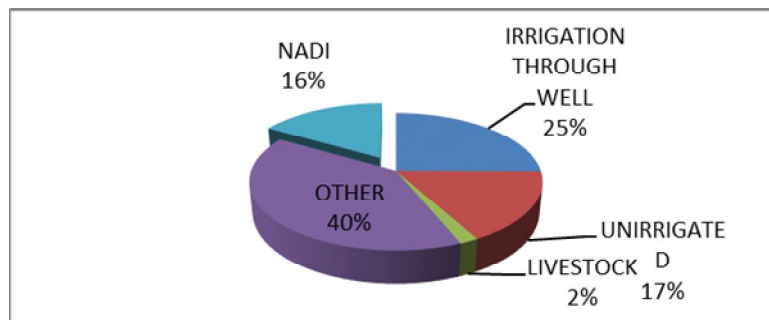
**Fig4.1(b): Annual income for medium Farmers**



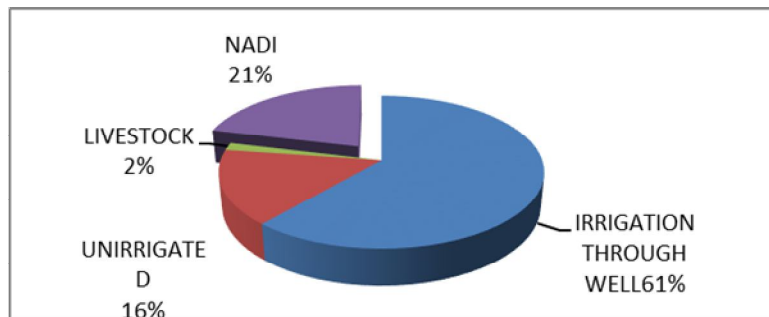
**Fig 4.1(c): Annual income for semi medium Farmers**



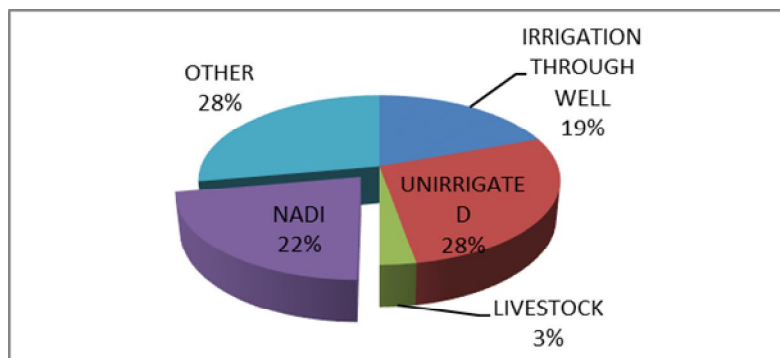
**Fig 4.2(a): Annual income for large Farmers**



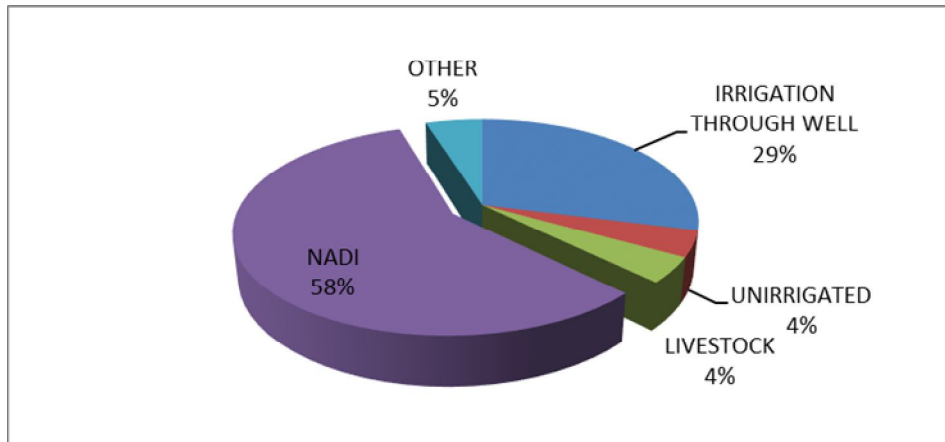
**Fig4.2(b): Annual income for medium Farmers**



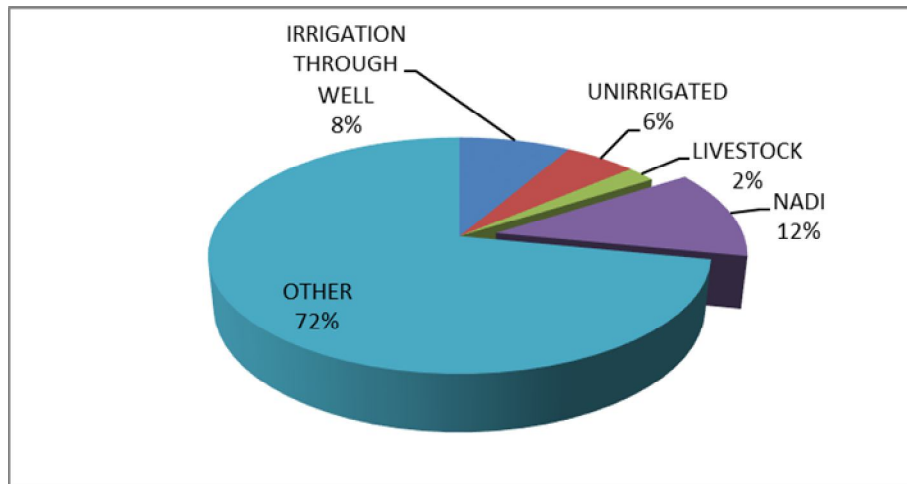
**Fig4.2(c): Annual income for semi medium Farmers**



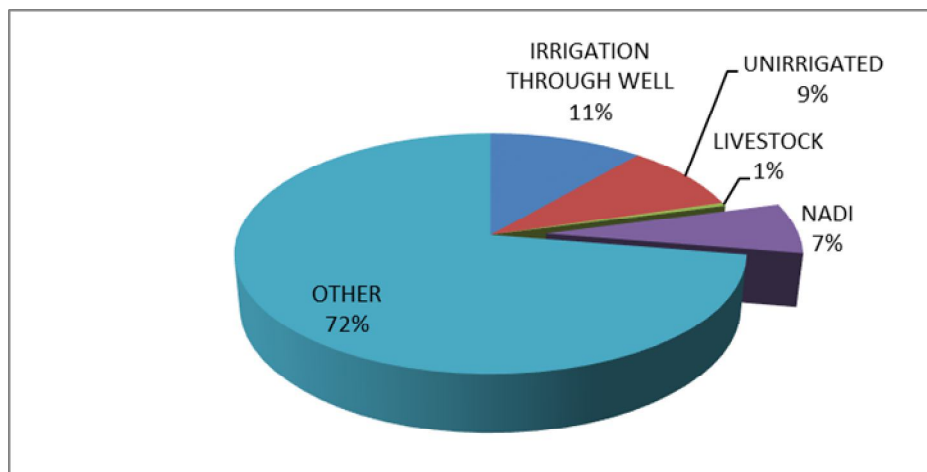
**Fig4.2(d): Annual income for small Farmer**



**Fig 4.3(a): Annual income for large Farmer**



**Fig 4.3(b): Annual income for medium Farmer**



**Fig4.3(c): Annual income for small Farmer**

## 4.2 CATCHMENT, STORAGE AND COMMAND AREA OF THREE SELECTED NADIS

Details of selected Nadis in each selected Panchayat Samiti were shown in Table 4.9.

**Table 4.9: Details of three selected Nadis**

S.No.	Location	Nadi characteristics			
		Catchment area (ha)	Storage area (ha)	Command area (ha)	Catchment command area ratio
1	Sidadiyas	50	4.043	11.5	4.35:1
2	Chalaniya	50	5.599	11.5	4.35:1
3	Baran	40	2.5	10.0	4:1

Results revealed that catchment command area ratio was varied from 4: to 4.35:1 for all the three selected Nadis. The maximum storage area (5.599 ha) was recorded in Chalaniya. Whereas least storage area was recorded in Baran. The catchment area of Nadi was varied from 40-50 ha in all the three selected Nadis.

## 4.3 PHYSICAL PROPERTIES OF SOILS OF THE STUDY AREA

**Table 4.10: Physical properties of soils of the study area**

Panchayat Samiti	Soil units	Soil texture	Depth(cm)	Average available water holding capacity(mm)
Banera	244,256	Fine loam and loam	100	120
Bhilwara	244,249	Fine loam and loam	100	120
Shahapura	244,249	Fine loam and loam	100	120

**Table 4.11: Physical properties of soil of all the three selected Nadis**

S.No	Location	Area	Texture	EC	PH	FC (%)	PWP (%)
1	Sidadiyas	Storage	Sandy clay loam	0.47	5.13	19.04	4.43
		Command	clay loam	0.15	6.13	26.51	10.64
2	Chalaniya	Storage	clay loam	0.80	6.51	23.44	11.39
		Command	clay loam	0.82	8.08	25.42	12.08

3	Baran	Storage	clay loam	0.72	7.77	20.90	5.57
		Command	clay loam	0.82	7.50	21.72	5.99

Physical properties of soils of the selected Panchayat Samitis were collected from National bureau from survey of India, Udaipur and is presented in Table 4.10. Results revealed that soil was fine loam and loam in texture at all three Panchayat Samitis. Soils of selected Panchayat Samitis is having depth of 100 cm and 120 mm average available water holding capacity (mm). Physical properties of soil of command area and storage area for all the three selected Nadi is shown in Table 4.11. Data on cropping pattern in VIII and IX plan was collected and is shown in Table 4.12. Results revealed that cropping pattern remains same more or less in both the plans.

**Table 4.12: Cropping Pattern of Bhilwara district**

	Crop	Plan VIII (1997-2002)	Plan IX (2002-2007)
Kharif (cereals)	Jowar	3.32	3.45
	Bajra	23.29	21.92
	Maize	4.63	4.43
	Small millets	0.12	0.12
Rabi (cereals)	Wheat	11.24	12.07
	Barley	1.04	0.99
	Gram	7.00	7.39
Food grains oilseeds Kharif	Sesame	2.13	1.97
	Groundnut	1.24	1.23
	Soybean	0.13	0.20
Food grains oilseeds	Rapseed&	12.02	11.63

Rabi	Mustard		
Other	Cotton	2.74	2.96

Source: State Department of Agriculture

#### 4.4 PROBABILITY ANALYSIS OF RAINFALL DATA

##### 4.4.1 Rainfall Data Analysis

Daily rainfall data of for a period 30 years (1981-2011) were collected from agrometrological observatory, Arjia, Bhilwara and for Sahapura and Baneda from Tehsil headquarters. These rainfall data were analysed for probability distribution using Weibull's technique. Probability analysis of rainfall was performed for all the three Nadis. Probability analysis for every rainy week (22-39) was performed. For estimation of runoff by SCS method. Rainfall at 80 per cent probability were considered for assured minimum runoff under different rainfall situations.

Probability analysis of Suwana, Shahapura and Baneda are shown in Table 4.13, Table 4.14 and Table 4.15, respectively. It is evident from Table 4.13, Table 4.14 and Table 4.15 that at 10 per cent probability Bhilwara was recorded highest rainfall i.e. 418.75 mm whereas lowest rainfall of 363.33 mm was recorded in Shahapura. At 20 per cent probability Shahapura is receiving highest rainfall of 252mm and Baneda is receiving lowest rainfall of 234mm. At 30 per cent probability, Bhilwara was received highest rainfall of 218mm whereas Shahapura received lowest rainfall of 146mm. At 40 per cent probability, Shahapura was received maximum rainfall of 206mm while Baneda received lowest rainfall of 114mm. At 50 per cent probability, Bhilwara was received highest rainfall of 103.72 mm whereas Shahapura is received lowest rainfall of 84.47 mm. At 60 per cent probability Baneda was received maximum rainfall of 79mm and Shahapura is receiving lowest rainfall of 51.92mm. At 70 per cent probability, Shahapura is receiving maximum rainfall of 66.03mm Baneda is receiving lowest rainfall of 33.62mm and similarly at 80 per cent probability Baneda is receiving highest rainfall of 19.2 mm whereas Shahapura is receiving lowest rainfall of 2.92 mm. At 90 per cent probability, Baneda was received highest rainfall of 17.02 mm whereas Shahapura received lowest rainfall of zero.

##### 4.4.2 Two Days Consecutive Rainfall

Two days maximum consecutive rainfall was recorded in Baneda Panchayat Samiti (1196.573 mm) while minimum was recorded in Shahapura (1022.76 mm). maximum mean rainfall was recorded in Baneda (597.9 mm) whereas minimum was recorded in Shahapura (509.45 mm). It can be concluded that Baneda was received maximum rainfall.

Similarly, 2 days consecutive rainfall and weekly maximum rainfall for Bhilwara district were forecasted probabilistically. The probabilities and recurrence intervals of maximum weekly rainfall for period 1981 to 2010 are shown in Table 4.11. Likewise probabilities and recurrence interval was calculated for every monsoon week (22<sup>nd</sup> to 39<sup>th</sup>) Rainfall in monsoon weeks (22<sup>nd</sup> to 39<sup>th</sup>) for 30 years were calculated at 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% probability levels and shown in Table (4.3). Rainfall at 80% probability level was considered for runoff estimation in all the Panchayat Samitis.

It is evident from Table 4.12 that the mean annual rainfall was found to be 637.28 mm for Suwana Panchayat Samiti. But maximum rainfall (1091.2mm) was occurred during the year 2006 which differed marginally with that of the year 1994 (1079.2 mm). Average rainy days was recorded in Suwana Panchayat Samiti, Shahapura Panchayat Samiti, Baneda Panchayat Samiti to be 32, 28 and 29 days, respectively.

#### **4.4.3 Annual Rainfall and Rainy Days**

Suwana Panchayat Samiti was recorded 41 days with maximum annual rainfall in 2006 year (Table 4.17). Whereas Shahapura and Baneda Panchayat Samiti was recorded 30 and 45 rainy days in 2006 year with maximum annual rainfall, respectively. Maximum annual rainfall with maximum rainy days was recorded in Suwana Panchayat Samiti. Whereas minimum mean annual rainfall (553.4 mm) and rainy days (28) was recorded for Suwana. It is evident from above discussion that Suwana Panchayat Samiti was recorded maximum rainfall. Maximum rainfall in Shahapura Panchayat Samiti was recorded during year 2004 (1026 mm) with 30 rainy days. Maximum rainy days 37 in Baneda Panchayat Samiti was recorded during the year 1994 with 580 mm annual rainfall.

Table 4.17 showed that of Suwana was recorded more rainy days than Shahapura and Baneda. Bhilwara was received more rainfall than that of other Panchayat Samitis. Value of annual Coefficient of variation for Bhilwara was more than Shahapura but Bhilwara was received more rainfall than other Panchayat Samitis. It indicates that rainfall was more erratic in nature in Bhilwara as compared to other Panchayat Samitis. Coefficient of variation for Shahapura is less but it has less coefficient of variation that means Shahapura will definitely

receive at least 1.70 mm rainfall. Higher monthly coefficient of variation was recorded in January month and it is higher for Bhilwara and lower for Baneda.

#### **4.4.4 Relationship Between Runoff, Catchment Area and Probability**

A graphical relationship was developed between runoff, catchment area and probability for all the three Panchayat Samitis and all shown in Fig 4.4, Fig 4.5 and Fig 4.6 For Suwana Panchayat Samiti; for 50 ha area and at 90 per cent probability level runoff will be  $153.95 \text{ m}^3$ , at 80 per cent probability level runoff recorded to be  $25120 \text{ m}^3$  and at 70 per cent probability level runoff recorded be  $205500 \text{ m}^3$ . For Shahapura Panchayat Samiti; for 50 ha area and at 90 per cent probability level runoff recorded to be  $3768 \text{ m}^3$ , at 80 per cent probability level runoff recorded to be  $60735 \text{ m}^3$  and at 70 per cent probability level runoff recorded to be  $122895 \text{ m}^3$ . For Baneda Panchayat Samiti; for 50 ha area and at 90 per cent probability level runoff recorded be  $2690 \text{ m}^3$ , at 80 per cent probability level runoff recorded to be  $20275 \text{ m}^3$  and at 70 per cent probability level runoff recorded be  $104650 \text{ m}^3$ .

**Table 4.13: Probability analysis of rainfall for Suwana Panchayat Samiti (1981-2010)**

<b>Weeks/ probability</b>	<b>10%</b>	<b>20%</b>	<b>30%</b>	<b>40%</b>	<b>50%</b>	<b>60%</b>	<b>70%</b>	<b>80%</b>	<b>90%</b>	<b>Two days consecutive mean</b>	<b>Daily data mean</b>
22	55.2	30	17.78	1.7	0	0	0	0	0	13.28	6.71
23	46.72	28.57	22.98	7.78	2.75	0	0	0	0	15.02	7.21
24	64.45	49.63	27.69	25.06	15.03	6.04	0	0	0	25.92	11.56
25	100.67	50.85	26.77	15.63	5.31	2.63	0.12	0	0	31.71	15.52
26	187.69	134.04	89.5	55.6	30.57	6.64	2.51	0	0	71.19	29.25
27	291.18	162.84	106.64	61.63	30.02	13.31	8.89	0	0	83.18	46.79
28	167.87	127.8	117.71	95.57	74.69	61.33	25.5	3.83	0.92	81.51	39.08
29	242.88	187.61	159.61	107.56	103.72	76.18	43.61	13.45	1.05	109.12	54.73
30	327.45	246.98	168.86	128.59	80.29	62.09	31.69	16.63	0	126.5	62.89
31	269.24	182.83	150.48	63.78	52.72	41.04	22.44	17.5	0.2	95.36	48.61
32	410.75	180.46	115.58	98.12	79.9	65.57	42.25	15.02	3.36	119.27	58.01
33	418.75	279.59	218.1	96.57	81.18	35.06	13.76	3.49	0	138.08	67.27
34	377.14	176.59	144.46	77.92	60.19	39.6	23.51	0	0	113.08	58.23
35	146.12	86.99	71.95	50.24	26.41	10.37	2.85	0	0	52.04	30.58
36	140.63	66.24	58.41	31.77	17.98	13.24	1.83	0	0	40.84	20.74
37	79.54	50.32	30.41	14.81	5.68	0	0	0	0	30.49	11.03
38	74.57	20.03	2.93	0	0	0	0	0	0	13.34	11.34
39	49.66	18.41	6.45	0	0	0	0	0	0	10.22	5.10
Sum	3450.51	2079.8	1536.31	932.33	666.44	433.1	218.96	69.92	5.53	1170.15	584.68

**Table 4.14: Probability analysis of rainfall for Shahapura Panchayat Samiti (1983-2010)**

<b>Week\probability</b>	<b>10%</b>	<b>20%</b>	<b>30%</b>	<b>40%</b>	<b>50%</b>	<b>60%</b>	<b>70%</b>	<b>80%</b>	<b>90%</b>	<b>Two days consecutive mean</b>	<b>Daily data mean</b>
22	48.39	30.84	14.89	3.35	0	0	0	0	0	15.27	212.5
23	37.21	10	2.76	0	0	0	0	0	0	7.87	98.5
24	115.42	55.07	30.28	18	10.61	4.67	0	0	0	25.45	396.6
25	91.29	43.14	25.38	13.4	4	0	0	0	0	24.48	360.4
26	208.92	104.92	76.16	37	26.92	16.61	5.78	0	0	55.78	633
27	154.06	102.9	63.8	47.3	37.92	19.85	6.01	0	0	89.78	1471
28	234.06	145.33	109	95.85	57.43	35.85	6.02	0	0	89.53	1319.5
29	269.07	160.38	131.38	206.33	84.47	30.54	66.03	2.92	0	108.77	1614
30	258.64	177.38	134.76	112.54	78.3	51.92	18.33	0.61	0	107.67	1673.5
31	183.33	134.73	108.59	78.33	58.57	37.92	12.095	0.61	0	76.67	1079.5
32	239.33	161.9	97.071	61.85	51.98	29.61	16.16	0.92	0	80.13	1119
33	363.89	217.85	146.09	107.619	61.3	30.61	10.61	0	0	123.03	1868
34	195.9	145.4	79.49	37.71	24.47	7.85	1.54	0	0	75.98	1273.5
35	157.07	252.71	84.21	54.3	38.3	1.54	0	0	0	52.22	803.5
36	148.44	82.02	37.59	23.65	20.61	0.61	0	0	0	39.55	612.5
37	74.73	39.13	14.76	8.61	0	0	0	0	0	24.32	356.5
38	55.66	17.59	6.69	0	0	0	0	0	0	12.83	215
39	27.52	12.69	7.69	2.61	0	0	0	0	0	13.43	177
Sum	2862.93	1893.98	1170.591	908.449	554.88	267.58	142.575	5.06	0	1022.76	509.45

**Table 4.15: Probability analysis of rainfall for Baneda Panchayat Samiti (1981-2010)**

Weeks/ probability	10%	20%	30%	40%	50%	60%	70%	80%	90%	Two days consecutive mean	Daily data mean
22	45.15	27.1	12.21	2.76	0	0	0	0	0	13.75333	7.026
23	42.63	30.76	19.38	10.14	0	0	0	0	0	14.14667	6.44
24	84.68	54.76	26.76	21.38	17.51	14.78	0	0	0	23.56667	11.6
25	114.06	56.28	31.07	14.07	5.75	2.61	0	0	0	32.33333	15.4
26	165.36	95.69	76.11	40	25.82	15.85	9.54	2.61	0	53.47333	25.42
27	289.4	132.87	99.45	79.52	57.23	23.54	8.61	0	0	86.53333	44
28	220.02	156	114.43	94.9	75.72	31.3	13	0	0	103.3	48.16
29	245.58	201	141.66	105.38	84.89	79.31	32.62	17.09	17.02	100.0667	52.63
30	246	186.9	153.13	114.14	91.11	54.95	25.23	19.2	0	123.5667	60.35
31	190.87	148.35	117.76	106.76	95.38	61.3	31.97	15.85	2.61	93.49333	47.48
32	238.85	202.85	152.14	112.35	98.52	67.85	20.3	1.3	0	110.68	54.27
33	288.11	234.66	172.21	98.71	43.12	24.16	15.16	3.92	0	115	57.55
34	365.02	156.83	129.38	91.21	57.07	55.86	23.92	0	0	110.5333	53.7
35	178	146.71	93.97	57.38	48.42	32.3	28.95	0	0	67.83333	40.21
36	129.49	66.65	34	25.45	14	1.3	0	0	0	38.71333	17.19
37	129.64	61.28	16.9	5.07	0	0	0	0	0	50.33333	19.23
38	168.71	76.21	21.66	8	5.07	0	0	0	0	44.1	27.3
39	46.14	15.07	7.57	0.69	0	0	0	0	0	15.14667	9.94
Sum	3187.71	2049.97	1419.79	987.91	719.61	465.11	209.3	59.97	19.63	1196.573	597.9

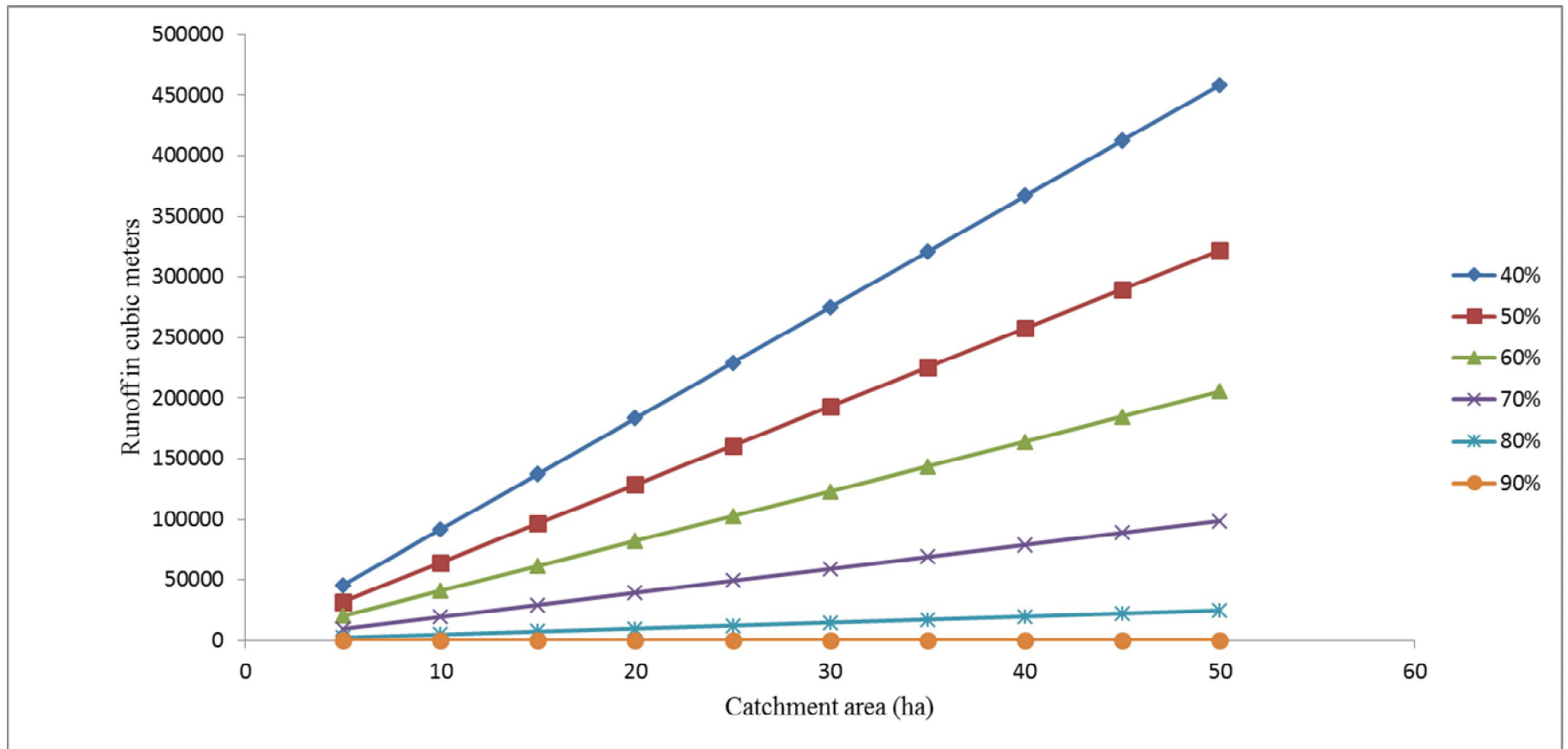
**Table 4.16: Probabilities and recurrence interval of rainfall for Suwana Panchayat Samiti**

Years	Rainfall	decreasing order	rank(M)	$P= M/(N+1)$	$T= 1/P$	%P
1981	1.4	74.4	1	0.03	31.00	3.23

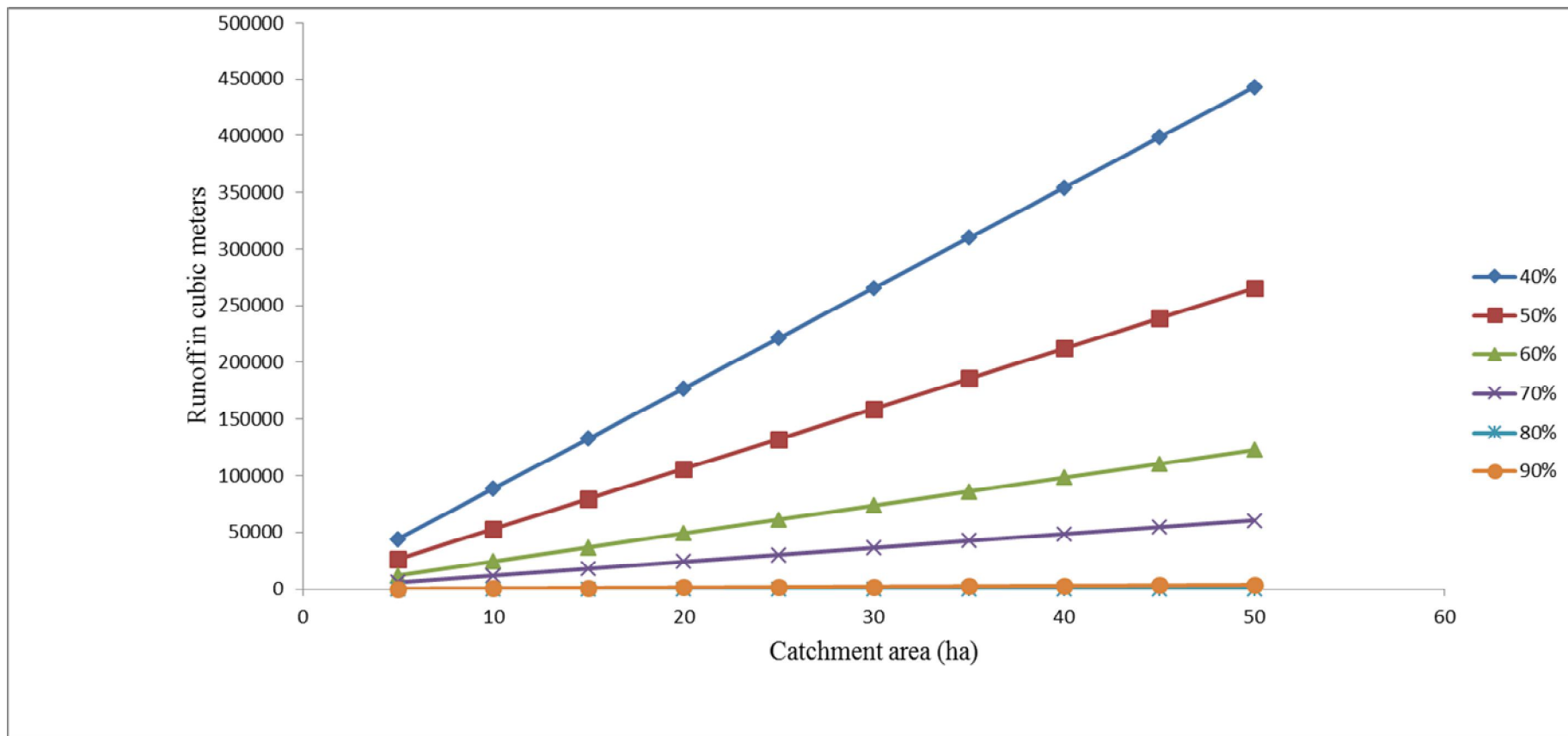
1982	2.4	67.2	2	0.06	15.50	6.45
1983	0	55.2	3	0.10	10.33	9.68
1984	0	55.2	4	0.13	7.75	12.90
1985	20.8	44	5	0.16	6.20	16.13
1986	33.6	33.6	6	0.19	5.17	19.35
1987	0	20.8	7	0.23	4.43	22.58
1988	0	18.6	8	0.26	3.88	25.81
1989	14	14	9	0.29	3.44	29.03
1990	0	8.7	10	0.32	3.10	32.26
1991	0	3	11	0.35	2.82	35.48
1992	8.7	2.4	12	0.39	2.58	38.71
1993	0	1.4	13	0.42	2.38	41.94
1994	0	0	14	0.45	2.21	45.16
1995	0	0	15	0.48	2.07	48.39
1996	0	0	16	0.52	1.94	51.61
1997	55.2	0	17	0.55	1.82	54.84
1998	0	0	18	0.58	1.72	58.06
1999	0	0	19	0.61	1.63	61.29
2000	0	0	20	0.65	1.55	64.52
2001	18.6	0	21	0.68	1.48	67.74
2002	55.2	0	22	0.71	1.41	70.97
2003	0	0	23	0.74	1.35	74.19
2004	0	0	24	0.77	1.29	77.42
2005	0	0	25	0.81	1.24	80.65
2006	67.2	0	26	0.84	1.19	83.87
2007	3	0	27	0.87	1.15	87.10
2008	74.4	0	28	0.90	1.11	90.32
2009	44	0	29	0.94	1.07	93.55
2010	0	0	30	0.97	1.03	96.77

**Table 4.17: Annual rainfall and rainy days in three selected Panchayat Samitis of Bhilwara district**

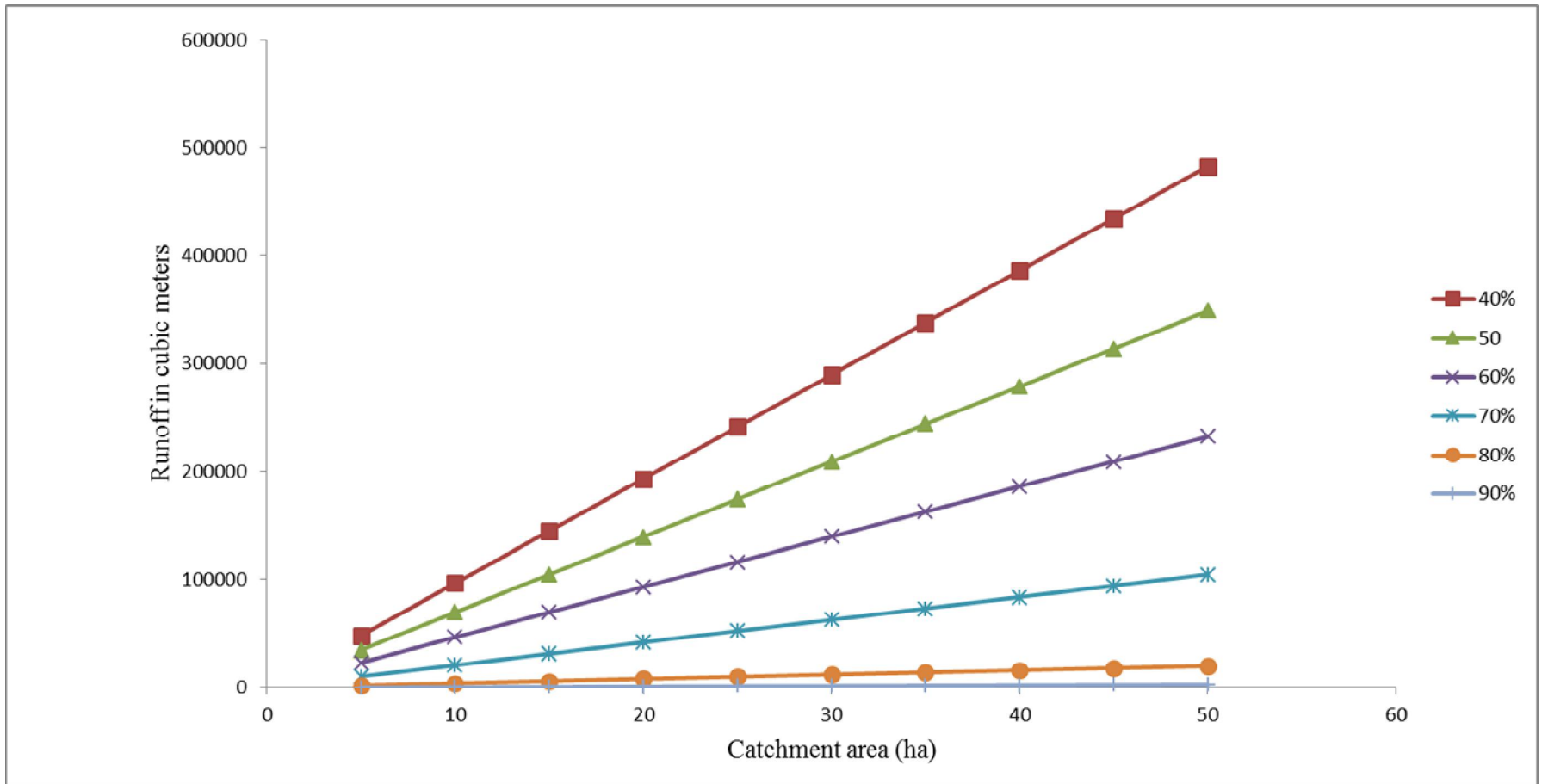
Suwana			Shahapura			Baneda		
Year	Rainfall	Rainy days	Year	Rainfall	Rainy days	Year	Rainfall	Rainy days
1981	451.8	24	1983	663	44	1981	508	26
1982	912.1	36	1984	477	24	1982	711	25
1983	913.41	38	1985	547	32	1983	874	37
1984	634	29	1986	679	33	1984	546	25
1985	471.6	30	1987	647	28	1985	668	30
1986	592.7	35	1988	672	30	1986	625	28
1987	509.7	21	1989	730	30	1987	429	18
1988	387.5	16	1990	730	38	1988	372	28
1989	916.7	37	1991	585	30	1989	840.4	34
1990	761.8	38	1992	560	25	1990	726	35
1991	675.9	26	1993	526	27	1991	620	29
1992	730.3	34	1994	818	52	1992	465	27
1993	310.4	18	1995	456.5	24	1993	447	24
1994	1079.2	40	1996	879	41	1994	580	37
1995	449.7	29	1997	664	42	1995	387	22
1996	880.8	37	1998	399	25	1996	783.2	33
1997	640.4	33	1999	443	23	1997	800	26
1998	510.3	33	2000	496	25	1998	563	31
1999	536.1	22	2001	603	19	1999	589	36
2000	432	22	2002	186	15	2000	560	23
2001	765.8	31	2003	379	35	2001	715.7	31
2002	307.1	21	2004	1026	30	2002	271	19
2003	491.4	32	2005	550	31`	2003	470	31
2004	1000.2	39	2006	640	30	2004	976	31
2005	419.2	32	2007	593	26	2005	494	27
2006	1091.2	41	2008	573	27	2006	983	45
2007	442.6	24	2009	454	25	2007	385	26
2008	700.6	35				2008	611	28
2009	347.2	22	2010	625	40	2009	243	15
2010	792.8	41				2010	675	38
	637.2	32		553.4	28		597.2	29



**Fig4.4 : Relationship between runoff and catchment area at different probabilities for Suwana Panchayat Samiti**



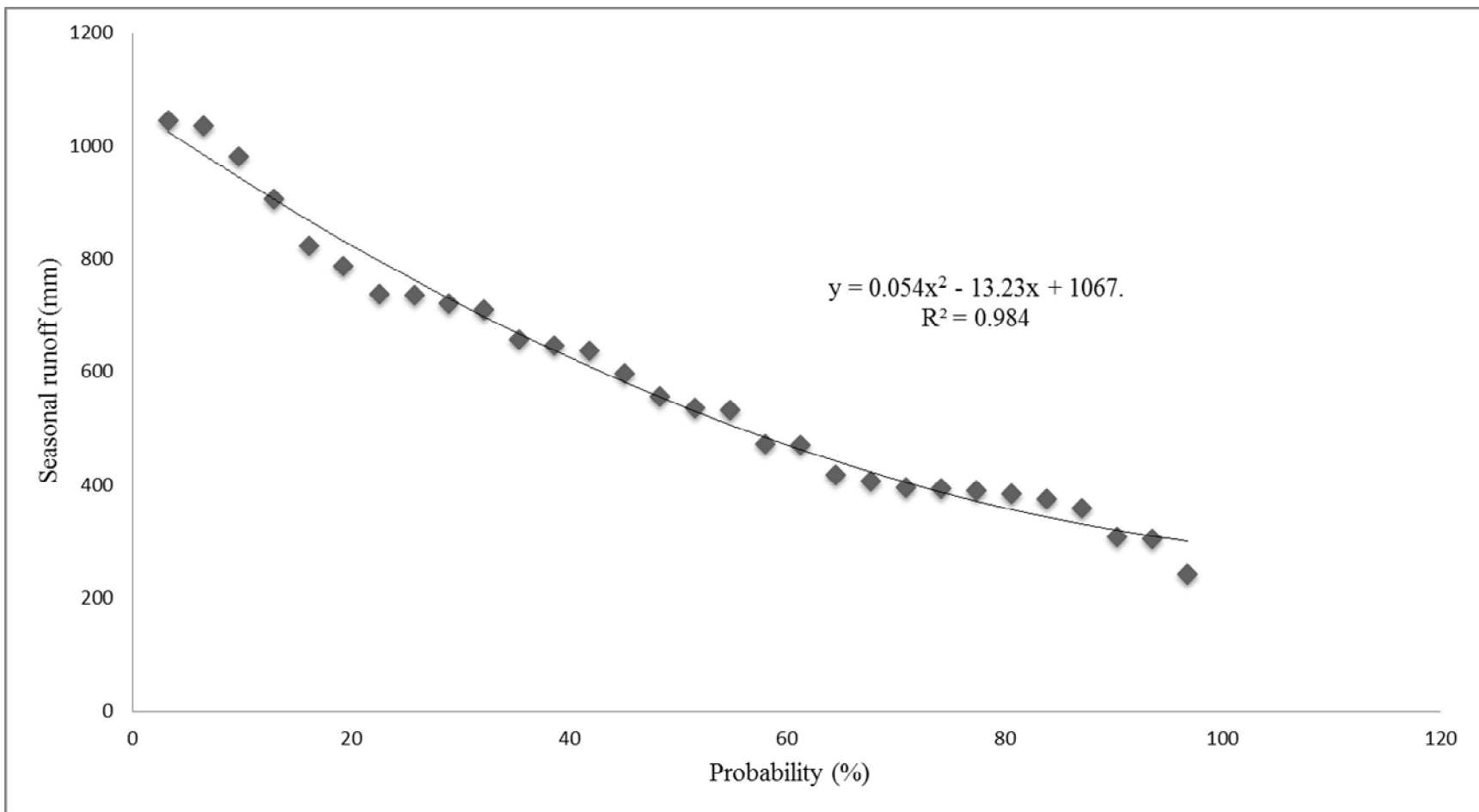
**Fig 4.5: Relationship between runoff and catchment area at different probabilities for Shahapura Panchayat Samiti**



**Fig 4.6: Relationship between runoff and catchment area at different probabilities for Baneda Panchayat Samiti**

**Table 4.18: Seasonal runoff for Suwana Panchayat Samiti**

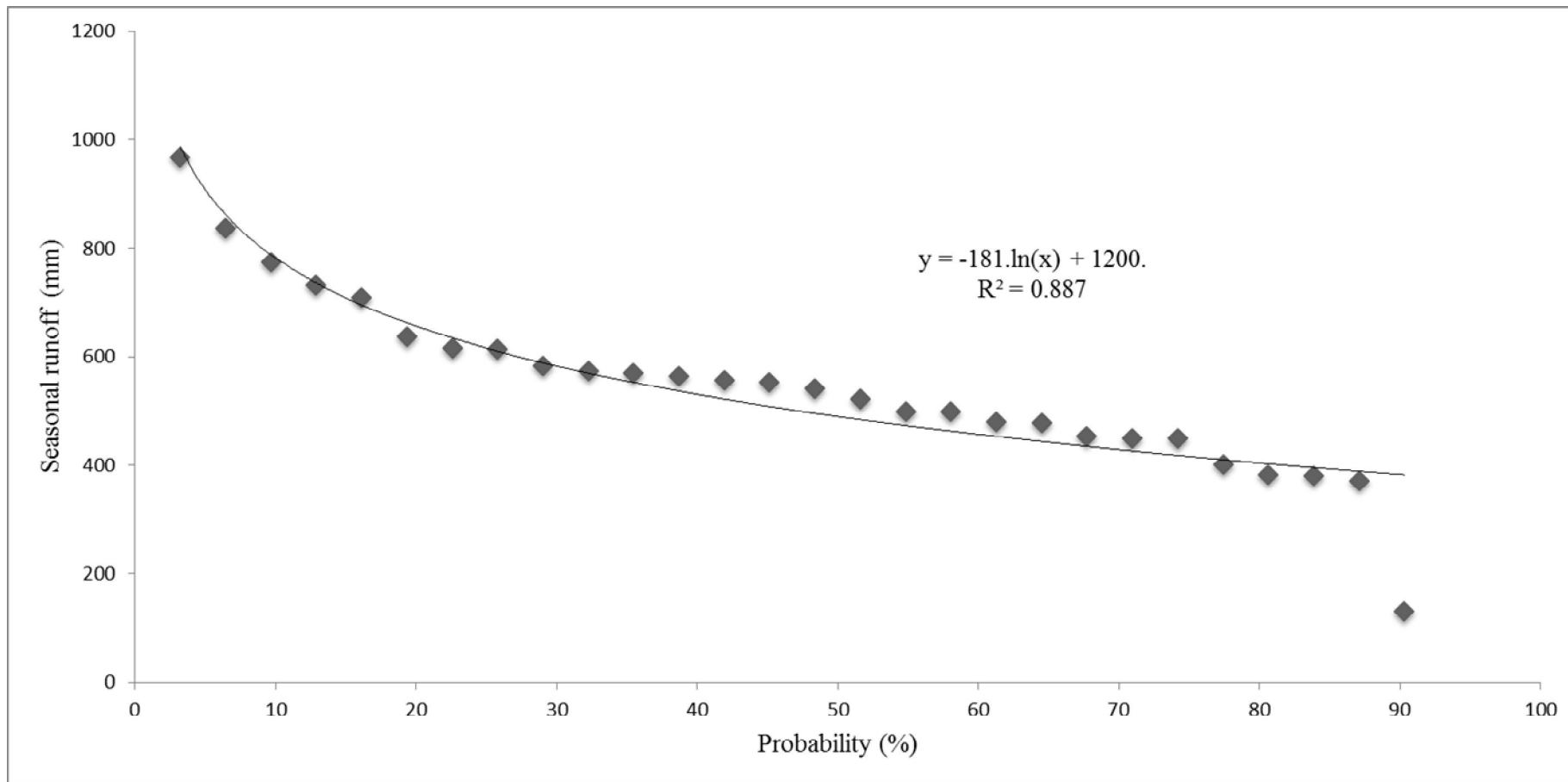
<b>Year</b>	<b>Runoff (m<sup>3</sup>)</b>	<b>Decreasing order</b>	<b>Rank(M)</b>	<b>P= M/(N+1)</b>	<b>T= 1/P</b>	<b>%P</b>
1981	375.96	1044.06	1	0.03	31.00	3.23
1982	710.41	1035.46	2	0.06	15.50	6.45
1983	786.71	981.07	3	0.10	10.33	9.68
1984	786.71	905.1	4	0.13	7.75	12.90
1985	393.24	823.49	5	0.16	6.20	16.13
1986	533.07	786.71	6	0.19	5.17	19.35
1987	470.79	737.1	7	0.23	4.43	22.58
1988	389.55	735.2	8	0.26	3.88	25.81
1989	905.1	721.31	9	0.29	3.44	29.03
1990	735.2	710.41	10	0.32	3.10	32.26
1991	656.53	656.53	11	0.35	2.82	35.48
1992	721.31	646.53	12	0.39	2.58	38.71
1993	307.83	636.73	13	0.42	2.38	41.94
1994	1044.06	595.74	14	0.45	2.21	45.16
1995	393.24	556.55	15	0.48	2.07	48.39
1996	823.49	536.66	16	0.52	1.94	51.61
1997	556.55	533.07	17	0.55	1.82	54.84
1998	359.57	472.29	18	0.58	1.72	58.06
1999	533.07	470.79	19	0.61	1.63	61.29
2000	416.63	416.63	20	0.65	1.55	64.52
2001	735.2	406.23	21	0.68	1.48	67.74
2002	242.14	395.34	22	0.71	1.41	70.97
2003	470.79	393.24	23	0.74	1.35	74.19
2004	981.07	389.55	24	0.77	1.29	77.42
2005	383.85	383.85	25	0.81	1.24	80.65
2006	1035.46	375.96	26	0.84	1.19	83.87
2007	406.23	359.57	27	0.87	1.15	87.10
2008	646.53	307.83	28	0.90	1.11	90.32
2009	303.73	303.73	29	0.94	1.07	93.55
2010	595.74	242.14	30	0.97	1.03	96.77



**Fig 4.7: Seasonal runoff (mm) at different probability (%) for Suwana Panchayat Samiti**

**Table 4.19: Seasonal runoff for Shahapura Panchayat Samiti**

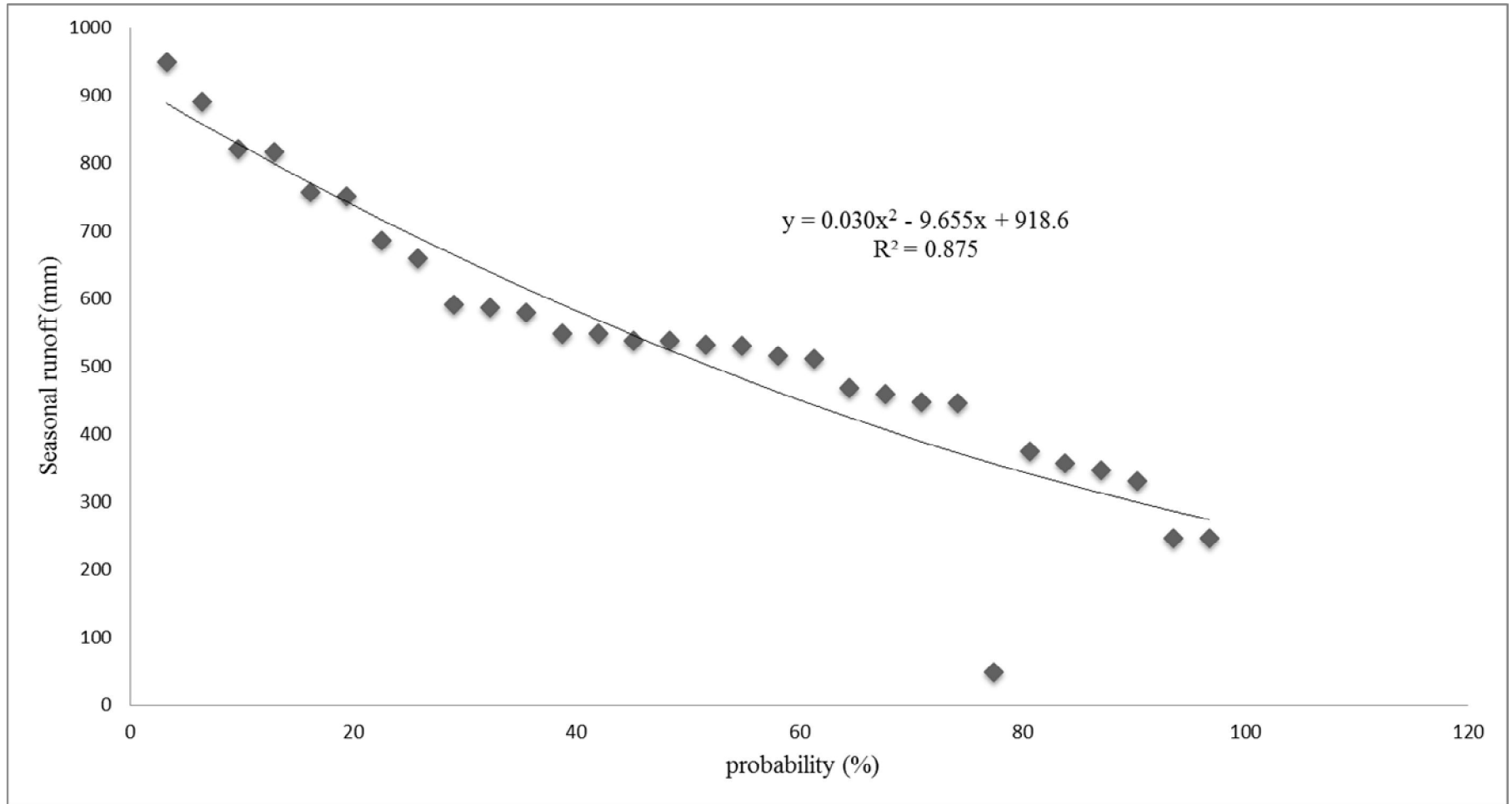
<b>Year</b>	<b>Runoff (m<sup>3</sup>)</b>	<b>Decreasing order</b>	<b>Rank(M)</b>	<b>P= M/(N+1)</b>	<b>T= 1/P</b>	<b>%P</b>
1983	612.74	967.67	3	0.10	10.33	3.23
1984	479.79	837.69	4	0.13	7.75	6.45
1985	452.8	773.7	5	0.16	6.20	9.68
1986	635.73	732.71	6	0.19	5.17	12.90
1987	499.78	709.71	7	0.23	4.43	16.13
1988	573.75	635.73	8	0.26	3.88	19.35
1989	732.71	614.74	9	0.29	3.44	22.58
1990	709.71	612.74	10	0.32	3.10	25.81
1991	552.76	583.25	11	0.35	2.82	29.03
1992	540.76	573.75	12	0.39	2.58	32.26
1993	499.78	569.75	13	0.42	2.38	35.48
1994	773.7	564.75	14	0.45	2.21	38.71
1995	380.85	556.76	15	0.48	2.07	41.94
1996	837.69	552.76	16	0.52	1.94	45.16
1997	583.25	540.76	17	0.55	1.82	48.39
1998	371.86	521.77	18	0.58	1.72	51.61
1999	401.84	499.78	19	0.61	1.63	54.84
2000	477.77	499.78	20	0.65	1.55	58.06
2001	556.76	479.79	21	0.68	1.48	61.29
2002	129.54	477.77	22	0.71	1.41	64.52
2003	381.85	452.8	23	0.74	1.35	67.74
2004	967.67	448.81	24	0.77	1.29	70.97
2005	521.77	448.81	25	0.81	1.24	74.19
2006	614.74	401.84	26	0.84	1.19	77.42
2007	569.75	381.85	27	0.87	1.15	80.65
2008	564.75	380.85	28	0.90	1.11	83.87
2009	448.81	371.86	29	0.94	1.07	87.10
2010	448.81	129.54	30	0.97	1.03	90.32



**Fig 4.8: Seasonal runoff (mm) at different probability (%) for Shahapura Panchayat Samiti**

**Table 4.20: Seasonal runoff for Baneda Panchayat Samiti**

Year	Runoff (m <sup>3</sup> )	decreasing order	Rank(M)	P= M/(N+1)	T= 1/P	%P
1981	510.7	947	1	0.03	31.00	3.23
1982	537.7	888	2	0.06	15.50	6.45
1983	820.6	818	3	0.10	10.33	9.68
1984	548.7	813.4	4	0.13	7.75	12.90
1985	548.75	755	5	0.16	6.20	16.13
1986	578.75	748	6	0.19	5.17	19.35
1987	374.8	683	7	0.23	4.43	22.58
1988	346.8	656	8	0.26	3.88	25.81
1989	816.09	588	9	0.29	3.44	29.03
1990	685.7	584	10	0.32	3.10	32.26
1991	590.7	576	11	0.35	2.82	35.48
1992	459.8	546	12	0.39	2.58	38.71
1993	447.8	546	13	0.42	2.38	41.94
1994	531.7	535	14	0.45	2.21	45.16
1995	329.9	535	15	0.48	2.07	48.39
1996	757.7	529	16	0.52	1.94	51.61
1997	750.7	528	17	0.55	1.82	54.84
1998	48.94	513	18	0.58	1.72	58.06
1999	537.7	508	19	0.61	1.63	61.29
2000	530.7	466	20	0.65	1.55	64.52
2001	658.7	457	21	0.68	1.48	67.74
2002	246.2	445	22	0.71	1.41	70.97
2003	445.81	443	23	0.74	1.35	74.19
2004	949.6	420	24	0.77	1.29	77.42
2005	468.8	372	25	0.81	1.24	80.65
2006	890.6	354	26	0.84	1.19	83.87
2007	356.8	344	27	0.87	1.15	87.10
2008	586.7	327	28	0.90	1.11	90.32
2009	246	243.2	29	0.94	1.07	93.55
2010	515.7	243	30	0.97	1.03	96.77



**Fig 4.9: Seasonal runoff (mm) at different probability (%) for Baneda Panchayat Samiti**

**Table 4.21:Runoff models for different Panchayat Samitis**

S.No	Location	$(R^2)$ Coefficient of determination					Best fit
		Exponential	Linear	Logarithmic	Polynomial	Power	
1.	Suwana	0.981	0.955	0.94	0.984	0.83	Polynomial
2.	Shahapura	0.715	0.862	0.887	0.87	0.605	Logarithmic
3.	Baneda	0.533	0.863	0.836	0.875	0.440	Polynomial

**Table: 4.22: Mean monthly rainfall and coefficient variation for three selected Panchayat Samitis in Bhilwara district**

Month	Suwana			Shahapura			Baneda		
	Mean rainfall(mm)	SD (mm)	Cv (%)	Mean rainfall (mm)	SD (mm)	Cv (%)	Mean rainfall (mm)	SD (mm)	Cv (%)
Jan	3.046	7.94	260.77	3.67	9.42	256.795	5.46	11.38	208.4
Feb	5.26	10.72	203.8	7.28	11.66	160.272	11.86	15.25	128.63
March	4.36	11.64	267	3.5	8.3	237.364	2.83	10.3	363.78
April	7.32	11.98	163	7.44	10.8	145.2624	5.83	9.58	164.31
May	9.48	56.26	593	7.875	13.96	177.27	9.54	48.6	509.011
June	62.66	57.91	92.4	55.32	42.6	77.01	53.45	47.26	88.42
July	225.68	112.21	49.7	225.39	103.8	46	212.16	99.42	46.86
August	237.59	168.09	70.7	198.37	163	82.17	221.96	149.29	67.26
Sept	56.39	54.16	91.1	54.07	56.24	104	56.56	64.8	114.57
Oct	11.09	25.49	229	9.25	15.4	166.5	7.4	20.27	273.96
Nov	10.72	34.56	322	5.39	25.53	473.35	16.2	34.53	213.2
Dec	4.98	11.62	233	3.89	11.31	290.86	3.23	9.26	286.84
Annual	637.28	624	98	553.35	167.28	28	597.24	499	83
Rainy days	32	19.20	62.89	28	11.08	40.56	29	16.42	56.97

#### 4.4.5 Best Fit Distribution for Panchayat Samitis

Best fit distribution was selected based on the chi-square test. Different distribution were fit to all the selected three Panchayat Samitis and is given in Table 4.22. For Suwana Panchayat Samiti best fit distributions are Log Gaussian, Inverted Gamma (Pearson Type V) Frechet (Extreme value type I) for maxima and Weibull (Extreme value type III) for minima. Shahapura Panchayat Samiti best fit distribution was Weibull (Extreme value type III) for minima. Baneda Panchayat Samiti best fit distribution was Log Gaussian and Weibull (Extreme value type III) for minima.

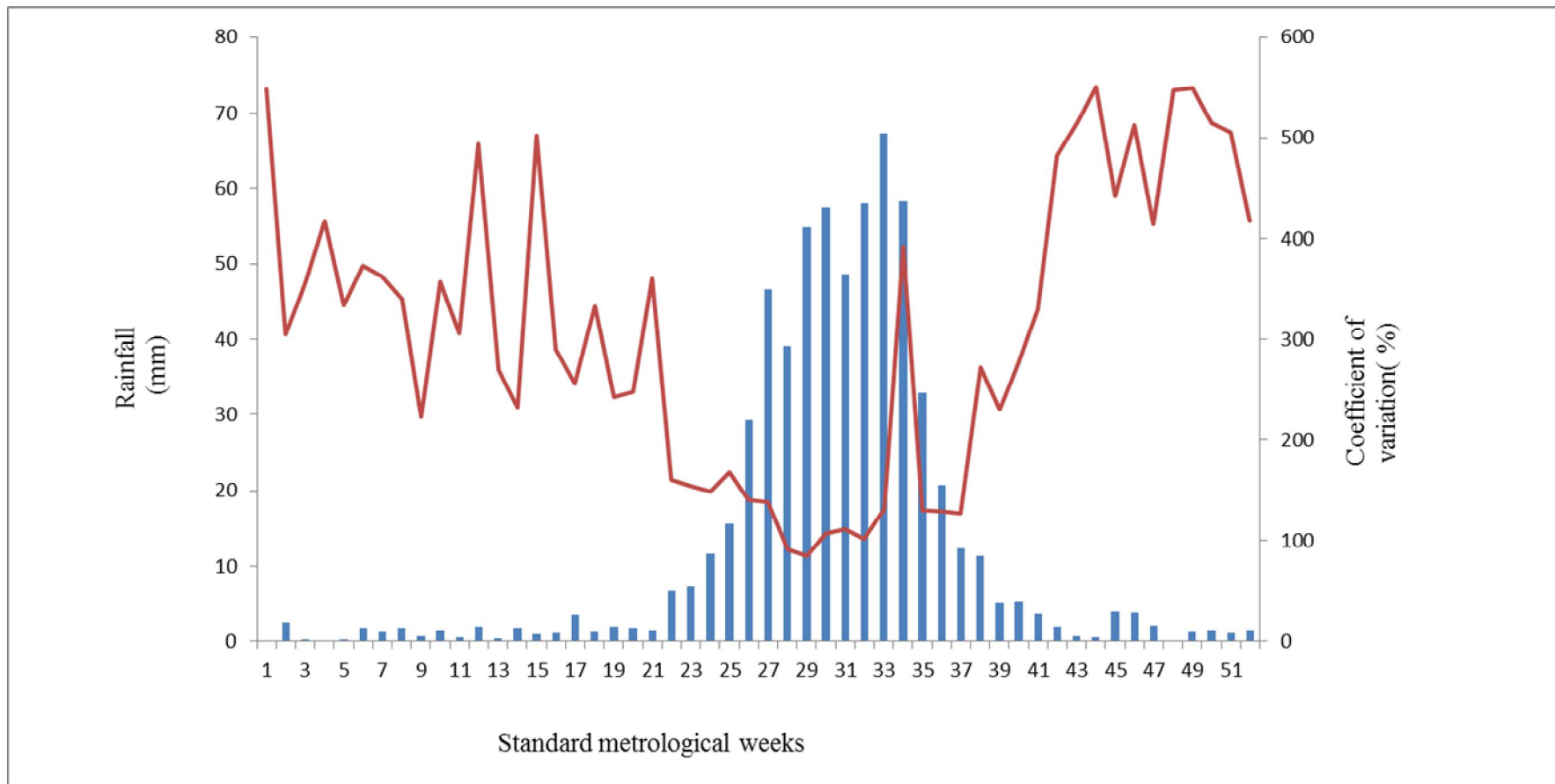
#### 4.4.6 Coefficient of Variation

Minimum coefficient of variation was recorded for all the Panchayat Samiti and from which we can say that rainfall was more stable for month of July (Table 4.22). In month of May Bhilwara and Baneda possesses very high coefficient of variation which denotes that in month of May nature of rainfall was erratic. Also for month of Jan., Feb., March, Nov., Dec. value of coefficient of variation was relatively more. It indicates that rainfall for these months were uneven. For rainy months value of coefficient of variation has less value than that of other months.

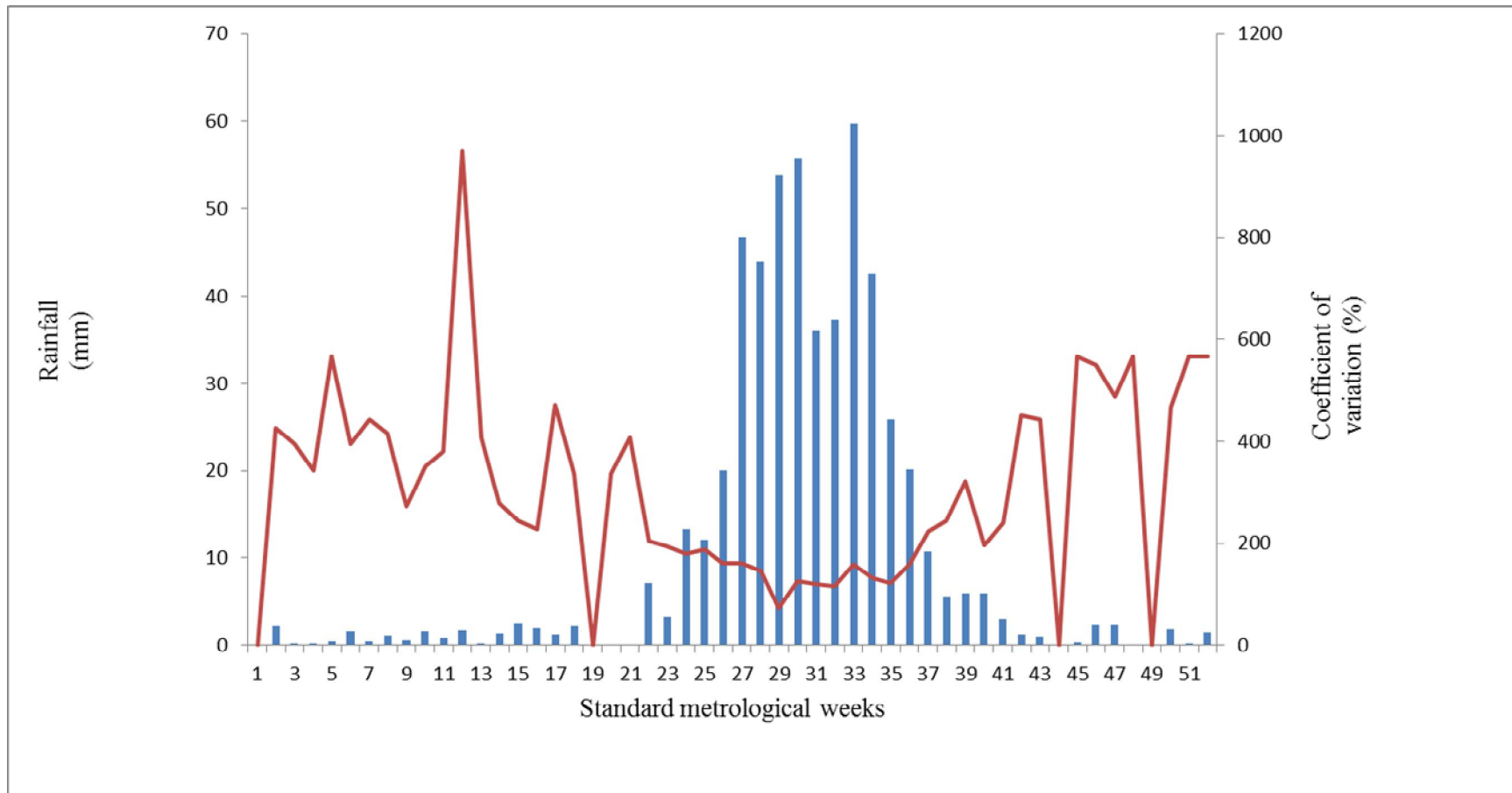
Fig 4.10, Fig 4.11, Fig 4.12 showed relation between rainfall and coefficient of variation. For first week coefficient of variation has more value for Bhilwara and has zero value for Shahapura. For 10<sup>th</sup> week Baneda has more value coefficient of variation whereas Shahapura has less value of coefficient of variation. For 20<sup>th</sup> week coefficient of variation has more value for Shahapura and less value for Baneda. For 30<sup>th</sup> week Shahapura has greater value of coefficient of variation and Bhilwara has lower value. For 40<sup>th</sup> week Baneda has more value of coefficient of variation and Shahapura has less value of coefficient of variation. For 52<sup>nd</sup> week Shahapura has more value of coefficient of variation and Bhilwara has low value.

#### 4.4.7 Rainfall Runoff Models for Panchayat Samitis

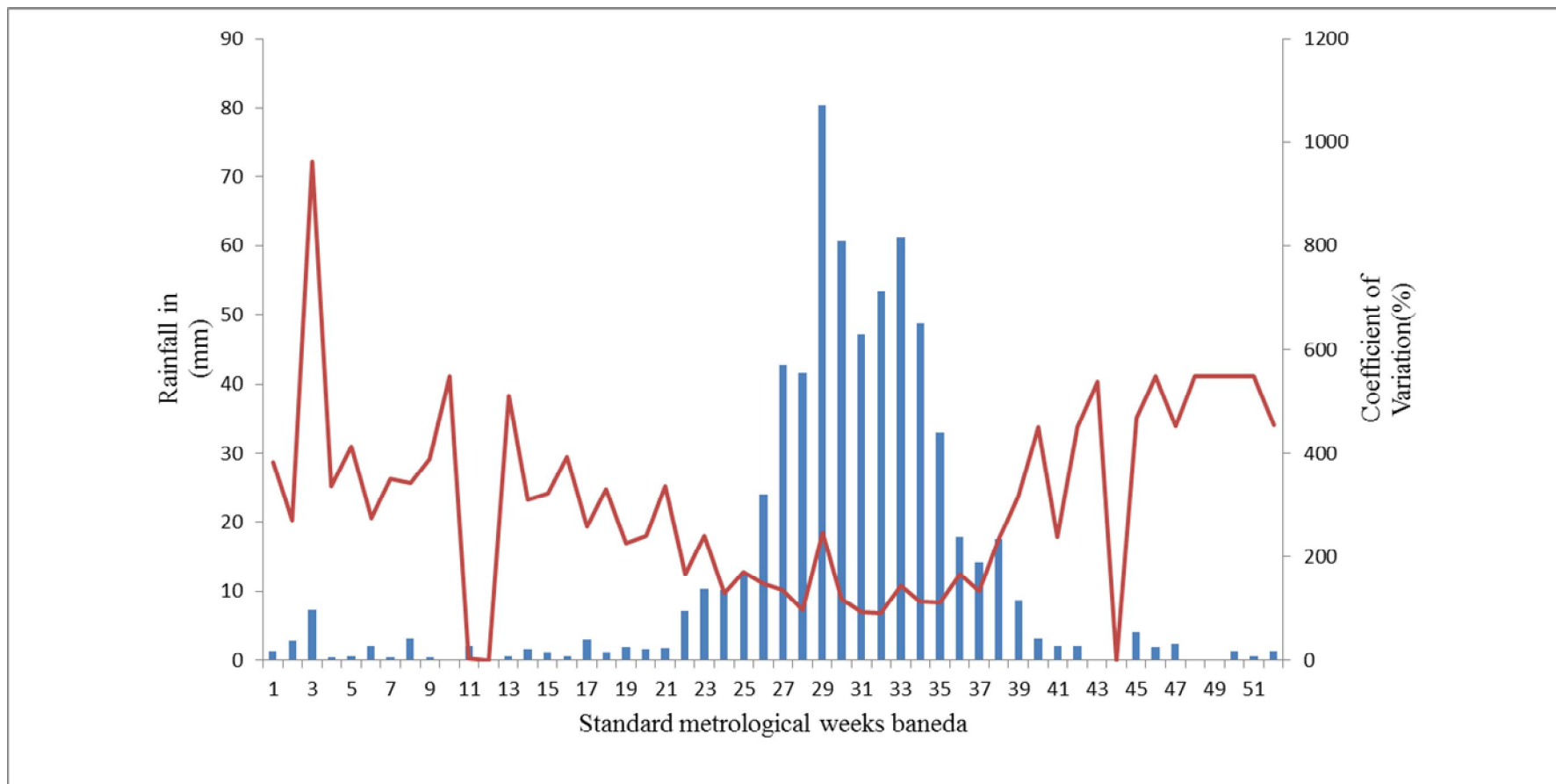
Rainfall runoff models have been developed for prediction of runoff in all the three selected three Panchayat Samitis. The best model was selected based on coefficient of determination ( $R^2$ ) and is shown in Table 4.21. Results revealed that polynomial model was found best for runoff prediction in Suwana Panchayat Samitis. Similarly, logarithmic and polynomial model was found best for runoff prediction in Shahapura and Baneda Panchayati, Samiti, respectively.



**Fig 4.10: Mean weekly rainfall and coefficient of variation for Suwana Panchayat samiti**



**Fig 4.11: Mean weekly rainfall and coefficient of variation for Shahapura Panchayat samiti**



**Fig 4.12: Mean weekly rainfall and coefficient of variation for Baneda Panchayat samiti**

**Table 4.23: Distribution for three Panchayat Samitis**

S.No	Particular	Suwana	Shahapura	Baneda
1	Gaussian	12.66	12.66	8.66
2	Log Gaussian	2	NA	0.66
3	Three parameter log Gaussian	NA	NA	NA
4	Exponential	NA	12.66	8.66
5	Shifted Exponential	12.66	12.66	NA
6	Beta	NA	NA	6
7	Gamma	8.66	8.66	6
8	Three parameter Gamma (Pearson Type III)	12.66	12.66	8.66
9	Log- Pearson Type III (Log Gamma)	NA	NA	NA
10	Inverted Gamma (Pearson Type V)	2	NA	NA
11	Gumbel (Extreme value type I) for minima	12.66	12.66	8.66
12	Gumbel (Extreme value type II) for maxima	12.66	NA	8.66
13	Frechet (Extreme value type I) for minima	18	NA	8.66
14	Frechet (Extreme value type I) for maxima	2	NA	2
15	Three parameter Frechet for maxima	12.66	12.66	4.66
16	Weibull (Extreme value type III) for maxima	NA	NA	NA
17	Weibull (Extreme value type III) for minima	2	0.66	0.66
18	Three parameter Weibull for minima	18	18	18

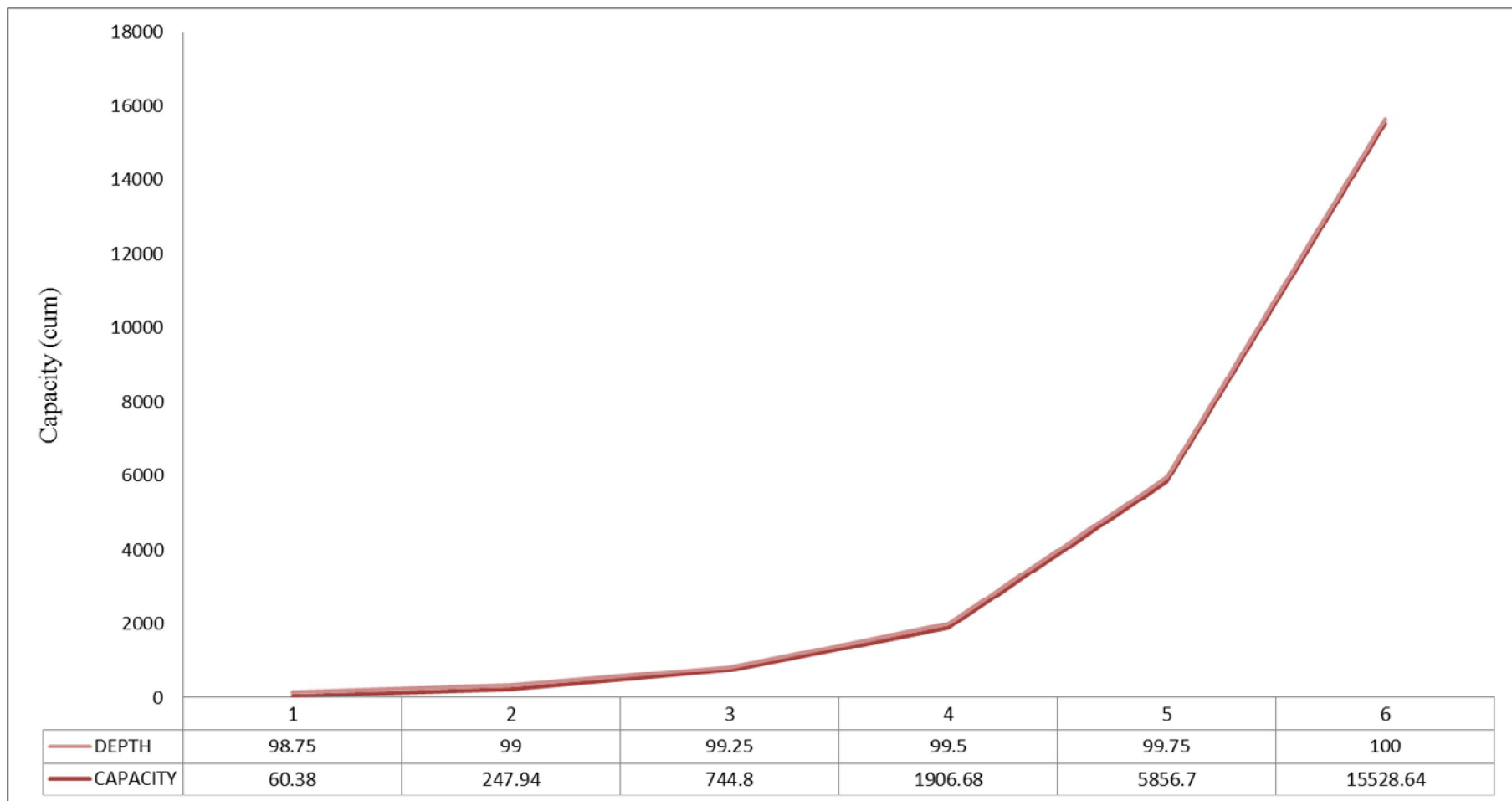
**4.5 ESTIMATION AND ANALYSIS OF RUNOFF**

#### 4.5.1 Depth Capacity Curve

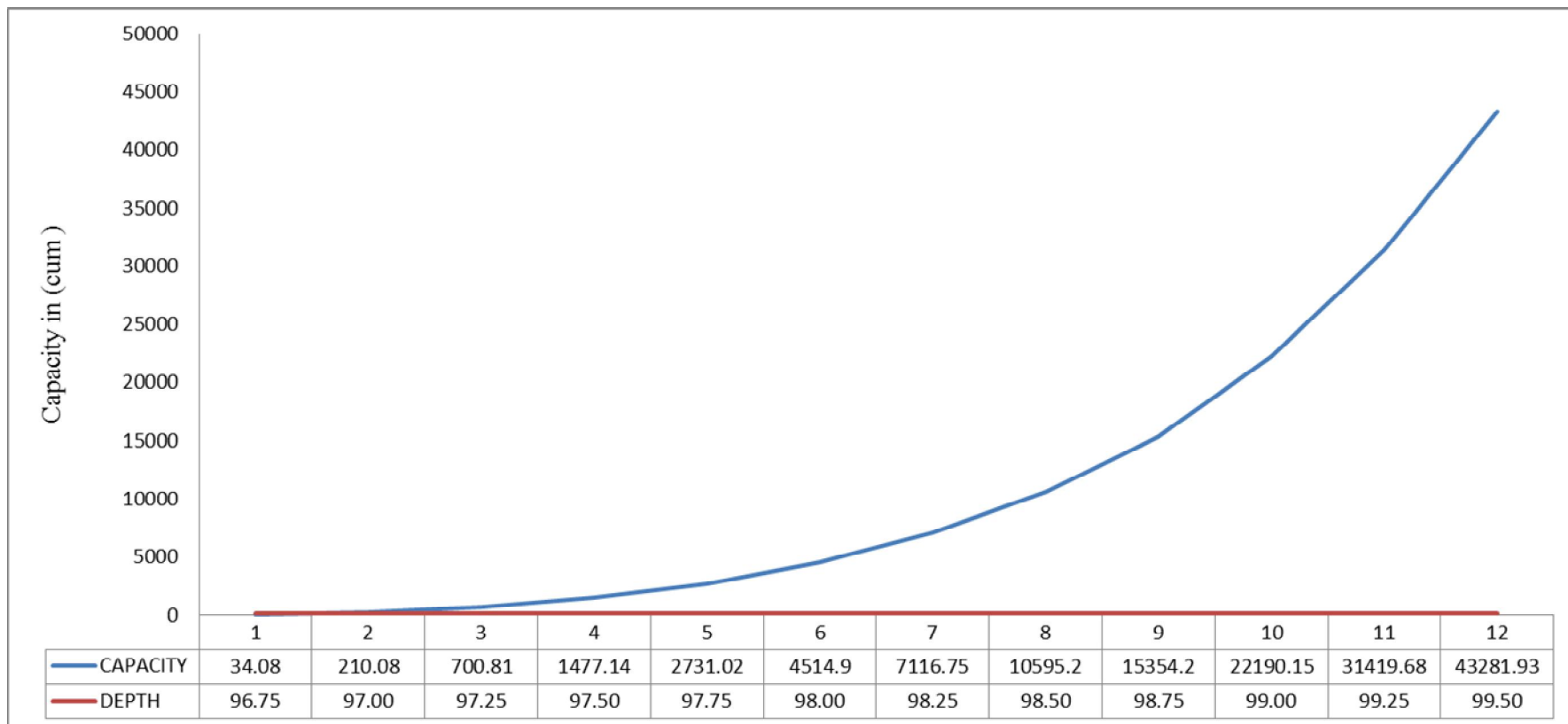
Depth capacity curve of three selected Nadis are shown in Fig. 4.19 to Fig.4.21. Capacity of Nadis were found to be 43247.85 m<sup>3</sup>, 15468.26 m<sup>3</sup> and 34821.63 m<sup>3</sup> for Sidadiyas, Chalaniya and Baran villages, respectively. Runoff was estimated by SCS curve number method. Results revealed that runoff of 205500 m<sup>3</sup> was recorded for Sidadiyas Nadi. Whereas existing Nadi (traditional) was having capacity of 43247.85 m<sup>3</sup>, it indicates that traditional Nadi was under design by 82.2 % in Sidadiyas village.

It is evident from Fig. 4.20 that Chalaniya Nadi was having capacity of 15468.26 m<sup>3</sup> against the estimated runoff of 52095 m<sup>3</sup>. It showed that existing Nadi was under design by 237 % over designed or refined Nadi. Similarly, Fig. 4.21 showed that Baran Nadi was having capacity of 34821.85 m<sup>3</sup> against estimated runoff of 55929 m<sup>3</sup>. It indicated that existing Nadi in Baran was under design by 60.6 % over designed or refined Nadi.

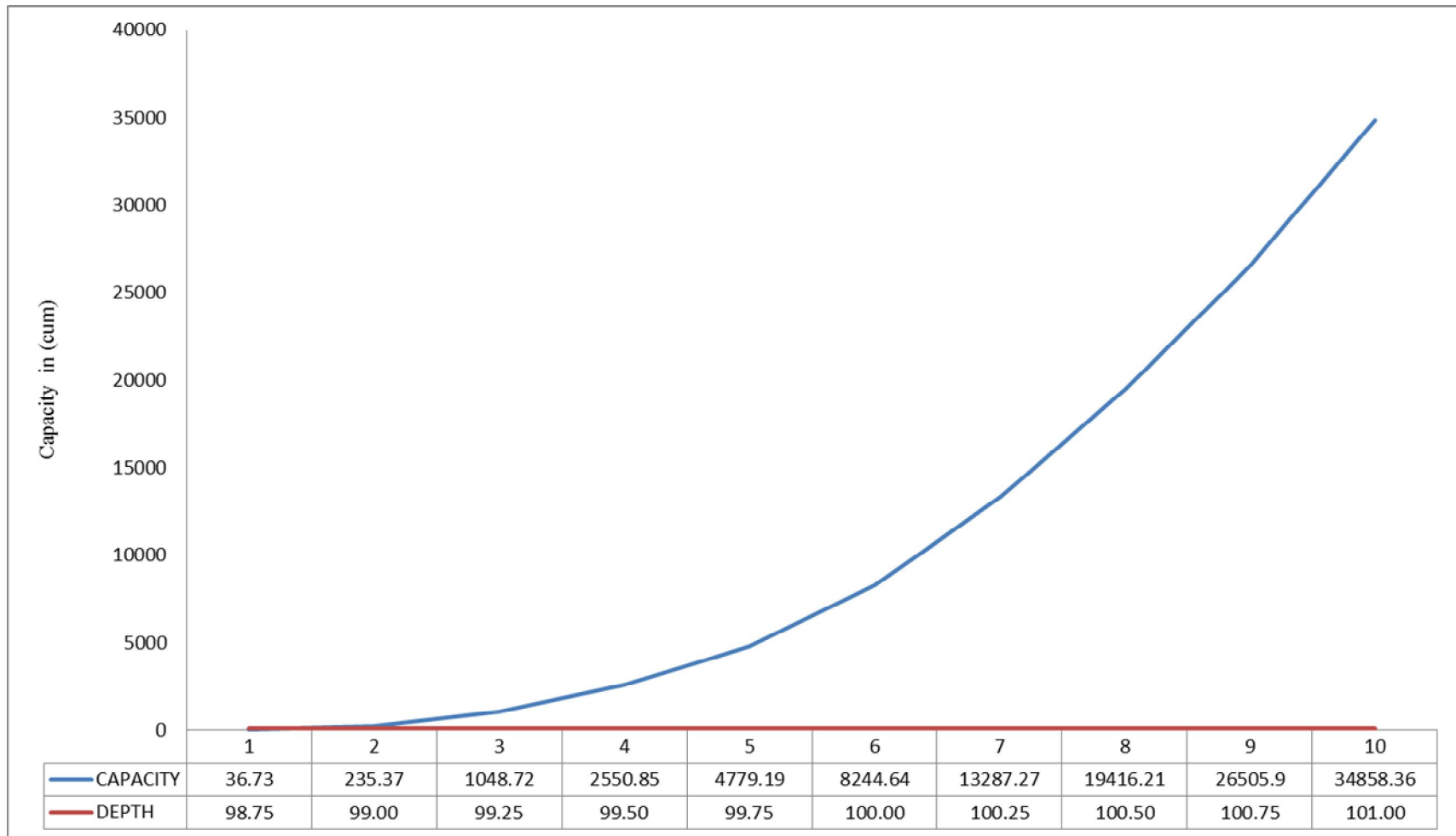
It can be concluded that all three selected Nadis were under designed. The capacity of existing Nadi (traditional) was much lower than designed Nadi of all the three selected Nadis in selected villages. Capacity of traditional Nadis can be increased by 60.6 in Baran to 237 % in Chalaniya or command area in vice versa. Thus in order to increase the capacity of traditional Nadis its height should be increased or depth of capacity may be increased. So that maximum available runoff water can be stored in the on farm reservoirs or refined Nadis and same could be judiciously used for irrigation purpose to enhance productivity.



**Fig 4.13: Depth capacity curve for ChalaniyaNadi**



**Fig 4.14: Depth capacity curve for Sidadiyas Nadi**



**Fig 4.15: Depth capacity curve for BaranNadi**

#### 4.5.2 Regression Model

The whole study was done for assumed Nadi catchment area of 8 to 25 ha in all the three different selected study regions Viz Suwana, Shahapura and Baneda. The studies done were with respect to:

- Calculation of two days maximum rain in the different standard metrological weeks
- Considered runoff producing rainfall at 80 % probability..
- Estimation of weekly runoff from the two days maximum weekly rainfall using SCN method.
- Probability analysis of estimated runoff to ascertain runoff expected at various recurrence intervals.

It is apparent that following the above steps for the determination of capacity of Nadi in different regions will pose practical difficulty. The present study has revealed that the Nadi capacity depends on the monsoon season rainfall, area, watershed area and probability of weekly runoff through a multiple regression model. As a result, the following model was developed:

$$\text{Runoff} = -29794911 + 14499 X_1 + 2055080 X_2 + 227 X_3 \quad \dots (4.1)$$

$(R^2=0.95)$

In developing above model, only those combinations of X1, X2, X3 were considered which resulted in the benefit cost ratio greater than 1 of the corresponding construction and activity.

Using the above model, capacities of Nadi for different areas and at different probability levels were predicted for the three rainfall situations. As a sample, a part of the comparison for three watershed area viz, and 8 to 25 ha and at two probability levels namely 0.1 and 0.4 for three regions are given in Table 4.24

A regression behaviour was further investigated individually for the three rainfall situation. The developed regression models for the three rainfall situations were described as under:

For Suwana Panchayat Samiti

$$\text{Runoff} = -31775580 + 14499 X_1 + 2191677 X_2 + 0 X_3 \quad \dots (4.2)$$

$R^2=0.957$

For Shahapura Panchayat Samiti

$$\text{Runoff} = -27342422 + 14499 X_1 + 1885942 X_2 + 0 X_3 \quad \dots (4.3)$$

$$R^2=0.963$$

For Baneda Panchayat Samiti

$$\text{Runoff} = -30266639 + 14499 X_1 + 2087612 X_2 + 0 X_3 \quad \dots (4.4)$$

$$R^2=0.96$$

**Table 4.24: Predicted and calculated runoff at three Panchayat Samitis in Bhilwara district**

Area (ha)	Probability levels	Suwana		Shahapura		Baneda	
		Cal	Predicted	Cal	Predicted	Cal	Predicted
8	0.1	27606136	36667301	22905496	28141889	25503736	32854064.7
8	0.4	7460862	1588878.8	7269582	-189088.2	7898061	956332.8
10	0.1	34507670	40777461	28631870	32252049.7	31879670	36964224.7
10	0.4	9326077	42690447.8	9086977	3921071.8	9872576	5066492.8
15	0.1	51761505	51052861.7	42947805	42527449	47819505	47239624
15	0.4	13989116	14544447.8	13630466	14196471	14808864	15341892.8
25	0.1	86269175	71603661.7	71579675	63078249.7	79699175	67790424.7
25	0.4	23315193	35095247.8	22717443	34747271.8	24681440	35892692.8

The equation 4.2, 4.3 and 4.4 are for Suwana, Shahapura and Baneda sites respectively.

As in the case of combined models, in the present case also the model predicted and calculated runoff were compared for three areas and two probability levels, for each of three rainfall regions and are given in Table 4.25 further results revealed that the average absolute percentage deviation between the model predicted and the calculated runoff were 0.33 per cent for Suwana, 0.28 per cent for Shahapura, 0.27 per cent for Baneda. Thus there was varying amount of reduction in the average absolute percentage difference when these separate regression models were used for the three different rainfall regions as compared to the case when a combined regression model was used for all the three rainfall regions. Further examination of the above table corresponding to individual rainfall regions revealed a relatively closer agreement between predicted and calculated runoff.

As in the case of individual models, results revealed that the average absolute percentage deviation between predicted and the calculated runoff were 0.55 per cent for Suwana, 0.27 per cent for Shahapura, 0.27 per cent for Baneda.

The developed models for Suwana was not suited for catchment area greater than 8 ha at 40 per cent probability level.

**Table 4.25: Predicted and calculated runoff at three Panchayat Samitis in Bhilwara district**

Area (ha)	Probability levels	Suwana		Shahapura		Baneda	
		Cal	Predicted	Cal	Predicted	Cal	Predicted
8	0.1	27606136	35779386	22905496	29411252	25503736	32642570
8	0.4	7460862	-729096	7269582	910206	7898061	744770
10	0.1	34507670	80162740	28631870	33013136	31879670	36828088
10	0.4	9326077	3654258	9086977	4682090	9872576	4919994
15	0.1	51761505	14612643	42947805	42442846	47819505	47255854
15	0.4	13989116	82896705	13630466	14111800	14808864	15358054
25	0.1	86269175	73037895	71579675	61302266	79699175	68131974
25	0.4	23315193	36529413	22717443	32971220	24681440	36234174

On the basis of above analysis it is felt that individual regression models for prediction of runoff as a function of area and probabilities level may be more acceptable than using a combined regression model expressing runoff as a function of area probabilities level and monsoon season rainfall. The possible reason for this particular behaviour of models could not be well understood. It is felt that there could be better predictability even with a combined regression model if a larger number of rainfall regions were included in the analysis.

#### **4.5.3. Embankment Design**

According to runoff estimation and capacity of Nadis it can be concluded that traditional Nadis constructed at three selected villages are under designed, hence in order to increase capacity of height of embankment should be increased as shown in Table 4.19.

Sample calculations for designing of embankment are shown in appendix H and appendix I. Nadi bed slope for Sidadiyas Nadi was  $0.35^\circ$ , for Chalaniya Nadi it was  $0.49^\circ$  and for Baran Nadi bed slope is  $0.89^\circ$ .

**Table 4.26: Comparative Characteristics of traditional and designed on farm reservoir (Nadi)**

S.No.	Parameter	Sidadiyas		Chalaniya		Baran	
		Traditional	Designed	Traditional	Designed	Traditional	Designed
1	Height (m)	2.5	4.25	2.6	5.50	2.42	3.61
2	Capacity (m <sup>3</sup> )	43247.85	78710	15468.2	52127.63	34821.85	55923.04
3	Command area (ha)	11.5	20 (74 %)	11.5	38 (230.4 %)	10	16.06 (66%)
4	Design	Under designed (82.2 %)	-	Under designed (237 %)	-	Under designed (60.6 %)	-

In embankment designing required height of embankment for Sidadiyas, Chalaniya and Baran should be 4.25 m, 5.50 m and 3.61m respectively. In Table 4.26 Designed Nadi, capacity of Nadi will increase by 82 % for Sidadiyas village, by 237 % for Chalaniya village, by 60.6 % and for Baran village. This increased capacity of Nadi will irrigate 74 %, 230.4 % and 66 % more command area for respective, villages.

Sample calculations to determine length, height and width of west weir are shown in appendix K. Dimension of west weir at all the selected Nadi was presented in Table 4.27

Results revealed that the length crest of west weir was more at Chalaniya as compared to rest of the Nadis. Similarly, height of crest was more at Sidadiyas as compared to other Nadis. Whereas, results of Nadi revealed that west weir was constructed only at Baran Nadi and at other two Nadi runoff was exposed through grassed water ways.

**Table 4.27: Design of west weir for Nadi**

S. No.	Location	Length (m)	Height (m)	Width (m)
--------	----------	------------	------------	-----------

1	Sidadiyas	0.92	0.4	3.08
2	Chalaniya	1.070	0.3	3.06
3	Baran	0.89	0.3	3.06

**Table 4.28 : Cost of cultivation per Hectare (In Rs.)**

S. No.	Cost Items	Crop			
		Maize	Cotton	Wheat	Barley
1	Fixed Cost	1927.45	8219.61	11857.98	8778.22
2	Rental value of owned land	4987.27	6321.38	7679.77	5701.82
3	Rent paid for leased-in land	0.00	0.00	767.80	173.45
4	Land revenue cesses and taxes	4.29	6.21	10.12	9.48
5	Depreciation on implements and Farm buildings	273.65	436.58	322.79	214.86
6	Interest on fixed capital	1826.72	1455.44	3077.50	2678.61
7	Human Labour				
	Casual	986.34	1274.39	1024.05	647.62
	Attached	109.98	830.94	181.70	104.33
	Family	4852.56	7072.76	5105.90	5534.04
8	Bullock Labour				
	Hired	31.65	34.12	38.88	16.66
	Owned	298.02	452.01	312.24	288.38
	Machine Labour				
	Hired	1893.20	1226.30	2998.88	3043.89
	Owned	19.89	29.03	306.28	317.56
9	Seed	298.87	877.15	2060.88	1742.71
10	Fertilizers	1067.67	1186.84	1669.64	1161.98
11	Manure	0.00	247.83	437.23	0.00
12	Insecticides	206.87	1736.26	109.73	128.58
13	Irrigation charges	934.17	619.18	3381.68	2829.75
14	Interest on working capital	247.73	266.06	391.29	321.30
15	Operational Cost (based on new methodology)	12645.61	16262.36	18227.30	16326.96
16	Human labour (based on new methodology)	4587.35	9587.58	6520.57	6476.15
17	Total	17198.78	24481.97	30085.28	25105.18

**4.6 BENEFIT COST ANALYSIS**

The investment of scarce financial sources justified only the water harvesting through on farm reservoirs (Nadi) are economic viable. The economic viability is there

fore, an assessment part of the on farm reservoir. For the assessment criteria, there streams, on one –side cost and on the other side benefit streams

#### 4.6.1 Cost of Cultivation of Crops

Cost of cultivation was worked out for prevailing cropping pattern at all three selected Nadis based on market price and is shown in Table 4.28. Results revealed that cost of cultivation include fixed variable cost. The higher fixed cost of cultivation was recorded in Rabi season than in kharif season. This might be attributed to more investment on infrastructure facilities such as water harvesting structure and implements etc.

Similarly higher variable cost of with cultivation was recorded in Rabi season than in kharif season. Thus might be attributed to higher investment occurred on inputs. Result revealed that wheat and barley was recorded higher total cost of cultivation per ha by 75.9% and 46% respectively over maize. Similarly, cotton was recorded higher cost of cultivation per ha by 42.3% over maize in region

#### 4.6.2 Cropping Pattern, Production and Productivity

The trend of cropping pattern showed that cotton occupied 71.4% area followed by maize (28.6%) in kharif in Chalaniya Nadi command area (Table 4.29). Whereas cotton occupied 55.2% area followed maize in kharif season Sidadiyas Nadi (Table 4.30). Result further revealed that wheat and barley occupied 12.6 and 19.1% area in rabi season in Sidadiyas Nadi Table 4.30 showed that cotton occupied 54.8% area follower by maize (13%) in BaranNadi in kharif season. Whereas wheat and barley occupied 16.4 and 17.8% area, respectively in rabi season, Thus, it can be concluded that cotton, wheat and barley being remunerative crops were preferred over other crops due to higher net return from increased irrigation facilities through on farm reservoirs in all the three selected nadis.

Table 4.29 to 4.31 showed that average productivity of maize was recorded higher in Sidadiyas and Baran (20 qtl/ha) than in Chalaniya Nadi. Similar trend of average productivity was recorded for cotton in all the three selected Nadis. The productivity of Barley and Wheat was recorded same in Sidadiyas and Baran Nadi. The improvement in yield of crops was attributed to introduction of improved packages of practices.

#### 4.6.3 Present worth of Construction of Nadi

The present worth of construction of all the three selected Nadi was estimated as:

For Sidadiyas;

$$S=6800 (1+0.08)^{52}$$

$$=Rs.3,72,001$$

For Chalaniya

$$S=150 (1+0.08)^{100}$$

$$=Rs.3,29,850$$

For Baran

$$S=7030 (1+0.08)^{42}$$
$$=Rs.1,78,136$$

Sidadiyas Panchayat Samiti was constructed 52 years ago in Rs. 6800 whereas present worth for construction of Nadi was worked out to be Rs. 3,72,001. For Chalaniya Panchayat Samiti was constructed 100 years ago and cost of Nadi Rs. 150. Whereas present cost for construction of Chalaniya Nadi was worked out to be Rs. 3,29,850. In Baran Panchayat Samiti construction cost of Nadi constructed 42 years ago was Rs. 7030. Whereas present cost for construction of Nadi was worked out to be Rs. 1,78,136.

#### **4.6.4 Economic Feasibility**

In Sidadiyas Nadi, total expenditure of Rs.1,40,393/-was incurred for developing water resources. Similarly, in Chalaniya and Baran Nadi, total expenditure of Rs. 154369.7/-and Rs.157933.2/- was incurred for developing water resources, respectively through on farm reservoirs. The net returns from agricultural crops in all the three selected Nadis were shown in Table 4.40 to 4.43 with the creation of water resources. Results revealed that maximum net returns (390042/-) was recorded in Sidadiyas Nadi. Whereas low net return was recorded in Chalaniya Nadi. Thus, it can be concluded that Sidadiyas Nadi gave higher net return as compared to other Nadis. However, higher B:C ratio was recorded for Chalaniya and Baran Nadis. Total net returns increased remarkably from developing water resources in all the three locations. A part from this B:C ratio for on farm reservoir without any further desiltation was found greater than one, which also indicated that the economic viability of the on farm reservoir (Nadi) in the region region for rain water harvesting.

**Table 4.29: Benefit cost ratio for (Chalaniya) Nadi in Shahapura Panchayat Samiti**

Crop	Area (ha)	Cost of cultivation (Rs/ha)	Total cost of cultivation	Production (qtl/ha)	Production of stover(qtl/ha)	Price of stover /qtl	Total price of stover	Market price (Rs/qtl)	GR (Rs)
Maize	1(28.6)	17000	17000	16	32	80	2560	840	16000
Cotton	2.5 (71.4)	24481.97	61204.925	24	0	80	0	3000	180000
	3.5		78204.925						196000
								NR	117795.1
								B:C	2.51

\*Figure in parenthesis indicates percent area occupied

**Table 4.30: Benefit cost ratio for (Sidadiyas) Nadi Suwana Panchayat Samiti**

Crop	Area (ha)	Cost of cultivation (Rs/ha)	Total cost of cultivation	Production (qtl/ha)	Production of stover(qtl/ha)	Price of stover /qtl	Total price of stover	Market price (Rs/qtl)	GR (Rs)
Maize	1.5 (13.0)	17000	25500	20	40	80	3200	840	28400
Cotton	6.35 (55.2)	24481.97	155460.51	28	0	80	0	3000	533400
Barley	2.2 (19.1)	25105.18	55231.396	26	26	80	4576	975	60346
Wheat	1.45 (12.6)	30085.28	43623.656	28	28	80	2240	1120	47712
	<b>11.5</b>		<b>279815.56</b>						<b>669858</b>
								NR	390042.44
								B:C	2.40

\*Figure in parenthesis indicates percent area occupied

**Table 4.31: Benefit cost ratio for (Baran) Nadi Baneda Panchayat Samiti**

Crop	Area (ha)	Cost of cultivation (Rs/ha)	Total cost of cultivation	Production (qtl/ha)	Production of stover(qtl/ha)	Price of stover /qtl	Total price of stover	Market price (Rs/qtl)	GR (Rs)
Maize	0.8 (11.0)	17000	13600	20	40	80	3200	840	16640
Cotton	4 (54.8)	24481.97	97927.88	28	0	80	0	3000	336000
Barley	1.3 (17.8)	25105.18	32636.734	26	26	80	4576	975	60346
Wheat	1.2 (16.4)	30085.28	36102.336	28	28	80	2240	1120	39872
	<b>7.3</b>		<b>180266.95</b>						<b>422858</b>
								NR	272591.1
								B:C	2.51

## SUMMARY AND CONCLUSIONS

### SUMMARY

A study was conducted to assess the 'techno feasibility of on farm reservoirs in Bhilwara district'. The study area lies between 25 degree 0 minutes to 27 degree 50 minutes North Latitude and 74 degree 3 minutes to 75 degree 25 minutes East longitude. Three Panchayat Samitis were selected viz Suwana, Shahapura and Baneda. Data were collected from 10 existing Nadis in each selected Panchayat Samiti of Bhilwara district. Topographic survey of Nadi were conducted (one each from each Panchayat Samiti).

Probability analysis of rainfall data of 30 years (1981-2010) were made by Weibulls Technique. The weighted curve numbers of the Nadis were determined for three antecedent moisture conditions (AMC I, AMC II, AMC III). Runoff was estimated by using SCS curve number method. The annual runoff was estimated 80 per cent probability level.

Analysis of rainfall revealed that Suwana Panchayat Samiti was recorded 41 days with maximum annual rainfall in 2006 year. Whereas Shahapura and Baneda Panchayat Samiti was recorded 30 and 45 rainy days in 2006 year with maximum annual rainfall , respectively. Maximum annual rainfall with maximum rainy days was recorded in Suwana Panchayat Samiti. Whereas minimum mean annual rainfall (553.4 mm) and rainy days (28) was recorded for Suwana. Maximum rainfall in Shahapura Panchayat Samiti was recorded during year 2004 (1026 mm) with 30 rainy days. Maximum rainy days 37 in Baneda Panchayat Samiti was recorded during the year 1994 with 580 mm annual rainfall.

Value of annual Coefficient of variation of rainfall was higher Bhilwara as compared to for Shahapura but Bhilwara was received more rainfall than other Panchayat Samitis.

In order to select best fit distribution for rainfall of study areas VTFIT software was used. Best fit distributions were selected on the chi-square value. Results revealed that Log Gaussian, Inverted Gamma k, (Pearson Type V) Frechet (Extreme value type I) for maxima and Weibull (Extreme value type III) for minima for Suwana Panchayat Samiti whereas Shahapura Panchayat Samiti best fit distribution was Weibull (Extreme value type III) for minima. Similarly Baneda Panchayat Samiti, best fit distributions were Log Gaussian and Weibull (Extreme value type III) for minima.

Runoff was estimated as 205500 m<sup>3</sup> by SCS curve number method for Sidadiyas. Whereas existing Nadi (traditional) was having capacity of 43247.85 m<sup>3</sup>, it indicated that traditional Nadi was under design (82.2 %) in Sidadiyas village. It Chalaniya Nadi was having capacity of 15468.26 m<sup>3</sup> against the estimated runoff of 52095 m<sup>3</sup>. It showed that

existing Nadi was under design 237 % over designed or refined Nadi. Baran Nadi was having capacity of 34821.85 m<sup>3</sup> against estimated runoff of 55929 m<sup>3</sup>. It indicated that existing Nadi in Baran was under design by 60.6 % over designed or refined Nadi.

Design dimensions for west weir for Sidadiyas Nadi length should be 0.92 m length of crest and 0.4 m height of crest. Similarly, for Chalaniya Nadi, length should be 1.070 m and height should be 0.3 m and Baran Nadi, length should be 0.89 m and height should be 0.3 m.

In embankment designing required height of embankment for Sidadiyas, Chalaniya and Baran should be 4.25 m, 5.50 m and 3.61m respectively. Designed Nadi will increase capacity of Nadi by 82 % for Sidadiyas village, 237 % for Chalaniya village and 60.6 % for Baran village. This increased capacity of Nadi will irrigate 74 %, 230.4 % and 66 % more command area in respective village.

Suwana Panchayat Samiti was constructed 52 years ago Rs. 6800 whereas present cost for construction of Nadi was worked to be Rs. 3,72,001. For Shahapura Panchayat Samiti was constructed 100 years ago cost of Nadi Rs. 150 whereas present cost for construction of Nadi Rs. 3,29,850. For Baneda Panchayat Samiti construction cost of Nadi constructed 42 years ago was Rs. 7030 whereas present cost for construction of Nadi was Rs. 1,78,136.

Cost of construction of Nadi and respective structure were calculated for each Nadi; Rs.140394 (Sidadiyas), Rs. 154369 (Chalaniya), Rs.155463 (Baran). Benefit cost ratio for each Nadi was found to be 2.51:1, 2.40:1 and 2.51:1 for respective locations. Results revealed that maximum net returns (390042/-) was recorded in Sidadiyas Nadi. Whereas low net return was recorded in Chalaniya Nadi. Thus higher B:C ratio was recorded for Chalaniya and Baran Nadis. Total net returns increased remarkably from developing water resources in all the three locations. A part from this B:C ratio for on farm reservoir without any further desiltation was found greater than one, which also indicated that the economic viability of the on farm reservoir (Nadi).

## **CONCLUSIONS**

Following conclusions were drawn from the study;

- 1) At 80 per cent probability level, annual rainfall of Suwana, Shahapura and Baneda Panchayat Samiti was recorded to be 69.92 mm, 5.06 mm and 59.97 mm respectively. At 70 per cent probability level was recorded to be 218.96, 142.575 and 209.3 mm in Suwana, Shahapura and Baneda Panchayat Samitis, respectively.

- 2) The weighted curve number of Suwana, Shahapura and Baneda Panchayat Samiti for AMC II was recorded to be 76.06, 78.56 and 78.25 which shows that the catchment area has good runoff potential.
- 3) For Suwana and Baneda Panchayat Samiti polynomial model was found to be good whereas for Shahapura Panchayat Samiti Logarithmic model was found to be good.
- 4) For Suwana Panchayat Samiti best fit distributions were found to be Log Gaussian, Inverted Gamma k, (Pearson Type V) Frechet (Extreme value type I) for maxima and Weibull (Extreme value type III) for minima. Similarly, for Whereas Shahapura Panchayat Samiti best fit distribution was found to be Weibull (Extreme value type III) for minima. Baneda Panchayat Samiti best fit distributions were found to be Log Gaussian and Weibull (Extreme value type III) for minima.
- 5) Sidadiyas Nadi (traditional) was having capacity of 43247.85 m<sup>3</sup> against the estimated runoff of 205500 m<sup>3</sup> by SCS curve number method. It indicated that traditional was under design (82.2 %) in Sidadiyas village.
- 6) Chalaniya Nadi was having capacity of 15468.26 m<sup>3</sup> against the estimated runoff of 52095 m<sup>3</sup>. It showed that existing Nadi was under design 237 % over designed or refined Nadi.
- 7) Baran Nadi was having capacity of 34821.85 m<sup>3</sup> against estimated runoff of 55929 m<sup>3</sup>. It indicated that existing Nadi in Baran was under design by 60.6 % over designed or refined Nadi.
- 8) Nadis constructed at Sidadiyas, Chalaniya and Baran should be modified in order to increase its capacity to increase yield and to improve benefit cost ratio.
- 9) In embankment designing required height of embankment for Sidadiyas, Chalaniya and Baran should be 4.25 m, 5.50 m and 3.61 m, respectively.
- 10) In west weir designing for Sidadiyas Nadi length of crest should be 0.92 m and height should be 0.4 m. Whereas for Chalaniya Nadi length of crest should be 1.070 m and height should be 0.3 m. Similarly for Baran Nadi length of crest should be 0.89 m and height should be 0.3 m.
- 11) Benefit:cost:ratio for all the three selected Nadis were found greater than one.
- 12) Maximum net returns (390042/-) was recorded in Sidadiyas Nadi. Whereas low net return was recorded in Chalaniya Nadi. Thus, it can be concluded that Sidadiyas Nadi gave higher net return as compared to other Nadis.

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