Maharana Pratap University Of Agriculture And Technology

College of Technology And Engineering, Udaipur

CERTIFICATE – I

Date

This is to certify that **Mr. Hemant Kumar Mittal** had successfully completed the Preliminary Examination held on _________________ as required under the regulation for Ph.D. degree.

(Dr. Virendra Kumar)
Head
Department of Soil & Water Engineering

Maharana Pratap University Of Agriculture And Technology
College of Technology And Engineering, Udaipur

CERTIFICATE – II

Date

This is to certify that this thesis entitled **"An Evaluatory Study on Morphological Characteristics and Ground Water Status in Selected treated Watersheds"** submitted for the degree of **Doctor of Philosophy** in the subject of **Agricultural Engineering (Soil & Water Conservation Engineering)** embodies bonafide research work carried out by **Mr. Hemant Kumar Mittal** 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 21.11.2002.

(Dr. R.C. Purohit)
Major Advisor

(Dr. Virendra Kumar)
Head
Department of Soil & Water Engineering

(Dr. A.N.Mathur)
Dean

Maharana Pratap University Of Agriculture And Technology

College of Technology And Engineering, Udaipur

CERTIFICATE – III

Date

This is to certify that this thesis entitled **"An Evaluatory Study on Morphological Characteristics and Ground Water Status in Selected treated Watersheds"** submitted by **Mr. Hemant Kumar Mittal** to Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Agricultural Engineering (Soil & Water Conservation Engineering)** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on this thesis has been found satisfactory; we therefore, recommend that the thesis be approved.

Maharana Pratap University Of Agriculture And Technology

College of Technology And Engineering, Udaipur

CERTIFICATE – IV

Date

This is to certify that **Mr. Hemant Kumar Mittal** student of **Doctor of Philosophy**, Department of Soil & Water Conservation Engineering, College of Technology and Engineering, Udaipur has made all the corrections in the thesis entitled **"An Evaluatory Study on Morphological Characteristics and Ground Water Status in Selected treated Watersheds"** which were suggested by the external examiner and the advisory committee in the oral examination held on …………. The final copies of the thesis duly bound and corrected were submitted on …………….. are enclosed herewith for approval.

(Dr. R.C. Purohit)
Major Advisor

(Dr. Virendra Kumar)
Head
Department of Soil & Water Engineering

(Dr. A.N.Mathur)

Dean

ABSTRACT

Nations with rich natural resources and wealth would not be able to have a sustainable development without wise management and planning soil and water are the two most important natural resources and their conservation on watershed basis has emerged as a most effective approach for sustenance of land productivity. The watershed, a single hydrological unit is independent of territorial and jurisdictional boundaries. There is a growing consensus that effective way to conserve the resources soil and water for sustainable productivity and protecting flora and fauna must be through watershed management programme.

To find out if a watershed development programme has generated any direct an effective evaluation is necessary. This may indude both physical and social benefits associated with the programme.

The evaluatory study of Cheerwa and Losing watershed of Udaipur division reflected a successive reduction in runoff and soil loss based on two years study (2000 & 2001) and the same was within permissible limits. It was also revealed that SCS curve number method is the most suitable method for runoff estimation which could be used for design of watershed measures.

The geophysical investigation of both sites showed that it is characterized by low to medium water potential zones. Based on this transmissivity of aquifer was found in selected walls and finally recharge was estimated. Study reflects that recuperation index was more by 1.8 and 1.4 times in Cheerwa and Losing watersheds respectively. The ground water recharge was more by 1.97 to 2.32 times in Cheerwa and 1.22 to 2.13 times in Losing area as compared to untreated area walls.

Further, due to increased irrigated area, moisture status in soil profile a significant change in crop yields was noticed which brought an additional income of Rs.2790.10 and Rs.2901.12 per ha in Cheerwa and Losing watersheds.

The afforestation & pasture development programme yielded successfully which reflected that species of babool could be planted successfully. The rate of silt deposition at loose stone check dams was found to be 1.08 and 1.36 m3/ha/yr. It was realized that after execution of the programme a reasonable time has been passed and the area is approaching towards stabilization.

The study also suggests after evaluation of these watershed that peoples participation and their inclination of adopting a specific technology along with technical appropriateness must always be considered and counted. Based on which it was revealed that soil and water conservation. Measures like stone wall terrace, Puerto Rico

terrace, loose stone check dam, V ditch, contour vegetative barrier, contour and staggered trenches can be taken up in the area.

CHAPTER – I

INTRODUCTION

1.1 General

Soil and water are the two basic natural resources which are of crucial importance for mankind. The continuing and ever accelerating depletion of the available soil and water resources in India and elsewhere in the World is a matter of great concern. Excessive biotic and abiotic interference have caused considerable degradation to our natural resources and these are under tremendous stress due to ever increasing population. These resources have been over exploited to meet the food requirement of the growing population and it has lead to land degradation. The magnitude of land degradation is alarming and possesses a serious threat to a sustainable production.

According to the National Commission of Agriculture the total land area of India is 329.0 m-ha, out of which 142.2 m-ha is net sown area. Forest area is reported as 67.9 m-ha, the cultivable wasteland and fallow land are reported as 15.9 m-ha and 23.4 m-ha. The area under non-agricultural uses is 21.2 m-ha whereas barren and uncultivable land is 19.7 m-ha. The rest of the area is under pasture, grazing, miscellaneous, trees and crops. Out of the total 329 m-ha geographical area of India, about 170.4 m-ha area is threatened by various types of land degradation such as water and wind erosion, salinity and alkalinity, water logging, gullying and shifting cultivation (Singh' 1981).

It has been estimated that about 6000 metric tonnes of soils are eroded from about 80 m ha of culturable land loosing 8.4 metric tonnes of nutrient annually (Singh' 2000).

Land is shrinking resource for agriculture. The per capita availability of arable land has decreased from 0.32 ha in 1951 to 0.17 ha in 1991 and 0.15 ha in 1998. It was decreased further by 0.1 ha by the end of century. Out of the 139 m-ha arable land in India, nearly 74 per cent is rainfed, which contributes 42 per cent of the total food production. Mismanaged use of land and water is one of the factor for low productivity. Hence, the efficient management of land and water should receive priority to improve the prospects of optimizing and sustaining the productivity of the rainfed lands.

The optimal management of these resources is essential not only for sustainable development but also for human survival. Watershed is an ideal unit calling for multidisciplinary approach to resource management. Watershed management is a single window, integrated, participatory and sustainable area development programme of a geophysically defined natural drainage unit of land. Soil and water conservation is a very important aspect of watershed management but in order to realize the highest benefits for the people, other aspects like socio-economic situation should not be neglected. Watershed management indicates the wise use of soil and water resources within a given geographical area so as to enable sustainable food, fibre & fuel wood production with minimum hazards.

It is essentially to relate the proper land use, protection of land against all forms of deterioration, enhancement and maintenance of soil fertility, conservation of water for farm use, proper management of water for drainage, flood protection, sediment reduction and improvement of productivity from all land uses. Though, watershed management is not new to India, since time immemorial, tanks and ponds have been developed and used to harvest and store water from watershed and recycle it for crop production.

Most of the development planning aiming to optimal utilization of natural resources is now increasingly oriented with watershed concept and it is a well accepted concept in various kind of management projects under different names in the country such as DDP, IWDP, NWDPRA, DPAP etc. It necessarily includes the optimal use of land, water, soil and ecological resources in sustainable development for the uplift of the quality of local people in the watershed. Owing to complex terrain and different physiographic conditions, watershed development in hilly areas has been a challenging task, yet proper management can lead to best developmental scenario. A watershed has been identified as the ideal geological unit for planning and executing development programmes aimed at achieving the rational utilization of all natural resources for sustained optimum production of biomass with the least damage to the environment. Watershed management is an integrated approach to the development of an area with the ultimate objective of improving the quality of life of the people who dwell within it.

Spatially, watershed consists of three physical sectors.

- Arable or cultivated lands which are privately owned
- Non arable land which includes village pastures, grazing cultivable waste lands and barren land.
- Net work of natural drains

These three subjects are hydrologically interspersed and are being treated as one organic geohydrological entity for project planning and implementation to ensure sustainable use of natural resources of land and water.

Large scale promotions of watershed management projects have been undertaken in India in the recent past under several centrally sponsored and other schemes. The results so far obtained are considered by many as just minute compared to what is actually needed for addressing the problems of natural resource management. A number of reasons may be attributed to this shortfall amongst which the lack of an effective project monitoring and evaluation plan has been considered to be a serious one.

Paroda (2000) has estimated a realistic demand for food grain of about 232-235 million tones by 2015. As the cropped area can not be significantly increased, major increase in food grain requirement must come from higher productivity. This is achieved through proper management of land and water resources and will be possible only through watershed development programme.

Broad objectives of watershed management can be human welfare coupled with environmental upgradation. In rainfed agriculture, the objective would be in-situ conservation, development and utilization of water, soil and vegetative resources for improved productivity, stability, sustainability and equability of agro-ecosystems. To achieve these objectives, watershed management steps includes diagnosis of resources, design of plan and operation of the planned programme. The plan need not to be an ideal one but should be feasible and flexible. The execution of designed programme on the basis of diagnosis and objectives need to be phased.

1.2 Rajasthan:

Rajasthan is the largest state of Indian Union covering an area of about 10.4 percent of the geographical area of India. Besides the area covered by soils, the terrain of Rajasthan state is also covered by several other physical features such as sand dunes, ranns, rock out crops, water bodies etc. Nearly 84.5 per cent of total geographical area (TGA) comes under soil mapping units, whereas rock out crops, active dunes, salt flats rannes, water bodies and habitation are occupying 4.86, 10.22, 0.13 and 0.04 per cent of TGA respectively. Natural division of the state in to distinct parts of Aravalli range influence the climate in a characteristic manner (Anonymous, 1998).

Management of natural resources, especially in the state like Rajasthan and still in its southern part for improved crop productivity in the form of developmental activities is a crucial issue. Because of higher growth rate of population, the burden on the available resources is creating point pressure load and disturbing the ecosystems. Sustainable use of natural resources to improve the environment is discussed at many forums in many ways. However, it is a fact that in ecosystem, human being is dominating the scenario and inspite of tireless efforts, many a times, the visible results are not encouraging. Similarly, the discussions held or policies decided are not transferable to ground because of social, financial and administrative constraints and thereby shaking the whole social structure.

In order to achieve economic upgradation of human life in rainfed areas, it becomes imperative to improve rainfed agricultural system through the adoption of watershed technology. Thus, the National watershed development project for rainfed areas is a major thrust programme launched by Department of Agriculture during 8^{th} five year plan to extent benefit to the farmers by various watershed technologies. This watershed development programme is an endeavor to achieve sustainable production, development and gain ecological balance. Accordingly, programme has been implemented in all community development blocks of the country. Similarly a World Bank assisted project was also implemented under the name of Integrated Watershed Development Programme in Rajasthan state including NWDPRA programme.

To find out if watershed development programme has generated any direct or indirect benefit, effective evaluation of soil and water conservation should be made. This will eventually assist researcher, extension specialists, policy makers, planners farmers etc. in determining the progress of development programme, evaluation is however, necessary in respect of achievements of its stated objectives, evaluation is also used to denote the assessment of success of the project in the context of its stated objectives. Very often, full treatment of watershed area is not done in India, therefore an evaluation can be made on the basis of different degree of coverage of work, subject to availability of relevant data for evaluation.

Usually project evaluation is carried out in two stages i.e. interim or on going evaluation, conducted early in the implementation phase of the project and the overall final evaluation in post implementation period. The on-going evaluation should not only assess achievements of physical and financial targets but also indicate discernible changes in the socio-economic parameters. In the final evaluation of the project it should be remembered that the impact of soil and water conservation measures is visible only after few years which may extend beyond the project life. However, trends may be discernible.

Watershed Management works executed under different projects are carried out under varied financial and social constraints said by the funding agencies for the area without being given specific weightage to technical need of the area. Therefore, the present study has been taken with an over all objective of evaluation of watershed executed to funding agencies in same agro climatic region with following specific objectives set for the study.

1.3 Objectives:

1. To study the different morphological characteristics of the watersheds in relation to runoff generation and to suggest best fit runoff estimation empirical equation for the area.

2. To conduct hydorogeological survey and geophysical investigations and to analyse ground water recharge.

3. To evaluate technical appropriateness and impact of existing soil and water conservation measures and

4. To suggest appropriate soil and water conservation measures for the area.

CHAPTER - II

REVIEW OF LITERATURE

Land and water are two basic natural resources on which a vast research work had been carried out by many research workers on different aspects. An effort has been made to collect and compile some of the research highlights on evaluation of watershed development programme, which are reviewed and presented briefly under following heads given below.

1. Watershed Morphology
2. Ground water status and recharge
3. General impact

The research reviews presented in the study report are related to pioneer works and reflect only correct decade review.

2.1 Morphology

Sharma (1986) developed a relationship between rainfall and runoff after observing fifteen microcatchments over a period of 7 years in Indian arid zone. The microcatchments observed were in the different combinations of slope and lengths. It was observed that these microcatchments can produce 13.3 to 45.4 percent of runoff depending upon morphological characteristics.

Singh (1995) studied 13 watersheds of the Jojri catchment using remote sensing technique and ground truth. Interrelationship between different geomorphic variables were established which were by and large significantly correlated to each other. Based on the findings priorities for development of watersheds were decided under four categories viz. Crop land, grasslands, woodlands and water harvesting at suitable locations.

Subudhi (1995) studied seven fan shaped sub watersheds in upper Damodar Valley for establishing a relationship between hydrological and geomorphological parameters of basin area. Various geomorphological characteristics e.g. drainage density, stream length, number of streams, length width ratio, stream density and other parameters viz., basin area, slope, mean annual rainfall, mean annual runoff, mean annual sediment production rate etc. were also measured. The relationship among the hydrological and geomorphological parameters were obtained using regression method. It was concluded that rainfall and drainage area have got significant effect on prediction of runoff as compared to other parameters. Drainage density, stream density and drainage area have got significant effect on prediction of sediment production rate as compared to other parameters.

Venugopal et al. (1996) studied a typical rainforest river basin in the Western Ghats of peninsular India for observing the role of vegetative cover in the evaluation of a drainage basin to its current hydrological and geomorphological status. Satellite data was the data base for study and control was aerial data. The vegetative cover of silent valley was classified to locate the rainforests and estimate the afforestation coefficient of each first order stream unit. The drainage density was computed and correlated to the afforestation coefficient to evolve a general relationship and the same was then verified with the adjacent basin. It was concluded that application of space technology can be used gainfully for study of the changes in hydrological parameters and other hydro environmental problems including morphological characteristics.

E. Suburayalu et al. (1998) made a study in the Gundagal watershed in the Nilgiri distt. of the Tamilnadu state. The work relates the geomorphologic characteristics and unit hydrograph. The drainage map of the watershed with 1:50,000 scale was used. The order of watershed was derived using Strahler system of stream ordering. Various geomorphologic characteristics of watershed were measured and GIUH (Geomorphological Instantaneous Unit Hydrograph) was developed for that watershed. Study indicated that the observed peak discharge of watershed varied from the simulated hydrograph between 11.69% to 37.31% for five rainfall run off events.

Wodeyar et al (2001) made geological, geomorphological and hydrogeological studies of Kandra basin in the Panhale Taluka, Kolhapur District, Maharasthra State. It was reported that the Cretaceous basalt are the litho units in the basin. The amygdoidal basalts are also found outcropping in the basin. The lateritic bauxites are found on the hill tops of the Panhala township. The western and the southern part of the basin is occupied by the flat topped hill ranges with steep hill slopes. The basin is of 5th order. The bifurcation ratio is 3 to 4.8. The homogenous nature of the litho units is supported by circularity ratio value. The drainage density value is 1.2 per sq. kms. indicating coarse drainage density. The hard and compact basalts possess only secondary opening by virtue of joints, fractures and fissures. The groundwater occurs in unconfined conditions. The groundwater is developed by either dug or bore wells. The dug wells are shallower while the bore wells are deeper and serve the local people in the dry season. The quality of the groundwater is suitable for both domestic and agriculture use.

2.2 Ground water survey and recharge:

Survey:

Kumar and Tomar (1998) made a study on "Prioritisation" of sub watersheds for water resource development in Usri watershed, Giridih, Bihar. The study was conducted in three different watersheds and the assessment of available surface water was done through remotely sensed data. Digital basement terrain model geophysical technique of groundwater investigation was used for the study. They found that watershed US-2 was having the highest possibility for development of ground water followed by US-3 and US-1 subtractive sheets. The aquifer resistivity was in the range of 0 to 50 ohm.m and 50 to 1000 ohm.m in this watershed.

Sinha et al (1998) made a research study on use of geophysical techniques in Gamharia nala watershed. The paper deals with the process of formulating action programme for accelerating human, agriculture and natural resources of Gamhariya Nala watershed suitable for the community to protect the soil & water resources from adverse effect. The geophysical measurements were the base for draft of master plan of the watershed. The detail analysis of soil profile, temperature, humidity, rainfall, resistivity and water quality revealed that, if properly addressed as proposed in master plan the results could be examined in terms of increased crop yield, sufficient fuel, fodder, water, livestock and other resources to cater the need of the area with perspective planning with accommodation for growing population.

Paliwal and Khilnani (2001) made a study on use of electrical resistivity data to assess aquifer parameters for better interpretation of hydrogeology for Naguar region of Rajasthan. This study was an attempt to prove that geoelectrical resistivity using vertical electrical sounding method surveys (VES) are highly useful, economical and reliable in groundwater investigations and assessment studies where aquifer parameters (excluding storavity) are determined directly from VES required for estimation of dynamic and static groundwater reserves. It has also been proved that the transmissivity values derived from aquifer resistivity and its thickness also hold good for consolidated, semi-consolidated and cavernous aquifers as was illustrated in the study. It is therefore strongly recommended that the present approach may be adopted in all the groundwater investigations and assessment studies not only to save time, energy and cost by minimizing exploratory drilling and pump tests but also to get the basic geoelectrical resistivity data bank for the area for future groundwater management program.

Subbarao and Reddy (2001) made an assessment of groundwater yield using electrical resistivity approach and the study was conducted in the khondalite suite of rocks of Visakhapatnam area of Andhra Pradesh, India. The study suggests that an approximate idea on groundwater yield can be expected from a well location using longitudinal conductance of an aquifer layer. An empirical relationship can be established between yield of water in wells and longitudinal conductance, calculated from the data of vertical electrical soundings conducted near such wells.

Recharge:

Anonymous (1988) reported from the studies conducted on evaluation of soil conservation at Central Soil and Water Conservation Research Training Institute, Dehradun that due to soil conservation programme, the number of wells increased from 47 during projected period to 94 up to 1988-89 the total area under-irrigation was increased from 88.53 ha to 2022.18 ha during 1987. The increment in number of wells was attributed to the increased available moisture status due to soil and water conservation treatments.

Sharma and Kalla (1980) studied effect of anicut on ground water recharge on a nala near Baori Village in Jodhpur district where three anicuts spaced at 320 and 260 meter were constructed during 1977. Monthly monitoring of static water level in wells surrounding these anicuts revealed that recharge to aquifer was increased by 5.3 to 27.0 per cent.

Dorge and Wankhede (1987) Studied on salient features of nala bunding works in Maharashtra State. Rapid survey carried out by statistics Department of Agriculture recorded that due to nala bunds, water level in the wells located on the down stream side of the nala bund increased by 0.7 meter which resulted increased irrigation potential considerably.

Pendke (1990) studied the effect of soil conservation measures on ground water recharge in six selected watersheds of Udaipur district. The result indicated that the wells under the influence of soil water conservation measures registered higher average ground water recharge to an extent of 35.97 percent as compared to an average recharge of 24.97 percent in wells located in untreated area.

Gawande (1992) estimated ground water storage of Shelgaon watershed of Manoli project, PKV, Akola by monitoring 30 open wells, during the year 1989-90 with 680 mm rainfall. The ground water status during June to October were observed in between 0.33 to 79.99 ha-m. The storage during the rabi season (October to January) were available in between 73.99 to 42.53 ha-m which reflected the outcome of watershed treatments.

Malikarjunappa *et al.* (1992) studied impact of Nala bund on ground water recharge. The study was conducted at Chandkanteo watershed located in Sindegi town of Bijapur district in Northen Karnataka, during the year 1987-88 having average annual rainfall of 551 mm by selecting wells to monitor the fluctuation of water tables. The study was made by keeping two open wells from zone of saturation of nala bunds with one control well. It was observed that there was rise in water table in all the wells located below the nala bund for most of the period of year as compared to control well. The average depth of water table for all study wells for the entire period of the observation i.e. May to January was 4.57 m against 5.13 m of control well. This indicated that nala bunding had a positive effect on the recharge of underground water, which was reflected in the form of rise of water table.

Mittal and Singh (1993) studied the effect of water harvesting structure on ground water recharge in an area of southern Rajasthan. The study revealed that the masonry structures called anicut have successfully proved their functional utility. It was reported that recuperation rate was 62.06 per cent higher in the well near the anicut than the distant wells. Further, the higher ground water recharge was observed ranging between 1.15 to 1.26 times more in the down stream wells as compared to up stream wells under influence of anicut.

Goel and Singh (1996) studied the impact of soil conservation measures on ground water availability. The study was conducted in Navamota watershed in the Aravalli foot hills having watershed area of 313 ha.. The analysis was conducted through collecting well water data of 12 wells. It was found that there was an average annual rise of 8 m in water table due to recharge. This rise in the water table was highly correlated to annual rainfall. Increase in availability of irrigation water in the wells resulted in 83 per cent increase in rabi cropped area and almost doubled productivity of rabi and kharif crops.

Pendke and Gore (1997) reported that in the Wagarwadi watershed of Parbhani district (Maharashtra) about 564 hectares was treated in the year 1992-93. Four open wells in treated and two open wells in untreated area of watershed were selected for monitoring ground water table fluctuation to see the effect of watershed management on increase in ground water potential. Meteorological data, viz. rainfall and evaporation were collected. The yield of 2.2 and 1.2 per cent and monthly change in ground water storage per unit area of 0.22 and 0.19 ha-m was calculated for treated and untreated area, respectively. The monthly cumulative ground water potential in both treated and untreated area was calculated. The increase of 40 to 45 per cent in accumulated ground water potential due to watershed management practices was observed in treated area after the period of four years.

Phandavis et al (1998) studied the impact of water harvesting structures on ground water recharge in semi arid region of Maharastra state. The study was undertaken on shallow black soils in Podalsingi watershed in the semi-arid region. Two nala bunds and one percolation tank constructed during the year 1987-88 were selected for the study. Recharge of ground water due to construction of percolation tank and two nala bund was observed through open wells located below water harvesting structures. It was observed that the water table in the wells located on the down stream side of water harvesting structures increased considerably. The average range of the rise observed for four years was in the range of 8.23 m to 4.93 m over bench mark. Further, it was also analysed that shrinkage in the water harvesting structure was within the safe limits.

2.3 General impact of SWC measures:

Kumar et al. (1991) Studied root development of rainfed maize variety 'Azad Uttam R-2' and its effect on yield with in-situ moisture conservation practice and fertility levels on light textured eroded and sandy loam soil of Kanpur. The results showed that, the inter row water harvesting with ridging and furrowing + vegetative bund increased root growth by 17.7 cm. number by 27.2 and root weight by 4.11 gm/plant over control. Application of paddy straw @ 30 q/ha also markedly improved the root development and yield of maize with application of fertilizer @ N(80 kg) + P_2O_5 (40 kg) + K_2O (40 kg) per hectare.

Kale et al. (1992) Studied the effect of various cropping system and land treatment in reducing runoff and soil loss at Solapur. The contour bunding + strip cropping system (CB +

SC) was found most efficient in reducing run off by 37.7 per cent and soil loss by 57.7 per cent over broad base furrow + inter cropping system (BBF + IC). However, (B+SC) system reduced runoff, soil loss by 51.5 per cent and 71.1 per cent over contour bunding + inter cropping (CB + IC) system respectively. Further CB+SC and BCF + IC system are equally rewarding in terms of crop production and monetary returns as compared to CB + IC system

Kale et al. (1993) studied the denudation of hilly soils in Konkan region on account of excessive soil loss due to erosion which is one of the major problems. The different soil conservation measures viz. contour bund, graded bund, bench terracing etc though projected on large scale have not been scientifically tested so far in this region for quantitating their effectiveness. The studies undertaken on latertic soils with 8 to 10 per cent slope under heavy rainfall area and rabi as a test crop indicated that contour bunding was most effective in reducing soil losses followed by bench terraces, graded bunding in comparison with control. Similarly, Contour bunding was found most effective in reducing runoff than control but it showed narrow differences as compared to graded bunding.

Hemalatha et al. (1996) conducted a study in four villages of Dharwad and Belgaum districts considering 240 marginal farmers, small farmers and big farmers for assessing the knowledge possessed by them on watershed development. The overall knowledge index of farmers on watershed development was 31.97 Majority of the farmers had moderate knowledge on watershed development (70 per cent). Significant association was observed between farmers education and their knowledge on watershed development and soil conservation. It was found from the study that still there is a wide knowledge gap among the potential farmers for which, appropriate extension educational activities have to be organized by the project implementing staff.

Subudhi and Senapati (1996) made a study to evaluate the effects of different vegetative measures on runoff and soil loss in kalahandi distt. of Orissa. The soil of the runoff plots were loamy sand having 68.4% sand, 22.4% silt, 9.2% clay with bulk density of 1.34 Mg/m3. Each plot had 1.6% uniform slope equipped with multi slot divisor and runoff tanks to collect runoff and soil loss. The results indicated that the maximum run off (23.5%) and soil loss (7.87 t/ha) was under cultivated fallow and the minimum under contour planting of vetiver grass, contour planting of *Cynodon dactylon, Pennosetum purpureum, Evlaliopsis binota* reduced the runoff by 23.3, 25.8 and 25.4 per cent respectively as compared to cultivated fallow and additional 47.7 mm of run off could be stored as soil moisture.

Bhardwaj and Dogra (1997) reported that watershed management programmes are having good production potential if they are managed with soil and water conservation measures. The study was referred to the ORP watersheds namely Sukhomajri of Shivalik Hills, Fakot in Himalayas. It was reported that major achievements of these projects were in terms of conservation of water (profile, surface and ground water storage), safe disposal of excess water, increase in production of agriculture, horticulture, forestry and grasses, milk, fish, employment generation and over all development of area and socio-economic upliftment of the people.

Khatik et al. (1997) made an impact study of operational research project on agricultural production through integrated watershed management programme in Rebari watershed of Panchmahal distt. of Gujarat state. The area was treated with various soil and water conservation measures like contour bund gully plugs, check dams and vegetative barriers. This enhanced the availability of water in the watershed and also increased ground water recharge. As a result, the irrigated area was also increased from 94 ha. to 142 ha in the 5-6 years of implementation of programme. It was also revealed that there was a reasonable increment in the food grains productivity due to watershed management programme.

Mishra et al (1997) tried four species of grasses to assess their effectiveness in achieving soil and water conservation based on overall performance in terms of overall performance index (OPI). They found that the highest OPI calculated for *Dichanthium annulatum* (0.88) closely followed *Vetiveria Zizanioides* (0.82) and suggested their suitability for retarding runoff velocity and associated sediment losses, increasing infiltration for insitu conservation of rain water.

Pendke et al.(1997) reported that Ghodegaon watershed (2754 ha) located at Aurangabad district of Maharashtra State was developed under National Watershed Development Programme for rainfed agriculture (NWDPRA) in the 8th five year plan. This watershed has been selected for research study concentrating on quantification of effect of conservation measures on watershed hydrology and its effect on farmers economy. Socio-economic survey was conducted for impact analysis study. Data on meteorological parameters, cropping pattern, inputs and occupation were collected and analyzed for pre and post development stage. The change in cropping pattern, increase in yield level, increase in input are the good indication of development. Due to availability of water in area, the yield of cash crop was considerably increased. There is a considerable increase in per capita income from Rs. 6767 to Rs. 11110. Increase in productivity has resulted due to technological changes including mechanization of different agricultural operations, use of chemicals, fertilizers and pesticides, irrigation potential and improved varieties of seeds.

Prasad et al. (1997) conducted a study in chhajawa watershed of district Baran to analyse impact of three watershed management treatments viz. Graded bunds, gully control structures and insitu moisture conservation practice on runoff, water resource development and productivity of arable land in south eastern Rajasthan from 1986-1993. Results indicated 7.8 per cent runoff of monsoon season rainfall as against normal runoff of 20-25 per cent from untreated arable lands in the region. Due to increase in number of wells from 16 to 39 in seven years the irrigated area increased from 32.5 to 300.4 ha. The average increase in yield of crops was 21.5, 115.9 and 57.0 per cent due to graded bunds, improved package of practices and one irrigation. It was also estimated that investment on the project was recovered in 4 years due to increased crop production. This project was economically viable.

Ranade et al. (1997) made an analysis to see the competitive performance of mechanical and vegetative soil conservation measures in vertisoils of Madhya Pradesh. In a six years study (1990-95), it was observed that mechanical and vegetative barriers are effective in reducing seasonal runoff and soil loss by about 20 to 25 per cent over control under moderate slope category (upto 2%). At the same time it was also observed that vegetative barriers are as effective as mechanical and they can be suitable alternative to mechanical measures in the region.

Singh (1997) evaluated rainwater conservation technologies in various catchment of left bank of Yamuna river watershed. The rainwater was arrested with three tier system in the operational area. Insitu rainwater conservation treatment viz. Vegetative hedge and contour sowing resulted almost equal yield of wheat, mustard, linseed to the mechanical rainwater conservation measures. The approach of "Filter strip cropping" was adopted in micro watershed, which was found beneficial in enhancing the production of cereals, pulse and oil seed from the degraded lands.

Hadda et al (2000) reported that soil erosion in the north-western sub-mountainous tract of India reduces soil productivity. The causes of reduced productivity on eroded soils was not only physically based, but also more complex in nature. Some of the soil and water conservation practices known to increase the crop yields include management of rain water and surplus runoff water and by adoption of appropriate mechanical and vegetative measures. These practices not only decreased the runoff and soil loss but also helped in increasing the profile water storage. The proposed soil and water conservation practices in improving the productivity of soils in north-western sub-mountainous tract of India are: suitable cropping practices, employing vegetative barriers, managing land and soil, employing deep tillage and applying mulches in the form of bands (vertical mulching), pre-monsoon ploughing, holding, harvesting runoff and constructing small earthen dams or small tributaries in the vicinity of cultivated area.

Mukesh Chand and Surajbhan (2000) studied the effect of different vegetative barriers in sorghum based intercropping system for runoff, soil loss and physio chemical properties during Kharif 1995-96. A field experiment was laid out at soil Conservation and Water Management Farm of the University on field having mild slope (2.4%) and alluvial soils of light texture. The treatments were comprised of 6 vegetative barriers viz. (i) *Sesbania sesban* (ii) *leucaena leucocephala* (iii) *Cajanus cajan* (iv) *Vetiveria zizanioides* (v) *Cenchrus ciliaris* and (vi) Control as main plots, and 3 varieties of sorghum viz. (i) CSV-13 (ii) CSV-15 (iii) *Varsha* as sub plots in split plot design replicated three times. The minimum runoff (127.0 mm/ha) was recorded under *Vetiveria zizanioides* barriers and the maximum runoff (215.6 mm/ha) under control plot. *Sesbania sesban, Leucaena leucocephala, Cajanus cajan, Vetveria zizanioides* and *Cenchrus ciliaris* reduced the runoff in the order of 84.2 mm, 82.4 mm, 72.3 mm, 88.6 mm and 75.5 mm, respectively over control. All the vegetative barriers were found effective in reducing soil loss, however, the performance of *Vetiveria* was best. The reduction in soil loss was 3.8, 3.8, 3.4, 4.0 and 3.5 t ha-1 due to *Sesbania, Leucaena, Cajanus, Vetiveria* and *Cenchrus,* respectively as compared to control. Significant reduction in soil loss due to *Vetiveria zizanioides* and *Sesbania sesban* barriers may be attributed to reduction in erosive velocity of runoff which helped to settle down and entrap soil particles behind the barrier.

Koppad et al (2001) made a study during 1994-98 to evaluate the performance of different soil and water conservation practices viz., mechanical measures, agronomic measures and alternate land use system on agricultural production in Varada watershed of Karnataka state. Productivity of different crops was assessed in treated area with such as conservation practices over control. Improved varieties of rice `Abhilash' pigeonpea `S-I', turmeric `Co-1' and Ginger Alleby gave an average yield of 24.66, 8.92, 220 and 245 qha $^{-1}$, respectively. The results showed that there was considerable increase in agricultural production by adopting new technologies in the area. Further, alternate land use systems such as teak based agro forestry and mango-based agri-horticulture extending these technologies to other areas of the watershed reflecting the importance of alternate land use system under watershed management..

Madhu et al (2001) studied the effect of contour staggered trenching (CST) and cover crop of beans in conserving soil and water and its effect on yield of green tea leaves in new Tea plantations in the Nilgiris. The mean of three years data revealed that, soil and water/moisture conservation efficiency was higher in combination of CST + cover crop of beans and Contour Staggered Trenching (CST). Tea canopy per cent, leaf area index and yield of green Tea leaves were significantly higher in cover crop of beans and CST + beans as compared to control and CST alone. Per cent increase in yield of green Tea leaves over control was 33.6, 30.9 and 11.4 in

CST + beans, cover crop of beans and CST alone, respectively. Tender pod and green forage yield of cover crop was higher during initial two years of tea planting due to better growth of beans and poor Tea canopy cover. Cover crop of beans and CST + beans in new tea plantation showed higher economic viability and environmental benefits.

Mishra and Sahu (2001) studied six locally available vegetative species as barriers at Jagannath prasad watershed of Ganjam district of Orissa as a part of world bank aided project. They reported that among this Vetiver recorded lowest run off of 12.72 cm and 10.83 cm in comparison to that of control (19.03 and 13.82) cm and soil loss of 2.54 and 1.78 t/ha with Vetiver in comparison to 5.60 and 4.20 t/ha with control during 1994 and 1995, respectively. Similarly highest black gram yield was recorded with Vetiver which was 38.7% higher than control (7.66 q/ha) *Barriers of napier* (20.1%) *agave* (19.5%), *kanna* (15.7%), *jatropha* (14.3%) and *sabai* (.74%) also recorded higher crop yield than control.

2.4 Critique of review:

Having looked at various research work in state, country and international level, it has been found that the none of the studies covers specific objectives set for the present study. Therefore, an attempt has been made in the present study to achieve specific objectives keeping advantages of previous research work done in other area.

Chapter - III

MATERIALS AND METHODS

This chapter describes general information about the study area, watershed characteristics, morphological characteristics, runoff analysis, measurement of runoff (at SOP and through empirical equations), ground water status in Rajasthan, hydro geological survey and physical investigation of study area, ground water recharge analysis, Criteria for adoption of soil and water conservation measures, socio economic and agricultural aspects and impact analysis of soil and water conservation measures executed in the study area.

3.1 General

Udaipur district is situated between 23° 40’ and 25° 30’ north latitude 73° 0’ and 74° 35’ east longitude. It is situated in the south-eastern part of Rajasthan state and lies in the Aravalli ranges. The district is having 17,62,2000 ha area surrounded by hills out of which 2,20,000 ha is under, forest, 4,14,000 ha is under cultivation and 5,97,000 ha is barren which is not used for cultivation due to excessive slope and other factors (Anonymous, 1981). Few years back, Department of watershed development & Soil Conservation, Govt. of Rajasthan had done efforts for protecting this land from erosion and related problems and making it productive through watershed development works.

Keeping this in view two watersheds treated by the Deptt. of Watershed Development & Soil Conservation, Udaipur were selected for evaluation. The two watersheds so selected are namely Eklingnath watershed (Micro-15, Named Cheerwa) and Losing watershed which were developed separately under two different schemes integrated watershed Development Project (IWDP) and National Watershed Development project for Rainfed Agriculture (NWDPRA) respectively. In Cheerwa watershed works were executed during the year 1990-96 and in Losing watershed works were carried out in year 1992-96. The criteria for selection of these watersheds were nearness to Udaipur and more or less same hydro geological region.

The detail characteristics of both the watersheds are discussed in the ensuring sections.

3.2 Watershed Characteristics

This section deals with specific location of selected watersheds, climate, physiography, soils, geology, ground water condition, land capability classification, and vegetation.

3.2.1 Location: Cheerwa watershed

The Cheerwa watershed is located at National Highway No. 8 on Udaipur - Nathdwara road around 15 km away from Udaipur district and lies in Girwa Tehsil. This watershed was treated under IWDP programme of GOI.

The Cheerwa watershed developed under IWDP lies in sub humid southern plain under IV-A of agro climatic zone of Rajasthan. It lies between 24˚ 33’ to 24˚ 49’ N latitude and 73˚ 37’ to 73˚ 59, longitude. It is represented by loamy mixed soil and the topography is undulating and hilly. The Cheerwa watershed comes under Macro 22 and micro 15. The details of the Cheerwa watershed are given in table-3.1.

Losing Watershed

The Losing watershed is located in panchayat samittee Badgaon, Distt. Udaipur. It lies between 24˚ 45’ to 24˚ 50’ N latitude and 73˚ 35’ to 73˚ 44’. Total area of watershed is 1362 ha which is divided in to 6 micro watersheds and located 26 km away from Udaipur on Udaipur Haldighati road. The details of Losing watershed are given in table 3.1.

Table 3.1 Basic Information of Cheerwa Watershed.

1.	Name of watershed				Cheerwa
2.	Macro w/s No.				22
3.	Micro w/s No.				15
4.	Location				15 km away from Udaipur
5.	Total geographical area				1580 ha.
6.	Name of villages covered				Cheerwa, Karelo ka Guda, Maruwas, Moonwas, Jhalo ka Guda
7.	Total land				1580 ha
B.	Arable land	397.80 ha			Irrigated 80 ha Unirrigated 317.80 ha
C.	Non-arable land	1072.20 ha	a.	Govt/Comm. Land	509.50 ha 234.20 ha
			b.	Private land	
A.			c.	Govt. land	346.20 ha

Table 3.2 Basic Information of Losing Watershed.

1.	Name of watershed			Losing
2.	P.S.			Girwa
3.	Location			26 km. From Udaipur
4.	Total geographical area			1362 ha
5.	Name of villages covered		Shrimaliyan ka kediya, Mataji ka kheda and Kumawato ka Guda	
6.	Arable	705 ha		Irrigated Unirrigated
	Govt. land			188.92 ha
	Nonarable land	657 ha	Private land	262.0 ha
			Panchayat land	159.08 ha
			Habitation	47.0 ha

3.2.2. Climate

The area of Cheerwa and Losing watersheds is characterized by sub humid climate with an average annual rainfall of 577 mm received during monsoon months of June to September, Mean annual maximum and minimum temperatures of the area are 42° C and 4° C, respectively. Relative humidity in the area is around 70 per cent during monsoon period and is below 30 per cent during the months of April and May. Average sunshine hours in both the area is about 10 hours during March to May while during July-August, they drop to 4-5 hrs due to cloudy weather. The annual rainfall of nearby rain gauge stations in different years is given in Table 3.3.

Table 3.3: Annual rainfall for the year 1995 to 2001.

S. No.	*Year*	Cheerwa Watershed (Rainfall mm)	Losing watershed (Rainfall mm)
1.	1995	337.1	443.7
2.	1996	628.1	685.5
3.	1997	588.6	651.1
4.	1998	513.1	718.1

5.	1999	412.8	405.9
6.	2000	439.9	454.3
7.	2001	515.9	543.7

3.2.3 Physiography

Cheerwa water shed:

The Cheerwa watershed comprises of undulating upland fields and hills. The general slope of the area is south-west to north-east direction. The slope of arable land is upto 6 per cent whereas non arable land including pastures is more than 6 per cent. The hilly area has slope percent more than 10 per cent. The area of watershed under different slope group is given in Table 3.4.

Table 3.4 Area under different study slopes in watershed.

S. No.	Slope group (%)	Cheerwa watershed Area (ha)	Losing watershed Area (ha)
1.	0-1	NIL	95.0
2.	1-3	123	213.38
3.	3-5	74	309.50
4.	5-8	200.8	410.64
5.	More than 8	1182.2	333.48
	Total	**1580.0**	**1362.0**

Losing watershed:

The Losing watershed also comprises of undulating upland fields and hills. The general slope of the area is from north-west to south-east direction. The slope of the arable land varies from 2 to 6 per cent while that of non arable land including pasture is more than 4 per cent. The area of watershed under different slope group is given in Table 3.4.

3.2.4 Soils

Detailed soil survey of both the watershed was done, the fertility status of the watersheds was determined by taking soil samples of the area and their analysis was made for knowing pH, organic carbon, available phosphorus & potash. The study area is characterized by medium to heavy textured soils having brown to grayish colour. The fertility of these soils is medium and soils have got good water retention capacity.

The salient features of both the sites are given in Table 3.5.

Table 3.5 Salient soil features of study watershed sites

S. No.	Particulars	Cheerwa watershed	Losing watershed
1.	Soil order	Altisols	Altisols
2.	Soil texture	Sandy clay loam	Sandy clay loam
3.	PH (mmhos/cm)	7.9	8.0
4.	Organic carbon (%)	0.36	0.10
5.	Available Phosphorus (Kg/ha)	21.50	102.0
6.	Available Potash (Kg/ha)	355.40	80.64

3.2.5 Geology

Udaipur district is part of the peninsular region of India and thus possesses peninsular characteristics. Geologically, Udaipur district consists of rock group of Archaean system (Aravalli super group). The main rock formations of the area under study are phyllites, schist's and quartzites. The parent rock system is of granite and gneisses.

3.2.6 Groundwater

Cheerwa watershed

The Cheerwa watershed consists of many dug wells with water table ranging from 9-10 meters below ground level (1995-2001) with seasonal fluctuations. The quality of water is generally good and wells have moderate yields.

Losing watershed

The Losing watershed also consists of many dug wells but water table is quite deep around 16-18 meters below ground water level. The wells have normally good quality of water with moderate yields. At both the sites dug out ponds/anicuts are also used for the purpose of irrigation in the area.

3.2.7 Land capability classification.

Land capability classification is an imperative grouping of soil according to their potential use based on inherent soil characteristics, external land features and environmental factors. The land use capability classification is a systematic arrangement of different kinds of lands according to their properties that determine the ability of land to produce on virtually permanent basis. The land capability classification of watershed with area under study is given in Table 3.6. This consists of class II to Class VIII land.

Class II Land –

It has some limitations that reduce the choice of plant and require moderate conservation practices. The land use may be limited by one or more factors such as gentle slope, moderate erosion, inadequate soil depth, slight to moderate saline/alkaline condition and some what restricted drainage. Management practices are required such as terracing and some agronomic practices. The area under this class was 123 and 80 ha in Cheerwa and Losing watershed respectively.

Class III Land –

It has severe limitations that reduce the choice of plants, crops and require special conservation practices. The use of soil is restricted due to moderately steep slopes, high erosion hazards, shallow depth, low water holding capacity and fertility. Cheerwa watershed consists of 74 ha and Losing 142 ha under this category.

Class IV Land –

Such a land has severe limitations on choice of plants and crops. Intensive soil and water management practices are required. The soil conservation practices must be applied more frequently than class III. Cheerwa watershed covers 200.8 ha and Losing watershed 478 ha in this class.

Class V Land –

It is not suited for cultivation because of wetness, stoniness and adverse climatic conditions. The soil is deep but because of limitations this kind of land is used or grazing or forestry. Losing watershed has got 486.0 ha under this class.

Class VI and VII land –

Soil of these class is not suitable for sustained economic crop production but are suitable for pasture development and afforestation with proper soil conservation and management practices. Cheerwa watershed covers 152 ha under the class.

Class VIII land –

It includes very steep, stony, rough, completely barren, bad lands, desert and high mountains. These limitations make them unsuitable for cultivation, grazing of forestry. It is only suited for wild life recreation or watershed protection or esthetic purposes. Cheerwa watershed having this category of land amounting to 110 ha.

Table 3.6: Area under different land capability classification (ha)

S. No.	Land capability class	Cheerwa watershed	Losing watershed
1.	I	0	0
2.	II	123	80
3.	III	74	142
4.	IV	200.8	478
5.	V	-	486
6.	VI	152	-
7.	VII	920.2	176
8.	VIII	110	-
	Total	**1580.0**	**1362.0**

3.2.8 Vegetation.

Most of the non-arable lands of the study area include private, government and other wastelands are heavily degraded. The details of the trees, shrubs and grasses found in the area are given in Table 3.7.

Table 3.7 Vegetation in the watersheds under study

Name of the watershed	Trees	Shrubs	Grasses
Cheerwa	Neem, Deshi Babool, Bans, Karanj, Mahuwa, Imli, Arusa, Kher	Anwal, Ber, Aak, Thore, Ratanjot	Sehima Nervosum (Sevan), Heteropogan Contortous (Soli), Eremopogan foveolqtus (Murjhaim), Dichhanthium annualatum (Karad) Cenchrus Cilliaris (Anjan), Cynodon dactylon (Doob)
Losing	Babool, Runjh, Kumat, Neem, Bans, Vilayati babool	Anwal, Ber, Aak, Thore, Ratanjot	Sevan, Dohida, Ratda, Soli, Lapla

3.3 Morphological characteristics:

The hydrological response of watershed is much dependent on the rainfall characteristics and also on drainage pattern of the watershed area. The rainfall characteristics can be measured by any nearby rain gauge station whereas the drainage pattern analysis i.e. morphological characteristics can be evaluated through the drainage map of the area. The drainage map of both study areas i.e. Cheerwa and Losing were collected from the Department of Watershed Development and Soil Conservation and morphological analysis was done. The various characteristics chosen for the analysis are discussed in forthcoming sections.

3.3.1 Properties based on linear aspect

Morphological characteristics based on linear aspects considered in the study area were stream order, bifurcation ratio, stream length and stream length ratio.

(i) Stream orders

The first step in a drainage basin analysis is designation of stream order, following a system introduced in the united states by Horton (1945) and slightly modified by Strahler (1957). The smallest fingertip tributaries having no branches are designated as first order streams, where two first order streams join, a channel segment of second order is formed and so forth. The maximum order segment carries the sediment and flow of water at the outlet of the watershed.

(ii) Bifurcation ratio (Rb):

The numbers of each segment is counted for each order say, u and defined as Nu. The bifurcation ratio is defined as the ratio of number of streams of order, Nu, to the number of streams of next higher order, N_{u+1}

$$Rb = \frac{Nu}{Nu+1} \quad (3.1)$$

(iii) Stream lengths (Lu):

All lengths of the drainage lines are measured with the help of Chart meter (Map measurer). The dial of map measurer shows the cumulative length of the drainage lines of all orders. To find out the mean length of the channel, Lu, of order u, the total length is divided by the number of segments, N_u of that order, thus,

$$\bar{Lu} = \frac{\sum_{i=1}^{N} Lu}{Nu} \quad (3.2)$$

Stream lengths are defined in m.

(iv) Stream length ratio (R_L):

Horton (1945) defined the stream length ratio, R_L, as the ratio of mean length, $\bar{L}_u$, of segments of order u to mean length of segments of the immediate lower order, $\bar{L}_{u-1}$

$$\frac{\bar{Lu}}{} \quad (3.3)$$

$$R_L = \frac{\quad}{Lu^{-1}}$$

3.3.2 Properties based on Arial aspects:

Morphological characteristics based on linear aspects considered in the study are stream orders, Bifurcation ratio.

Many characteristics based on area measurement of the watershed are basin area, circulatory ratio, elongation ratio, basin shape factor, form factor, constant of channel maintenance and ruggedness number.

(i) Area of the watershed (A):

Area of the selected watersheds has been measured with the help of a plan meter. The areas are expressed in ha.

(ii) Circulatory ratio (Rc):

Circularity ratio, R_c is defined as the ratio of circumference of a circle of same area as the watershed to the watershed perimeter (Miller, 1953) or ratio of basin area (A) to the area of circle (A_C)having equal perimeter as the perimeter of drainage basin.

$$R_c = \frac{A}{A_C} \qquad (3.4)$$

(iii)Elongation ratio (Re):

Elongation ratio, R_c, is defined (schumm, 1955) as the ratio of the diameter of a circle (D_c) with the same area as the watershed to the maximum length of the watershed (L_{bm}). This parameter is used to assess whether the shape of the basin approaches a circle.

$$R_c = \frac{D_c}{L_{bm}} \qquad (3.5)$$

(iv) Basin shape factor (Sb):

Basin shape factor has the significant influence on the runoff and sediment transport phenomenon. Horton (1932) defined the basin shape factor S_b, as the ratio between the square of the maximum length of watershed and the area of the watershed.

$$Sb = \frac{L_b^2}{A} \qquad (3.6)$$

(v) Form factor (Rf):

It is defined as the ratio of the basin area (A) to the square of basin length (L_b)

$$R_f = \frac{A}{L_b^2} \qquad (3.7)$$

(vi) Drainage density(D_d):

The drainage density (Dd) is defined as the ratio of the total length of all streams of all orders within a watershed to the total area of watershed (A) i.e.

$$D_d = \frac{\sum_{i=l}^{K} \sum_{r=1}^{N} Lu}{A} \qquad (3.8)$$

Here, Dd = Drainage density

Lu = Length of stream segment of order u

A = Total watershed area

K = Principal order = highest stream order

A high value of Dd indicates a relatively high density of streams and thus a rapid stream response.

(vii) Constant of channel maintenance(C)

The constant of channel maintenance C is the inverse of drainage density (Dd)i.e.

$$C = \frac{1}{Dd} = \frac{A}{\sum_{i=l}^{K} \sum_{r=1}^{N} Lu} \qquad (3.9)$$

It indicates the magnitude of surface area of watershed needed to sustain unit length of stream segment.

(viii) Stream Frequency or stream density(F):

It is the number of stream segments per unit area of watershed.

$$F = \frac{\sum_{i=l}^{K} N_u}{A_k} \qquad (3.10)$$

Where, F= Stream frequency

N_u = Number of stream segments of order u

A_k = Basin area of principal order (k)

K = Principal order = highest stream order

(viii) Ruggedness number (N_R):

The product of relief (H) and drainage density (D_d)is called ruggedness number.

i.e. Ruggedness number = H. D_d (3.11)

3.2.3 Properties based on relief aspects

Parameters involving elevation difference are important because these parameters define the potential energy or erosion potential of a watershed. These parameters are evaluated with the help of the contour maps of the watersheds. The relief characteristics considered for the study are relief, relief ratio and relative relief.

(i) Maximum watershed relief (H):

Maximum watershed relief, H, is the elevation difference between basin mouth (discharge point) and the highest point on the basin perimeter. Maximum watershed relief is obtained from the available contour maps of the watersheds. It is expressed in meters.

(ii) Relief ratio(Rr)

Schumm (1956) defined the relief ratio, R_r, as the ratio of maximum watershed relief divided by the maximum watershed length.

$$R_r = H/L_b \tag{3.12}$$

(iii) Relative relief (R_R):

Melton (1957) defined relative relief, R_R as the ratio of the maximum watershed relief to the perimeter length. It is computed using following expression.

$$R_R = H/L_p \;.\; 100 \tag{3.13}$$

3.4 Runoff Analysis:

Runoff is that portion of rainfall, which moves down to stream, channel, river or ocean as surface a subsurface flow. In planning soil and water conservation measures, the design of hydraulic structures, quantitative estimates of runoff rates, volumes and distributions are to be worked out.

The runoff analysis of both the watershed was done through the actual runoff and soil loss measurement at silt observation post and also estimated by various available empirical equations and methods given by different scientists. Finally effort has been made to relate actual measurement with empirical estimation to know that which equation/estimation will be most suitable for this area for runoff analysis.

3.4.1 Silt Observation Post

Silt observation posts or runoff gauging stations are installed for monitoring the runoff and sediment losses of the watersheds, which helps in planning, and designing of various soil and water conservation measures/structures. The sequential monitoring of runoff and sediment losses of the watershed can also be carried out to assess the effectiveness and extent of various conservation measures on reducing the runoff and sediment losses. For effective monitoring of watersheds silt observation posts should preferably be constructed at the outlet of stream having catchments area less than 500 ha.

The shape of the silt observation posts may either be triangular, rectangular or trapezoidal depending upon the site conditions. Triangular shape is the most appropriate one as runoff generated through small rainfall event will provide sufficient head, which can be recorded in it, but the construction of triangular shape silt observation posts is very difficult in the field and there is also a problem of clogging due to the silt. The SOPs at study sites are of rectangular shape. The SOPs at study area are of rectangular shape, the size is 1.75 m x 2 m for Cheerwa & 2 m x 3 m for Losing watershed contributing 82 ha and 368.34 ha respectively.

Stage measurement and preparation of rating curve

Preparation of stage discharge curve also known as rating curve is the first step, which needs to be developed for every silt observation post. The stage discharge relationship is established by taking observations for low and high flows at different depth. The velocity of flow is measured at different depth and their corresponding cross sectional area is calculated. Knowing velocity "V" and cross sectional area "A" at particular stage, discharge "Q" can be measured for different stages. Finally, from these data a graph between stage and discharge is plotted which is known as stage discharge curve or ratting curve.

Sediment Sampling

The sediment sampling involves collection of known volume of water sediment mixture from the stream, which is further analyzed to determine the quantity of sediment yield. In case bed load is not measured, 10 percent of the suspended load is generally added to find out the total sediment yield.

3.4.2 Estimation of discharge rate:

In the design of soil and water conservation measures/structures, quantitative estimates of runoff rates and volumes are to be worked out. Accurate computation of runoff amount is difficult as it depends upon several factors related to atmospheric and watershed characteristics. The following methods are frequently used in soil and water conservation for estimating the peak rate of runoff and runoff yield.

1. Rational method
2. Empirical formulae and table
3. Curve number method

Rational Method

This is a most common method to predict the design peak rate of runoff. This is the oldest and simplest formula proposed by CE Ramser of the USA. This formula is called “rational” because units of quantities involve in this formula is numerically consistent. It is expressed by an equation.

$$Q = \frac{CIA}{36} \qquad (3.14)$$

where,

Q = design peak runoff rate

I = Intensity of rainfall for a duration equal to the time of Concentration and for a given recurrence interval

A = Watershed area

Dicken’s formula:

Empirical formulae and methods are attempts to arrive at simple forms of relationship for peak flow and runoff yield in terms of one or more flood producing factors, the most common being the catchments area. The more important formulae used in this country are the Dicken, Ryve and Inglis formula for peak flow estimation and Barlows strange table for runoff yield estimation.

This is generally applicable for moderate size basins in North and Central India.

$$Q = CM^{3/4} \qquad (3.15)$$

Where Q= discharge rate m^3/sec.

C = Constant taken as 11.4 for this area considering rainfall in the range of 600-1250 mm.

M = Area in sq.km.

Ryve’s formula:

The formula was derived from a study of river basin in South India. The ranges from 6.76 to 40.50.

$$Q = CA^{2/3} \qquad (3.16)$$

Where Q= discharge rate m^3/sec.

C = Constant taken as 10 for this area considering hilly terrain.

A = Area in sq.km.

Barlow’s Tables

T.G. Barlow carried out studies of catchments mostly under 130 sq. km. in U.P. and gave the following values of K as runoff (in percentage) for various types of catchments. Further specifying, he suggested that these percentages are for the average type of monsoon and are to be modified by the application of the following coefficients according to the nature of the season. Here in present study for Cheerwa watershed category "B" and "E" with percent of runoff valuing 15 and 40 were taken for flat partly cultivated and hilly and steep area categories respectively. Finally, weighted percentage was estimated. The categories considered for Losing watershed was "B" and "D" with percentage of runoff taken as 15 and 35 according to land use pattern and topography.

Strange Tables

W.L. Strange evolved some ratios between rainfall and runoff based on data in Maharashtra. He accounted for the geological conditions of the catchments as good, average and bad and surface condition viz., dry, damp and wet prior to rain. The rainfall runoff relationship was given by him for daily rainfall as well as yearly rainfall. For present study, yearly rainfall has been considered for estimating cumulative runoff by this method. Considering rainfall amount to be 515.9 and 543.7 mm in Cheerwa and Losing watersheds and considering condition of watershed as bad catchments the percent considered for runoff was 7.65 and 8.2 respectively.

Inglis and De. Souza's formulae

As a result of studies made by these scientists for catchments in Western Ghats and plains of Maharasthra, C.C. Inglis and De Souza gave the following relations.

For ghat area

$$R = 0.85\,P - 30.5$$

Where R and F are both in cms.

For plains

$$R = \frac{(P-17.8)\,P}{254} \qquad (3.17)$$

The runoff was estimated using equation 3.2

Curve number method:

The SCS curve number method was first developed by SCS, USDA (1964). This method requires individual storm rainfall, land use type, hydrologic soil group and antecedent moisture condition of watershed as input. In this method, the potential maximum retention storage of watershed is related to a discrete number called curve number which is a function of land use, different land treatments, antecedent moisture condition and soil type of watershed. Curve number is dimensionless and its value varies from 0 to 100.

Computation of runoff curve number (CN):

A curve number is an index that represents the combination of a 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 runoff curve number for various hydrologic condition, land use and soil group are given in Appendix-A. The curve number given in Appendix-A apply for normal antecedent moisture conditions (AMC II).

The weighted curve number for a watershed having more than one land use, treatment or soil type can be found by weighing each curve number according to its area and is given by

$$\text{Weighted CN} = \frac{A_1\,CN_1 + A_2 + \ldots\ldots + A_n\,CN_n}{A_1 + A_2 + \ldots\ldots\, A_n}$$

$$= \sum_{i=1}^{n} \frac{A_i CN_i}{A} \qquad (3.18)$$

Where, A_1, A_2, ……A_n are the respective area of CN values CN_1, CN_2 …Can and A is the total area of the watershed.

For dry conditions (AMC I) or wet conditions (AMC III), equivalent curve numbers can be computed by

$$CN(I) = \frac{4.2 \times CN(II)}{10 - 0.058 \times CN(II)} \qquad (3.19)$$

and

$$CN(III) = \frac{23 \times CN(II)}{10 + 0.13 \times CN(II)} \qquad (3.20)$$

Antecedent moisture condition (AMC):

The antecedent moisture condition (AMC) is the index of watershed wetness, which is determined by the total rainfall in 5 days period preceding a storm. An increase in index means an increase in the runoff potential. Such indexes are only rough estimations because they do not include the effects of evapotranspiration and infiltration on watershed wetness.

Hydrologic condition:

The hydrologic condition for a given land use and treatment is given in general classification as good, fair and poor. The hydrologic condition is based on the cropping practices, conservation measures for agricultural lands, plant cover, density for pasture and range lands and depth of litter, humus and humus type for forested areas.

Estimation of runoff:

This method is applied to the study watersheds. For a simple storm, the relation between rainfall, runoff and retention in which rainfall and runoff begin simultaneously over a watershed is given by

$$\frac{F}{S'} = \frac{Q}{P} \qquad (3.21)$$

Where F = actual retention, mm

S' = potential maximum retention (S'≥ F), mm

Q = actual runoff, mm

P = potential maximum runoff (P≥Q), mm

The parameter S' in Equation 3.21 does not contain the initial abstraction. The retention S' is a constant for a particular storm because it is the maximum possible retention over a watershed under existing conditions. The retention (F) varies because it is the difference between P and Q at any point on the mass curve, i.e.,

$$F = P - Q \qquad (3.22)$$

Then Equation 3.21 Becomes

$$\frac{P-Q}{S'} = \frac{Q}{P} \qquad (3.23)$$

Solving for Q, Equation 3.23 results in

$$Q = \frac{P^2}{P + S'} \qquad (3.24)$$

It represents the rainfall runoff relation in which the initial abstraction is ignored. Taking initial abstraction in to account and replacing retention parameter S' by S, the Equation 3.21 becomes.

$$\frac{F \qquad\qquad Q}{} \qquad (3.25)$$

$$S = P - I_a$$

Where Ia is the initial abstraction, $F \geq S$ and $Q \leq (P-I_a)$

The parameter S includes I_a i.e. $S = S' + I_a$

Now equation (3.22) becomes

$$F = (P-I_a) - Q$$

Equation (3.25) becomes

$$\frac{(P- I_a) - Q}{S} = \frac{Q}{P-I_a} \qquad (3.26)$$

Solving Equation 3.26 For Q gives

$$Q = \frac{(P-I_a)^2}{(P-I_a) + S} \qquad (3.27)$$

Which is rainfall runoff relation with the initial abstraction.

Where Q = Runoff depth, mm

P = Rainfall depth, mm

S = Maximum retention potential, mm

I_a = Initial abstraction, mm

The initial abstraction consists mainly of interception, infiltration and surface storage, which occur over the watershed before runoff begins. The relation between I_a and S was developed by using rainfall and runoff data from experimental small watersheds (SCS USDA, 1964) is as follows.

$$I_a = 0.2.S \qquad (3.28)$$

Therefore, the Equation for runoff estimation becomes

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S} \quad \text{for } P>0.2\,S \qquad (3.29)$$

$$= 0 \quad \text{for } P \leq 0.2\,S$$

Vandersypen et al. (1972) has presented following two formulate for different regions of India.

$$Q = \frac{(P - 0.3\ S)^2}{(P + 0.7\ S)} \quad \text{for all regions} \tag{3.30}$$

and

$$Q = \frac{(P - 0.3\ S)^2}{(P + 0.9\ S)} \quad \text{for black soil regions} \tag{3.31}$$

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

S = (25400/CN) - 254

3.5 Ground Water Resources in Rajasthan 3.5.1 General scenario

Due to scarcity of surface water, Rajasthan has to depend on ground water resources to a great extent. An assessment of available ground water resources in the state was initially carried out in the mid seventies, which has been up dated. The ground water resources position as per ground water Atlas Rajasthan (2000). on 1.1.1995 is given in table 3.8.

Table 3.8 Ground water status for the State.

S. No.	**Particulars**	**Status**
1.	Total ground water resources	13,157.16 mcm
2.	Utilization for domestic and industrial use	696.58 mcm
3.	Utilizable ground water for irrigation	11,028.22 mcm
4.	Utilized for irrigation	6,493.71 mcm
5.	Ground water balance	4,534.51 mcm
6.	Stage of ground water development	58.88 per cent

The state has been divided into 594 ground water potential zones. Out of these 322 zones fall in the “White” category where ground water development is less than 65 per cent, 71 zones fall in the `Grey’ category, having 65 per cent to 85 per cent stage of development. The remaining 201 zones have been categorized as `Dark’, where the stage of ground water development is more than 85 per cent. Out of these, 173 zones are over exploited, having a stage of development that is more than 100 per cent. The study area i.e. Udaipr is covered under 'white' category of ground water development which is considered to be within safe limit.

3.5.2 Dynamics of Ground Water:

Ground water is dynamic resource, which is annually replenished. The replenishment takes place primarily through percolation of a fraction of precipitation to aquifers, after passage through the unsaturated soil zone. Ground water recharge also occurs through seepage from lakes and tank beds, canal bottoms and through the return flow of a certain percentage of the water applied as irrigation.

Ground water is harnessed mainly by large diameter wells and tube wells. Also, large diameter open wells have proved more successful than tube wells in aquifers of low transmissivity. Such aquifers are mainly found in hard rocks. The area under study is mainly characterized by the hard rocks. Details of the method used for knowing ground water status, estimation of recuperation index i.e. transmissivity, specific yield and ground water recharge are discussed in the succeeding sections.

3.5.3 FACTORS CONTROLLING GROUND WATER CONDITIONS:

The occurrence of ground water in a region depends on number of controlling factors such as rainfall, topography, vegetation, drainage, the structure and nature of geological formations and degree of their weathering.

3.5.4 METHODOLOGY OF INVESTIGATION:

The investigation was done in two phases viz.

Phase-1 Consists of Geo-morphological, Geological and Hydro geological survey and

Phase-2 Geo-physical investigation through resistivity method

Hydro geological survey comprised of the study of physiography, drainage pattern, vegetation growth, soil characteristic, fracture pattern of the surrounding rocks and inventory of the existing ground water structures.

All possible Hydro geological details like depth and lithology of aquifers, present water level, yield, draw-down, rate of recovery and the general quality were recorded from dug wells/hand pumps in the existing area for judging general hydrology. This is also supported by the Geo-physical survey data.

3.5.5 GEO-PHYSICAL INVESTIGATION:

The factors favourable for ground water recharge and movement are usually studied from surface geological evidence as well as from wells that are existing in an area. Utilizing this information, one makes attempt to predict the locations favourable for ground water occurrence, but such a study usually meets with little success in areas where the information from the wells and that provided by surface geology is either scanty or completely absent. An elegant scientific tool that aids us in discerning the subsurface conditions in such circumstances is the geophysical method of exploration. The geophysical methods play a vital role in exploration of earth's natural resources like minerals, petroleum and ground water. The methods that are particularly useful in ground water exploration are the Seismic, Electromagnetic, SP and the Electrical Resistively method. Of these four, the later are preferred because of low costs involved, ease of field operation and its unique features of distinguishing fresh water zone. Thus the Self-potential, Electromagnetic and Electrical Resistively methods find its widest application in the search of ground water.

Resistivity surveys has proven to be one of the most useful geophysical techniques in minerals exploration, ground water investigation, engineering and environmental studies. In this study vertical electrical sounding method has been used.

After conducting VES, parameters of aquifer like transmissivity and specific yield were measured.

3.5.6 Recovery test for estimating transmissivity

After pumping has stopped the water level ceases to decline in the well and starts rising. This rise in the well is known as recovery of the well. The rise of water is measured as residual drawdown "s" i.e. the difference between the original water level prior to the pumping and the actual water level measured at a certain moment, since pumping stopped. The data obtained during recovery is used for calculating transmissivity (T). Two wells inside the watershed and one well out side the watershed were selected for the estimation of recuperation index i.e. transmissivity (T) to study the effect of soil and water conservation measures.

The recovery method (1935) was used for analysis of recovery data from wells, for small values of `u' (dimension less time, $r^2 S / 4 t T$, the relationship used was

$$s' = \frac{2.3\, q}{4\pi T} \log \frac{t}{t^1} \qquad 3.32$$

Where

T	=	Time since pumping started (min)
t'	=	Time since pumping was stropped ($t=t_p + t'$)
t_p	=	Time of pumping,
Q	=	constant rate of pumping
T	=	Transmissivity.

The solution of equation 3.1 was obtained by plotting residual draw down s’ on arithmetic scale and t/t’ on logarithmic scale. Straight lines were fitted for both early and late recovery periods separately. The slope of the line in each case equal to 2.3 Q/4πT and also equal to the change ∇s in s’ per unit log cycle. Thus, transmissivity was calculated as,

$$T = \frac{2.3\, q}{4\pi \nabla s'} \qquad (3.33)$$

3.5.7 Groundwater Storage changes

The present study deals with assessment of groundwater recharge due to precipitation using water table fluctuation method. Water levels of representative wells in the watershed in relation to precipitation of the meteorological station nearly the vicinity of the wells were measured. The wells were selected both within the watershed area and outside to study the effect of soil and water conservation measures on groundwater recharge.

3.5.8 Effect of soil conservation measures on ground water recharge

The rise of water level can be expressed as

$$h = Pi/Sy \qquad (3.34)$$

Where

h	=	rise of water levels, cm
P_i	=	Portion of precipitation that percolates to the water table i.e. recharge to ground water, cm.
S,	=	Specific yield, per cent.

The rise of water level were obtained from the data, specific yield was calculated from the relation

$$h = h_0 e^{-\alpha t}$$

This equation is analogous to the Bossiness's equation $Q = Q_0 e^{-\alpha t}$, which deals with the physical process of releasing water from storage in the aquifer to the stream as base flow. The constant 'α' is governed by hydro geological characteristics of the basin. Analogous to this,'α'in the relation $h = h_o e^{-\alpha t}$ may be considered to give the value of specific yield of a particular hydro geological formation.

Here,

h = water level in the well at any time t,

h_o = initial water level in the well,

t = time interval of water level rise from h_o to h, days

Thus, having calculated average specific yield for each well P_i is calculated as

$$P_i = h \times S_i$$

Further, recharge in terms of percentage of rainfall at different well location was also estimated. For calculation of average recharge following relationship was used.

$$Wav = W \frac{Pn}{Pe} \qquad 3.35$$

Where,

W_{av} = average recharge, percent

W = recharge during the year of estimation

P_n = normal annual rainfall (mm)

P_e = annual rainfall during the year of estimation, (mm).

3.6 Criteria for Adoption of soil and Water Conservation Measures

Looking to the physiography, geology and other watershed characteristics and plan of the area, various soil and water conservation measures namely, contour vegetative hedges, stone wall terrace, drainage line treatment, loose stone check dam, staggered trenches, contour furrow with stabilized bund, afforestation silvi-pastoral, pasture development were adopted in the area.

Details of these measures are discussed here and design dimension are given in Fig. 3.1 to 3.7

3.6.1. Vegetative barriers or live bunds

Vegetative barriers, or vegetative contour hedges, or live bunds, alone are proved to be useful in preventing soil erosion and conservation of natural moisture in the soil, when placed at suitable interval. Once established, such live bunds need almost no maintenance and will continue to protect the land from erosion for years as they build up natural terraces. Vegetative barriers are planted on contour, which also serve the purpose of guidelines for contour cultivation.

Contour bunds (earthen), an engineering measure, have shown an impact in reducing erosion but this method for purpose of soil conservation has not been found suitable particularly for small land holdings. These earthen bunds with a usual cross section of 0.34 m^2 do not put only a wide strip of cultivated land out of production over the entire length of the bund but also require high cost of construction and regular maintenance to be remain effective for years together. Thus, farmer (especially small farmers) is reluctant to adopt them and if they are constructed at government expense, farmer usually neglects to maintain them and even take active steps to breach and reduce them. Vegetative barriers in contrast are cheaper to make, involve less space and are self-maintaining once established.

When runoff water reaches the vegetative barrier it slows down, spreads out evenly, drops its silt load, and slowly passes through the hedged rows, a large portion of the water soaked into the land along the way. Almost no soil is lost and there is no loss of water through the concentration of runoff in particular areas. This system requires no engineering skill and the farmers can do the complete job themselves. For such live bunds, mainly vetiver or khus grass (*Vetiveria zizanioides*) is used. Vetiver grass is found to be most effective vegetative barrier in checking the erosion and also in conserving moisture. It is claimed that if vetiver grass is properly established, there appears to be no better cost effective method of reducing soil loss and improving insitu moisture conservation. In some areas local grass (Lemon, Munj) cymbopogon flexuous, Saccharum munja are also used for the purpose. For better establishment in the initial stages a small cross sectional `V' ditch is also constructed along with planting of vetiver hedge.

Design criteria: The main consideration of design is the horizontal spacing of the hedge rows, which depends on the vertical interval and slope. In general, CVH is laid at an approximate horizontal interval of 40 m. but some times it is also planted on the field bunds irrespective of the horizontal spacing. Vetiver grass slips are planted at an interval of 10 cm (Plant to Plant spacing).

In the study area the main vegetative barriers used for controlling erosive velocity runoff were khus grass and munj.

3.6.2 Stonewall terrace

In this type of terraces, bunds are formed gradually by allowing erosion on the upper parts of sloping fields and arresting the soil by creating stone barriers on the contour on the lower side of the fields. By adopting this practice, land with limited depth of soil can safely be put under cultivation and also supplement in checking soil erosion. The followed cross section in the area was taken as height (0.8 m), bottom width (1.20 m), top width (0.40 m), depth of foundation (0.20 m) with a depth of foundation (0.20 m) and side slope (1:1).

3.6.3 Loose stone check dams:

This is a very common and adoptable practice in the area. It consists of a terrace with stonewall barriers or check dams across the slope in the valleys or nallas where some soil depth exists and there are chances of deposition of silt. Hence, in the study areas, no waste weir was provided because during initial stage, extra runoff water could safely flow through the structure at a non-erosive velocity while after the treatment of upper reaches the runoff concentration is reduced. In between two LSCD, vegetative checks of *Agave sislana* (Ram bans/sisal), *Jatropha curcas* (Ratanjot) and *Aloe* sp. (Gwarpatha) are also provided. The volume of silt deposited at the up streams of the check-dams was estimated for evaluation of the effectiveness of check-dams. A representative area was selected and its volume inclusive of silt deposited was estimated. Finally, the total silt load from all the area was estimated. The followed cross section in the area was taken as height (0.80 to 1.0 m), bottom width (1.4 m), top width (0.40 m), depth of foundation (0.20 m) with a depth of foundation (0.20 m) and side slope (1:1).

3.6.4 Pasture development and silvi-pastoral system

Most of the non-arable lands including waste lands are completely degraded and devoid of any kind of vegetation, such lands have been developed under pasture/silvipastoral systems, Silvipastoral system has proved to be a dependable proposition for utilization of such degraded lands in watersheds under study.

For in-situ conservation of moisture, contour trenches, contour furrows were constructed. The cross section of contour furrows and contour trenches was kept ½ x 0.40 x 020 m and 0.30 x 0.30m respectively. These were constructed at an approximate horizontal spacing of 10 m on contours. About 150 trees per ha were planted after digging 0.45 x 0.45 x 0.45 m pits. Over seed ling of grasses was also done particularly in between the contour furrows/ trenches and also on the bunds. Grass seeds of Daman (*Cenchrus ciliaris*) and Stylo (*Stylosanthes hamata*) were used. The area was also protected from grazing by erecting a stone wall/vegetative fence.

3.6.5 Afforestation

Watershed management through afforestation provides a new dimension of land use for higher productivity and protection of land. It is an intensive land use system, which yields maximum sustained income. Class VI and VII land in Cheerwa & Losing watersheds were put under afforestation. In this system, for in-situ moisture conservation contour trenches/staggered trenches were provided. In the valleys LSCD supported by vegetative checks were also provided. Over seedling of grass was also done in the area. These areas were also protected from grazing by erecting stone/vegetative fence. The size of pit taken in afforestation programme was 0.45 m X 0. 4.5 m X 0.45.

3.6.6 Contour Trenches:

Contour trenches can be constructed both on hill slopes as well as on degraded and sloping wastelands for soil and water conservation and establishing vegetative cover. The recommended cross section is 0.3 m x 0.3 m. The object being merely to hold sufficient moisture in the soil to enable the berm to be revegetated and to support the planted tree. They are run perfectly level to use their capacity to the best possible advantage. Contour trenches are generally recommended to be constructed for the land having slope up to 30 per cent only, because for the slope above this, it is not stable and also technically not feasible. The cross section of contour trench was 0.30 m X 0.45 m.

3.6.7 Staggered trenches:

Staggered Trenches are excavated trenches of shorter length in a row along the contour with inter spaces between them, constructed in a staggered manner. The vertical interval between the rows is restricted to impound the runoff expected from the catchments area without overflowing the trenches. The cross section area of these trenches is designed to collect run off expected from the most intense storms having recurrence interval of 10 years. The dugout soil is heaped up on the down streamside of the trench leaving a berm of 15 cm. Staggered Trenches are recommended to be constructed for the land having slope greater than 30 per cent. The cross section of this measure was 0.30 m X 0.30 m with a length of trench as 3.0 m.

3.6.8 Puerto Rico Terrace (PRT):

Puerto Rico Terrace (PRT) of dry stone is constructed along the contours, which develop in to level bench terraces due to shifting of soil down the slpe every time after ploughing. This type of terrace is specially suitable for arable lands when slpe in more than 6 per cent and where depth of soil is shallow. Thse are mostly constructed in the areas where stones are easily available at the site. For increasing crop productivity in rainfed areas these terraces are very effective. The cross section followed in the area was 0.45 m X 0.45 m.

3.7 Socio-economic and Agricultural Aspects

India with rural economy has a strong base of agriculture, animal husbandry, marketing and processing industries in a coordinated sense. It is on account of this that a larger proportion of people earn their livelihood in the agricultural sector, which, at the same time constitute a major objective of the expansion and development of the makers of the agricultural industries output. The need for improvement in agriculture income is, therefore, imperative.

Development of agriculture is instrumental to economic growth, which brings about significant changes in cultural and social attitudes of the farmers. In order to bring such changes in social and cultural attitudes government has been giving emphasis on increasing the level of education, improvement in health and hygienic condition, development of agencies imparting knowledge and improvements in life style of rural population. In order to do this, farmers need the technical assistance of soil conservationists.

As the watershed management programme (specially soil and water conservation practices) has direct and indirect effects on raising overall socio-economic status, the parameters related to socio economic and agricultural aspects the study considered are as follows:

Parameters related to socio economical and agricultural aspects in terms of the input and output of important crops grown and post project changes in various aspects like crops, land use pattern, area irrigated etc were analyzed.

Socio economic conditions of the farmers prior to the treatment was taken from project report of the watershed and for present conditions, interviews with the farmers were conducted. Out of the total beneficiaries in Cheerwa and Losing watershed representative sample of farm families were selected randomly with the view that these will give true representation of the area. The farmers were selected on the basis of their land holding viz. less than 1 ha, 1-2 ha, 2-4 ha and more than 4 ha. A survey proforma was developed and farmers were interviewed as per information required in the proforma. Finally, the overall effectiveness of watershed programme and socio-economic benefits were studied.

3.8 Impact analysis of SWC measures:

The watershed development projects under different programmes often failed to achieve their desired results on account of faulty programme, design and inappropriate management practices/structures. Even in cases where progress has been satisfactory, development has not been sustained because of inappropriate selection of soil and water conservation measures. In Rajasthan, specifically in Southern part (area of study) the problems of erratic rainfall distribution, sandy nature of soil, barren hills, low crop yield and insufficient ground water availability combined together and effects the over all economy of the area.

The different soil and water conservation measures are planned, designed and executed in the study area on the basis of land slope, rainfall, soil type, land use capability classification and adoptability of the structure in the area, conservation measures include protective measures, productive measures, community works, conservation structures etc. These measures have evolved over a long period of time tested and tried in various agro-climatic conditions and modified to the location specific and need based. These measures may serve different purposes (from soil moisture conservation to flood control and from prevention of sheet erosion to prevention of land degradation) in different watersheds. But all of them have to be looked upon as a means of (i) reaching higher productivity on a sustainable basis (ii) improving the economic status of the farmer and (iii) generating employment.

Considering all above factors the technical appropriateness of the executed SWC measures in the study watersheds were analyzed in terms of their functional utility for which they were constructed. This analysis included change in cropping pattern, productivity status, additional returns from crop, also performance of pastures in terms of grass production, assessment of afforestation programme (survival percentage), assessment of loose stone check dams for silt deposition and overall benefit accrued through these projects.

The change experienced in all these aspects was measured considering condition before and after the project. This was estimated on the basis of the data collection from the representative farm families of the study area.

Based on above analysis it finally suggested that which of these measures are most suited to this area for deriving maximum possible best results. It is expected that this would help to give a direction to the project implementing agency of the district for preparing future watershed development plans and thereby indirectly helping to have proper and judicious use of funds involved in such valuable projects.

Table- Daily runoff according to Strange

Daily rainfall in mm.	Runoff percentage and yield when the original stage of ground is					
	Dry		Damp		Wet	
	Percentage	Yield in mm	Percentage	Yield in mm	Percentage	Yield in mm
6.25	-	-	-	-	8	0.5
12.5	-	-	6	0.75	12	1.5
25.0	3	0.75	11	2.75	18	4.5
37.5	6	2.25	16	6.0	25	9.5
50.0	10	5.0	22	11.0	34	17.0
75.0	20	15.0	37	27.75	55	41.25
100	30	30	50	50	70	70

Note- for good or bad catchments, add or deduct upto 25% of yield.

About IWDP

Integrated watershed development programme (IWDP) launched by the Ministry of Rural Development (MORD) and at the start of this project it was implemented in 300 districts of 22 states. So far at start a total outlay of Rs. 442 crores was sanctioned or released for treatment of 2.4 mha of land. Despite problems, the results of conservation even in poorly implemented watersheds were reported to be encouraging, which proved the potential of resources and the people and justifies restructuring of IWDP from a supply to demand driven programme. The word "integrated" prefixed with the watershed development programme refers only to integration of funds under Drought Prone Area Programme (DPAP), Desert Development Programme DDP), Integrated Watershed Development Programme (IWDP), Integrated Jawahar Rozgar Yojana (I-JRY) and Employment Assurance Scheme (EAS). As far as integration of privately owned land resources with community resources under the control of various departments for an integrated planning for conservation activities, production system and bio-enterprises is concerned, it is nonexistent. Integration of different production systems that result from conservation is ecologically as well as economically viable and needs to be included in the micro plan.

Average slope of watershed

Erodibility of a watershed directly depends on the average slope of the watershed, S_a. If other factors are constant then the erodibility increases with the slope of watershed. The average slope of the watershed is calculated by using the following formula.

$$S_a = H L_{cs} / 10 A$$

Where, L_{cs} is the average length of all the clearly identifiable contours in a watershed, which is calculated using the following expression:

Where,

L_{ci} = length of each contour in km

I = 1,…………………N

N = number of clearly identifiable contours.

The length of each clearly identifiable contour is measured for each watershed with the help of map measurer and the average, L_{ca}, calculated using above expression.

(v) Main stream channel slope

Main stream channel slope is the hypotenuse of a triangle having the same base length and area under the actual longitudinal profile of the main stream channel from gauge to divide –

$$S_c = \frac{H_e}{1000 L_{as}} \times 100 = \frac{H_e}{10 L_{as}}$$

Sediment samples can be taken through the following two methods.

1. Depth integration method
2. Point integration method

Depth Integration Sediment Sampling

Depth integrated samples are taken with a sampler that has an intake which points directly in to the current. The sample is collected as it traverses the depth of the stream at a uniform speed. For stream less than 3 meter deep, the sampler is lowered to the bottom of the stream at a uniform rate and raised back to the surface at uniform rate but not necessarily the same rate. Deeper streams are integrated in more than on sampling trip. A series of U.S. Department of Agriculture depth integrating samplers like USDH-48, USDH-59, USD-74 have been developed which are widely used for sediment sampling. This method is advantageous to the fact that a single sample provides a discharge-weighted concentration. However, it leaves an unsampled zone at the bottom, which may require separate computation of unmeasured suspended sediment. The approximate location and number verticals is given in Table 10.2

Approximate location and No. of verticals for sediment sampling

S. No.	Width of Stream (m)	No. of Verticals	Location of verticals
1.	0-5	1	At greatest depth
2.	5-30	3	25,50 and 75 percent of the width
3.	30-300	5	25,35,50,65 and 80 percent of the width
4.	>300	7	15,30,40,50,60,70& 85% of width

In the study USDH-48 sediment sampler was used.

Antecedent Moisture Condition (AMC)

It is defined as the wetness index of the watershed. On the basis of runoff potential the AMC can be classified in to three different levels, which are as under.

AMC - I This represents the lowest runoff potential because the soils are dry enough.

AMC – II Average condition regarding runoff potential.

AMC - III This represents highest runoff potential of the watershed.

The AMC is determined on the basis of 5days total antecedent rainfall. The rainfall limits for estimating antecedent moisture condition is as under.

Antecedent moisture conditions	5 days total antecedent rainfall (cm)	
	Dormant season	Growing season

I	Less than 1.25	Lass than 3.5
II	1.25 to 2.75	3.5 to 5.25
II	More than 2.75	More than 5.25

Method of Analysis:

The different variables considered for the estimation of curve number of the watershed were discussed earlier. For classifying the watershed area in to hydrologic soil groups, working unit personnel of Watershed Development and Soil Conservation Department was consulted and few visits to the watershed were also made. Many visits were also made to find depth of soil, infiltration rate, soil texture etc. The land use pattern and treatment practices in the watershed area were obtained from concerned Patwari. The information about the hydrologic conditions of the watershed was also collected.

Table- Barlow's percentage runoff coefficients.

Class	Description of catchments	Percent run-off
A	Flat, cultivated and black cotton soils	10
B	Flat, partly cultivated various soils	15
C	Average	20
D.	Hills and plains with little cultivation	35
E	Very hilly and steep, with hardly any cultivation	40

Table- Barlow's runoff coefficients for different nature of season.

S. No.	Nature of season,	Class of catchments				
		A	B	C	D	E
1.	Light rain, no heavy downpour	0.70	0.80	0.80	0.80	0.80
2.	Average or varying rainfall, no continuous downpour	1.00	1.00	1.00	1.00	1.00
3.	Continuous downpour	1.50	1.50	1.60	1.70	1.80

He divided special tropical rainfall into the following four classes.

i) Negligible falls-

All falls under 12 mm a day unless continuous for several days; also falls 12 to 24 mm a day not followed or preceded by any rain.

ii. Light falls.-

All falls upto 25 mm a day followed by similar or heavier falls. Steady pours of 25 to 40 mm a day, when there is no rain of similar or greater amount before or after that.

iii. **Medium falls-**

Falls from 25 to 40 mm a day when preceded or followed by any but light falls.

iv. **Heavy falls**

(a) All falls over 75 mm a day or continuous falls at 50 mm a day.

(b) All falls of an intensity of 50 mm or more per hour.

He gave the runoff percentages as shown in Table…

Table- Barlow's runoff percentages.

S. No.	**Nature of rain fall**	**Percent of flow on catchments of different types**				
		A	**B**	**C**	**D**	**E**
1.	Negligible falls	-	-	-	-	-
2.	Light falls	1	3	5	10	15
3.	Medium falls	10	15	20	25	33
4.	Heavy falls	20	33	40	55	70

Computation of annual discharge:

The daily discharge was estimated by the data received at stage level recorder. The stage of flow and its corresponding time for a particular rainfall storm on specified dates was analyzed for computation of discharge. The average discharge is calculated against the average stage by using the rating curve. The annual flow is calculated by summing up of all the events of the flood flow through SOP. By this a rainfall developed for the different value of runoff.

In resistivity methods a known electrical current (I) is sent in to the ground through a pair of electrodes and the potential developed due to this current is measured across two other pair of electrodes. The ratio between the potential difference, between the potential electrodes (V) and the current (I) gives Apparent Resistance (R) which depends on the resistivity of the surface formations and the electrode arrangement (configuration). There are number of electrode arrangements (configuration) for sending current and measuring the potential difference, the most popular being Wenner and Schlumberger.

Fig.3.1 shows the disposition of electrodes in both these configurations. In Wenner configurations, the current and potential electrodes are in a line symmetrically placed over the point of observation.

The Wenner configuration is the most commonly used array proposed by Wenner in 1916 and it is useful for detailed investigations. The four electrodes C_1:P_1:P_2:C_2 are placed at the surface of the ground along a straight line symmetrically about a point "O". The observation point is in such a way that the distance between $C_1P_1 = P_1P_2 = P_2C_2 = a$, where "a" is called an electrode separation. Current is sent generally through outer electrodes C_1 and C_2 and the potential difference V is measured between P_1 and P_2. The configuration factor G for this arrays is $2\pi a$, and Apparent resistivity which is used for the further analysis is calculated with formula.

$$Paw = GR = 2\pi a R$$

In electrical profiling the electrode separation is kept constant and the electrode array moved as a whole with the center of configuration occupying successive points along a traverse. The value of apparent resistivity is plotted at the center of the electrode array. This technique is used to examine a slice of ground parallel to the surface of the ground, the thickness of the slice being a function of the electrodes separation. The result obtained by electrical horizontal profiling may be presented as apparent resistivity profiles or as apparent resistivity maps if measurements are taken along a number of closely spaced parallel profiles. The direct current and alternate current instruments are used for the investigations.

The interpretation of resistivity data is carried out in two steps. First the data is interpreted in terms of physical parameters namely resistivity and thickness of the formation and in the second step these parameters, with the help of existing geological information are interpreted to know the nature and sub surface distribution of formations. There are different methods of interpreting the resistivity data. The most popular and conventional methods are the curve matching techniques, semi empirical method and inverse slope method.

The inverse slope method is semi-empirical and gives resistivities and depths directly from a plot of field data on a linear graph and there is no need to have theoretical curves. This method can apply for both Weneer and Schlumberger configuration.

The resistivity response depends primarily on the amount of impregnating water, the conductivity of the water and the manner in which it is distributed. Summarisingly, it can be stated that dry formations are poor conductors and hence, the resistivity increases, but the resistivity of these formation decreases with the increasing amount of pore water.

3.5.6 Ground water recharge by precipitation

Main source of groundwater recharge is generally from precipitation particularly in those areas where average annual precipitation exceeds potential evaporation. Evaporation may deplete the water held in surface storage, in the soil or in aquifer.

Ground water recharge occurs when residual precipitation (precipitation less actual evaporation) has infiltrated into groundwater reservoir (Fig.). This may occur any where between several hours to several months after the precipitation event. Groundwater storage occurs because of difference between inflow rates to and outflow rates from ground water. This difference will vary in space and time, particularly from one climatologically zone to another due to different precipitation and evaporation patterns. In some areas groundwater recharge may be derived predominantly from precipitation directly and in other areas from infiltration of surface water.

This method was developed by Ogrosky and Mockus (1957) for determining peak rate of runoff for small watersheds by synthesizing information about flow characteristics, physiographic factors and soil cover data. Soils have been divided into four hydrologic soil groups according to their hydrologic properties and characteristics. The peak rate of runoff is obtained by the following equation.

$$q\ peak = \frac{0.0208 \times A \times Qd}{Tp}$$

Where q peak = Peak rate of run off, m^3/sec.

Qd – runoff depth, cm.

Tp = Time to peak, hr.

= 0.6 Tc + Tc, Tc = Time of concentration, minute

This method of runoff estimation is based on the recharge capacity of the watershed. The recharge capacity of area is determined by wetness of the watershed i.e. the antecedent moisture condition and physical characteristics of the watershed. In this method curve number represent an index, which is a combination of a hydrologic soil group and antecedent moisture conditions. Curve number method can be used for estimation of water yield as well as peak rate of runoff from areas above 50 ha.

Estimation of Runoff from Rainfall: -

The curve method for rainfall- runoff relationship was developed with the help of amount of rainfall and watershed characteristics and following equation were suggested to find out the direct runoff.

$$Q= \frac{(P - Ia)^2}{P - Ia + S} \tag{3.1}$$

Where,

Q= actual runoff, cm

P= rainfall, cm

Ia = initial losses such as interception, infiltration through the soil, depression storage, etc. cm.

S = recharge capacity or potential maximum retention of the watershed, cm.

If it is assumed that Ia is to be a fraction of recharge capacity (S) then

Ia = 0.2S (For black soils) or

Ia = 0.3S (For all other soils)

Putting the value of Ia = 0.2S in equation 3.1

$$Q = \frac{(P-0.2S)^2}{P-02S+S}$$

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

The recharge capacity (s) of the watershed is calculated using curve number.

$$CN = \frac{2540}{25.4+S}$$

Where, CN= Curve Number

The availability of ground water depends upon the nature of rocks and their water bearing characteristics. Approximately, 40 per cent area of Rajasthan is occupied by hard rocks consisting of the Archaean crystalline, Aravalli super-group and Delhi super-group, the Erinpura Granites, Malani suite of igneous rocks, their equivalents the Vindhyans and the Deccan Traps. The crystalline (igneous and metamorphic rocks) ranging in age from Archaean to Upper Proterozoic, have negligible primary porosity. Significant secondary porosity is introduced into them locally due to weathering and fracturing; the yield of wells generally ranges from 10,000 to 50,000 lph. Vindhyan sandstones and limestone's occupying parts of Kota, Baran, Jhalawar, Bundi, Chittorgarh and those of Marwar super group in Jodhpur and Nagaur districts are promising aquifers with moderate to high discharge due to their porous and permeable nature. The discharge in limestones varies from 30,000 to 1,00,000 lph in Bilara and Borunda (Jodhpur) area. Similarly, discharge in sandstone ranges from 20,000 to 80,000 lph in Mathania and Osian area of Jodhpur district.

The Deccan traps show low to medium permeability depending on the primary and secondary porosities and their variation from place to place. In the hard rock terrains, the valley fills consisting of river and stream laid deposits, often contain highly productive aquifers, with limited groundwater resources. The alluvium and the blown sand, which occupy the major part of the state and the semi-consolidated formation comprising the Territories and the Mesozoic rocks.

The alluvium contains the most productive aquifers in the region but locally; the quality of ground water is saline. The blown sand also forms moderate potential aquifers at places, particularly in western Rajasthan. Among the semi-consolidated formations, the Lathi sandstones are found to contain moderate to high productive aquifers. Higher yields are obtained from wells tapping sandstones, lime stones and fractured crystalline.

Ground water development is significantly high in the eastern part of Rajasthan as compared to the western part. The annual ground water recharge is relatively less in western Rajasthan, due to low and erratic rainfall, absence of surface water resources, and high evapotranspiration. However, in some of the thick aquifers, the storage is many times the annual recharge and hence, sustained pump age can be achieved even during a dry spell, without causing adverse effects.

The depth of water varies widely throughout the state. To the east of Aravalli, the depth to water is comparatively shallower than in the west. It generally varies between less than 10 to 25 meters in the eastern part, whereas in the western part, it ranges between 20 to 80 meters. The water level slopes towards the east and the south-east on the eastern side, whereas to the west of Aravallis, it slopes towards the west and the north-west. Shallow water levels have been noticed in the canal command area of Ganganagar, Banswara, Kota and Bundi districts whereas the higher value of depth to water has been observed in the western districts of Rajasthan particularly Jaisalmer, Bikaner, Barmer and Jodhpur.

In general, the chemical quality of ground water is fresh in the eastern part except in the localized area of Bharatpur district, particularly in Sewar, Nagar, Kumher and Deeg blocks where the ground water is brackish to saline. The chemical quality in the major parts of western Rajasthan is brackish to saline. However, potable water is found in the areas covered by sandstone and limestone of Marwar super Group. Lathi formation in Jaisalmer and Barmer districts and

Territories in parts of Bikaner, Nagaur, Churu, Barmer and Jaisalmer districts and localized pockets in Quaternaries.

CHAPTER V

SUMMARY & CONCLUSIONS

Soil, water and vegetation are the most vital natural resources for the survival of man and his animals. For their efficient and sustainable management, one has to look for sustainable unit(8) of management so that these three resources are handled and managed effectively, collectively and simultaneously. Watershed which is hydrologic unit of a drainage outlet, forms an integral component of the basic natural resource, the land mass, presents an ideal unit for managing three vital resources. The comprehensive development of a watershed so as to make productive use of all its natural resources and also protect them may be termed as watershed management.

Watershed management arrests soil erosion, reclaims vast tracts of eroded lands, improves soil moisture, harvests rain water, reduces floods, recharge ground water and revives greenery. In due, course it restores rainfall, revives healthy climate, regenerates soil regime, rejuvenates green foliage and improves environment. Further, it renders the rural population self sustaining in food, fat, fodder, firewood, fruit, health and hygine. In an sequences, dependence of the rural poor reduces, their farm produce increases, per capita income grains and economy improves. Whether a watershed development programme undertaken at a particular place has proven to be a success, it becomes an essential process to go for an expost evaluation of that project. The evaluation may be done with the extent to which various technological interventions introduced in the programme to achieve its stated objectives. The effect of watershed management programmes are not visualize immediately after the execution but it may take few years to achieve and restore the original state of the natural resources. Despite of understanding the importance of evaluation in such programmes not much emphasis has been given to this by the engaged executive agencies. Keeping this in mind research study entitled “An evaluatory study on morphological characteristics and ground water status in selected treated watersheds” for this region has been undertaken. Based upon the study the various conclusions drawn are enlisted below.

The evaluation study made under this research project at Cheerwa and Losing watersheds lead to the following conclusions.

1. In both the watersheds the trunk order of the stream was three.
2. The number of streams of particular order is more than the next higher order but less than the immediate lower order in study watersheds.
3. The value of bifurcation ratio was found to be 2.84 and 2.80 in Cheerwa and Losing watersheds which reveals that basin are normal basins.
4. The elongation ratio at both study sites namely Cheerwa and Losing was evaluated to be 0.68 and 0.83, which suggests that watersheds are under moderate slopes.
5. The Cheerwa watershed has higher value of drainage density than Losing which reveals that soil loss in Cheerwa is 1.25 and 1.15 times than Losing in the year 2000 and 2001, which confirms the property of these characteristics.
6. Runoff volume reduced by 1.6 percent considering year 2000 to 2001, where as soil loss reduced from 1.5 to 1.29 tons/ha. It infers that in Cheerwa watershed is now trailing towards stabilization and soil loss is within permissible limits.
7. The similar trend for runoff and soil loss was found in Losing watershed.
8. Using Rational formula higher time of concentration T_c (57.87 minutes) was found in Cheerwa (1580 ha) watershed resulted in lower peak discharge rate by 1.1 times to that of Losing watershed with T_c amounting to 49.43 minutes.
9. Peak discharge rates through Dicken, Revy's and Inglis formula are matching in both the watershed as they considers area only. The variation in discharge rate can be comparable with the variation in size of these watersheds.
10. Discharge volume estimated through Barlows and Strange tables shows reasonable variation and reason being the amount of rainfall is considered as main variable.
11. Runoff depths estimated through S.C.S. curve number method are much comparable with the runoff depths measured at SOP than any other empirical method or equation.
12. It reveals that for estimating runoff depths/volumes S.C.S. curve number method is most suited to this region.
13. Resistivity survey made in the study area reveals that the potentiality of ground water

availability is low to moderate.

14. The open wells can yield moderately at reasonable depth depending upon the general topography of the area.

15. Location 2 in Cheerwa watershed and Location 1 at Losing watershed were selected for the pumping test analysis in the existing open wells of this location.

16. The value of aquifer property transmissivity in Cheerwa watershed was estimated to be 153.5 and 159.7 m^2/day in treated area whereas in untreated the same was 88.14 m^2/day in Losing watershed these values were found to be 206.0 & 211.34 m^2/day within treated whereas 180.63 m^2/day in untreated area.

17. The recuperation rate was 1.8 and 1.4 times more in treated area of Cheerwa and Losing as compared to untreated area.

18. The net rise in water column during monsoon months is more by 2.0 to 20.0 percent in watershed wells in Cheerwa. The same was 4.9 to 26.5 percent more in Losing watershed wells.

19. The specific yield in watershed wells was in the range of 2.69 to 3.23 percent where as in outside wells the same was 1.10 to 1.34 percent in Cheerwa. The same for Losing watershed wells was 0.75 to 1.05 percent and outside wells registered 0.59 to 0.64 percent.

20. The average ground water recharge in wells within Cheerwa watershed was to the time of 1.97 to 2.32 times considering outside wells. The same in the Losing watershed was recorded to be 1.22 to 2.13 times more as compared with wells of untreated area.

21. The recharge values are suitably weighted for normal rainfall year.

22. The irrigated area increased - times in Cheerwa and times in losing watershed.

23. With the imposition of soil and water conservation measures and increased moisture status in the area the cropping intensity increased from 30.3 to 99.64 percent in Cheerwa and 79.43 percent to 97.19 percent in Losing watershed.

24. Additional farm income fetched through higher production in different kharif and rabi crops in Cheerwa was Rs.2790.10 whereas in Losing the same was 2901.12 /ha.

25. The highest cost benefit ratio was found in 1.92 to 3.1 in Urd crop in Cheerwa

whereas in Losing the same was risen from 2.04 to 3.29.

26. The moderate shifting in occupation was found in both watersheds under labour with farming profession. The shift was 3 and 6 percent in Cheerwa and Losing as compared to base status of the area.

27. The rate of silt trap at Loose stone check dam (Stone wall terrace) was found to be 1.08 m^3/ha/yr. And 1.36 m^3/ha/yr in Cheerwa and Losing watersheds.

28. Afforestation programme revealed that in Cheerwa tree species of babool survived the most whereas in Losing the eucalyptus plant showed maximum survival.

29. Due to peoples intrest, social fencing and increased water availability through various conservation measures, grass production from the previously known wastelands was received to the time of 1.35 tons/ha in Cheerwa and 1.6 tons/ha in Losing.

30. The study reveals that for Udaipur region the most suitable watershed measures which could be executed

on arable lands	-	Puerto Rico Terrace, Stone wall terrace, contour bunding.
On non-arable lands	-	Loose stone check dams, V ditch contour trenches, staggered trenches

31. Study concludes that peoples participation in watershed management programme is imperative, without which the programme does not become a viable sustainable proposition.

CHAPTER IV

RESULTS & DISCUSSION

This chapter deals with the results obtained and discussion there on for each of the stated objective of the study as already mentioned in chapter I. The methodology adopted and process of data collection for achieving results is discussed thoroughly in Chapter III. The results so received are suitably discussed with supporting research work.

The chapter is organized in sub heads viz. morphometric analysis, runoff and soil loss measurement at SOP, rainfall - runoff morphology inter relation hydro geological survey and geophysical investigation, analysis of this survey , estimation of transmissivity, effect of SWC measures on recuperation rate, effect of rainfall and SWC measures on ground water fluctuations, ground water recharge, effect of SWC measures on ground water recharge, socio economic analysis, employment generation, performance of LSCD on silt deposition, effect on soil moisture status, afforestation programme, pasture development and suggested appropriate soil and water conservation measures for the area.

4.1 Morphometric analysis:

It includes the analysis on systematic description of the watersheds geometry and its stream channel system to measure the linear aspects of drainage network, aerial aspects of drainage basin and relief aspects of channel network. The first two categories of measurement treat the projected property of watershed on a horizontal plain, termed as plan metric, whereas the third category of measurement counts the vertical inequalities of forms of drainage basin. The various morphological characteristics of study area are discussed in ensuing section for measuring and analyzing morphological features of both the watershed under study, the drainage maps were collected from the project implementing agency and then they were studied in relation to various aspects (Characteristics) mentioned earlier in section 3.

4.1.1 Liner aspects:

It refers to analysis of stream order, stream length and length of overland flow. In both the watershed as shown in table 4.1 i.e., Cheerwa and Losing, the highest order of streams was found to be three. In all the three order numbers of streams found in Cheerwa watershed were higher than those of Losing watershed. This is an indicative of better drainage network in Cheerwa as compared to Losing watershed. It is found that the number of streams of particular order are more than the next higher order but less than the immediate lower order. It means that number of streams of a particular order decreases with the increase in stream order.

In Cheerwa watershed length of streams of order 1,2 & 3 was found to be 29000, 20000 and 9600 m respectively while that of in Losing watershed same was 21000, 8750 and 3500 m respectively. However, in general, the mean length of the stream of the particular order increases with the increase in the order of stream which means the mean length of a stream of a given order is greater than that of immediate lower order but less than that of the next higher order. This confirms the property of the stream order number and their corresponding length. Similar results have also been reported by other research work in Chambal catchments (Mishra 1994).

The average bifurcation ratio was estimated as 2.84 and 2.80 in Cheerwa and Losing watershed whereas the average length ratio estimated to be 0.63 and 0.95 in these watersheds respectively. It can be seen from the table that length ratio values of RL_1 & RL_2 are very close to each other for both the watersheds which confirms the property that length ratio tends to be constant throughout the successive orders of stream segments in the watershed. The values of bifurcation ratio in study area indicate that the shape of watersheds is some what belonged to normal basin (R. Suresh 2000).

The length of overland flow has not been estimated in this study as this parameter of liner aspects is commonly used for small watershed whereas our study watersheds were relatively large.

4.1.2 Aerials aspects:

This aspect of morphological study includes the description of arrangements of area elements mainly the basin shape. The evaluation of basin shape has significant importance to predict its effect on stream discharge characteristics. The quantitative expression of drainage basin shape is estimated under different forms. Referring table 4.1, it shows that values of form factor in Cheerwa and Losing watershed is 0.36 and 0.54 respectively whereas values of circulating and elongation ratio were estimated as 0.57, 0.87 and 0.68, 0.83 for Cheerwa and Losing watersheds respectively. These values are in confirmation with already reported values (Singh, V.P.) that the elongation ratio varies between 0.6 to 1.0. However, this also suggests that watersheds are under moderate slopes as values are more closer to the lower range values. Further, higher value of elongation ratio in Cheerwa and higher value of circulatory ratio in Losing indicates that watershed is approaching towards elongated and circulatory shape respectively which is also confirmed through the maps.

Another important characteristic under this aspect is drainage density. It is an important indication of elements in the stream eroded topography. The study shows that value of drainage density of Cheerwa watershed is 3.71 as compared to 2.44 that of Losing watershed. Further, related to drainage density another morphological property of drainage basin is constant of channel maintenance which was found to be 0.27 and 0.40 sq km per km in Cheerwa & Losing watershed respectively. The lower value of drainage density in Losing watershed as compared to Cheerwa was due to the fact that former watershed was under denser vegetation than the later and also having low relief. This is also evident from the values of relief ratio i.e. 4.2 per cent and 3.6 per cent in Cheerwa and Losing watershed respectively.

4.1.3 Relief aspects:

Under this section various aspects of relief and associated properties have been discussed. Referring back table 4.1 estimated value of relief in Cheerwa and Losing watershed was 270 m and 180 m respectively based on which relief ratio was found to be 0.042 and 0.036 respectively. The relative relief was estimated to be 1.45 and 1.28 per cent in both the watersheds respectively.

Associated to these properties another characteristics are ruggedness and geometric number. It is seen that values of ruggedness number is 1001.7 and 439.2 and geometric number is 238.1 and 122.0 respectively in Cheerwa and Losing watersheds. The values so estimated indicate that both Cheerwa and Losing watershed has comparatively longer but gentle slopes. In case of very high values of ruggedness number, it is considered that watersheds are having very steep slopes, which is not the case under study.

A similar study was made by Wodeyar et al. (2001) in Kolhapur district of Maharashtra suggest that the basin under study was having streams of the order 5^{th} and bifurcation ratio was 3-4.8 which suggested that the basin was under flat topped hill ranges with steep hill slopes. The value of drainage density for the basin was estimated to be 1.2 km./sq.km. which indicated the coarse textured nature of soil whereas considering drainage density of study area it could be infer that soils are of medium textured, which is confirm by the soil analysis and characteristics shown in table-3.6.

Results and discussion based on morphometric analysis are indicative of the fact that it could be infer that watersheds under study are having normal to circular shape with moderate general slope in the area. The values found for various morphological characteristics also reveals that basin is under good vegetation with moderately permeable subsoil materials.

4.2 Runoff and soil loss measurement at SOP:

As mentioned in earlier chapter SOP were installed for monitoring runoff and sediment loss from a basin and used for evaluating watershed developmental works. The first step in this process was to develop the rating curve for the study area for further analysis. The silt observation post in both the watersheds were of rectangular type and for both the SOPs rating curves (curve between stage & discharge) had been developed which is shown in Figure 4.1 and 4.2 for Cheerwa and Losing watersheds. The corresponding data for developing these curves are shown in table 4.2 & 4.3. But these data are related to the observed stages which do not utilized full carrying capacity of SOP, therefore, based fit curve between observed stages and discharge was developed and their corresponding equation were found as

$$Y = 0.3516\ X^{0.5105} \qquad \text{(4.1, for Cheerwa), and}$$

$$Y = 0.2202\ X^{0.5565} \qquad \text{(4.2, for Losing)}$$

Both the curves have goodness of field with R^2 values closer to unity. These curves were extra plotted by using dotted line in the figure 4.1 and 4.2 to know runoff corresponding to those stages which were not measured. Further, these curves were used to estimate runoff for various rainfall events for the year 2000 and 2001 in the study areas.

The total runoff corresponding to different stages noticed at SOP due to each rainfall event is computed from hydrograph obtained at SOP and corresponding rating curve. Sediment samples collected during each rain storm were also analyzed and total soil loss due to particular rain storm is calculated and shown in Table 4.4 to 4.7 for Cheerwa and Losing watershed during the year 2000 and 2001 respectively.

The assessment through SOP at Cheerwa watershed reveals that total runoff volume for the year 2000 was 25275.0 m^3 against total rainfall amount of 439.9 mm which yielded ten runoff producing storms. The same for the year 2001 was found to be 30443.6 m^3 having total precipitation of 515.9 mm and 14 runoff producing events. The heaviest storm in the year 2000 was of 61.2 mm which yielded 3512.8 m^3 runoff volume where as in 2001 the same was of 90 mm yielding 8118.0 m^3. The runoff study reveals that the runoff volume is decreased by 1.6 per cent in the succeeding years, which may be due to increased and dense growth of vegetation caused by the construction of soil and water conservation measures. This is also evident from the succeeding reduction in the soil loss from the year 2000 to 2001, which amounts to 1.51 ton/ha to 1.29 ton/ha. Though this reduction in sediment transport seems to be very meager but it can very well understood that the watershed has already completed 5 years of its execution and considering this time span, the soil loss is very well within the permissible limits and showing that area is trailing towards stabilizing stage.

In Losing watershed total rainfall for the year 2000 and 2001 was recorded to be 454.3 and 543.7 mm respectively which produced 10 and 12 runoff producing storms in these years (Table-4.6 & 4.7). Further, it can be seen through table 4.6 that the heaviest rainfall storm amounted to 77.8 mm yielding 17194.1 m^3 runoff volume causing soil loss of 0.288 t/ha. This was followed by another heavy storm of 48.4 mm yielding 11053.1 m^3 runoff volume which recorded a soil loss of 0.165 t/ha. It can be revealed from table 4.6 that total runoff volume for the year 2000 was 84517.4 m^3 with a soil loss of 1.2 t/ha. In the year 2001, heavy precipitating storms of 71.5, 56.5 and 48.2 mm were recorded which produced runoff quantum of 21595.7, 14151.6 and 13137.0 m^3. The sediment loss recorded during these storms was 0.263, 0.153 and 0.130 t/ha respectively. The total runoff volume and soil loss for the year 2001 was estimated to 99240.2 m3 and 1.08 t/ha respectively. This is evident from the results that there has been a reduction in per cent of runoff volume as well as in quantum of soil loss. This can now be very well understood that this reduction is assigned to the cause of developmental works taken in the watershed i.e. different soil and water conservation measures and agronomical practices. However it would be appropriate to mention here that Losing watershed was completed in the year 1994-95, thus at the lapse of 6-7 years time the watershed is leading to stabilizing stage and ranging in safe limit of soil loss.

A study made by Mishra & Sahu (2001) reported that there was considerable reduction in runoff as well as soil loss under various soil and water conservation measures. Among all vetiver recorded the lowest run off of i.e. 12.72 and 10.83 cm in comparison to that of control and soil loss was 2.54 and 1.78 t/ha with vetiver as compared to 5.60 and 4.20 t/ha with control during 1994 and 1995. This proves the effectuality of soil and water conservation measures (vegetative or engineering) in reduction of soil loss and run off.

4.3 Rainfall–Runoff - Morphology interrelation:

Considering yearly rainfall & basin area of study watersheds peak discharge rate, volume of runoff and runoff depth has been estimated using various empirical equations & method. Result obtained from different equations has been shown in table 4.8 (a & b).

Rational method of estimating peak discharge rate shows that in Cheerwa watersheds (1580 ha) peak discharge rate was less than losing watershed (1362 ha.). This result can obviously be understood with the fact that time of concentration (T_c) estimated for Cheerwa watershed was 57.87 minutes where as the same for Losing watershed was found to be 49.43

minutes. Thus, it would take more time for runoff water to reach at outlet in Cheerwa watershed as compared to Losing and therefore more volume of runoff water would infiltrated in soil profile resulting into lesser amount of peak volume in Cheerwa area, now considering bifurcation ratio of both the watersheds the variation was only of 1.4 per cent and henceforth it is expected that the difference in peak discharge rate of both the watershed should be with in same range. The same is estimated to be 1.1 times in Losing over Cheerwa, which confirms the property of bifurcation ratio and suggests that the watersheds are normal basins. The peak discharge rate was also estimated based on two another empirical equations given by Dicken and Ryve and presented in table-4.8. The discharge rate by Dickens formula was estimated to be 90.34 and 80.82 cumec respectively in Cheerwa and Losing area and the same by Ryve's formula calculated to be 62.90 and 57.03 cumec respectively. The values so estimated for both the watershed could be understood to be appropriate as it considers only basin area as a main variable and hence higher values for Cheerwa watershed. But, the discharge rate found through Dicken's equation is more closer to Rational method thus seems to be more practical for design purpose after rational method. However it could be revealed from the study that if average value of constant in Dicken's and Ryve's is taken as 16.6 and 20.8, this would result in more closer estimation for rational values. Thus these constants can be considered for further runoff estimations in watershed planning. Similarly, since basin area is more than the extent of order number of streams would be more and also expected discharge quantum will be more in larger area.

Considering runoff measurements at SOPs for both the watersheds, it was evaluated that runoff depth (mm) is higher in Cheerwa watershed as compared to Losing watershed in both years i.e. 2001 and 2002 (Table 4.8 b) which was 30.82 and 37.12 mm in Cheerwa as compared to 22.9 and 27.0 mm in Losing and confirms the basin property basin with larger area would result in to higher runoff volumes.

Associated to this, the morphological properties like drainage density and relief ratio suggests the intensity of erosion process of the basin. Hence, according to it, a basin with higher relief ratio and drainage density is expected to have more erosion and there by more soil loss per year considering other aspects to be same. Here, in the study areas both the watersheds were already developed and passed a reasonable time after execution thus assuming other aspects to be same specially vegetation, the area with higher drainage density and relief ratio would represent more soil loss. The results shown in table - 4.4 to 4.7 reveals that higher soil loss in tons/ha was received in Cheerwa watershed in both the years which was 1.25 times in 2000 and 1.15 times in the year 2001 as compared to Losing watershed in these years. This confirms the analytic view of morphological property as stated above i.e. drainage density and relief ratio which is higher in Cheerwa as compared to Losing. The interpretation and interrelation analysed between basin properties and discharge measurements are in confirmation with the theories given by various text return on the subject.

Another commonly used empirical equations/methods used for estimating runoff yield were Inglis equation, Barlows table, Strange's table and Curve number method. It can be seen from the table - 4.8 b that volume from each of these method except curve number method was found to be 107.44, 304.78, 172.2 ha. m for Cheerwa and 106.23, 160.2 and 148.45 ha-m for Losing watershed considering rainfall year 2001. As these methods are empirical and considers mainly rainfall as the variable, the variation from actual measurement at SOP is quite large and non-considerable. But, on the contrary the runoff depth and thereby runoff volume is also estimated by curve number method which considers various factor(variables) as mentioned in Chapter III. The runoff yield estimated by this method are given in table-4.9 & 4.10. It can be seen from the values observed at SOP for Cheerwa location runoff was measured as 30.82 mm (Table 4.8 b) and 26.3 mm by curve number method giving a variation of 14.6 per cent over measured value in year 2000 where as the same was found to be variating by 13.42 per cent in the year 2001. At another site Losing, watershed, the variation in runoff depths between observed and estimated by curve number method was found to be 37.6 and 19.7 per cent for the year 2000 and 2001 respectively. The similar variation is expected in runoff volume (ha-m) for both the watersheds considering runoff depth and area. Thus, with these results it can be analyzed that curve number method for estimating runoff depths in much closer to that of actual measurement in the area hence, it can be infer that for most of the practical purposes of watershed planning and design of soil and water conservation measures in this area curve number method is the most fit method. The result found, can suitably be supported by Ray (1998) whose study on runoff estimation through daily rainfall using different methods reveals the curve number method can be used as appropriate matter for this region.

The present study considers in addition to curve number method, three others method and suggests that curve number methods is the best methods for runoff estimation. Design of structure based on other method will have heavy over estimation of runoff volume which will cost, cost overruns.

4.4 Hydro geological survey& geophysical investigation

Geophysical investigations were conducted at three sites in both the watershed having two different locations at each site. In all at twelve places geophysical investigation

using vertical electric sounding method were made and the observation recorded at three locations are given in Appendix A-1 to A-12. Interpreted results of geophysical investigation from site one to three, for location one and two (Cheerwa watershed) are presented in Table 4.11 to 4.13 and Table 4.14 to 16 (Losing watershed) respectively.

Site One

Hydrogeology:

Hydro-geological inventory of the existing ground water structure around the investigated area at Cheerwa site one reveals that the first regional ground water layer occurs in between 16.00 meter to 24.00 meter below ground level in low lying area and it is also depending on topography. However, the existing open wells are in operation at shallow depth at location one.

There exists three tube wells drilled in near by area but they were very low yielding. Shallow open wells inventories around the investigated area reveals that the present yield of water is not satisfactory due to depletion in water level. Quality of ground water is generally good in this area.

Geologically the investigated area consists of contact of rocks. Ground water seems to occurs in weathered /fractured /joints at different depth as per hydrogeological area is low to moderate saturated and moderate to deeper depth. Hence water in open wells can be tapped at dipper depth.

Electrical resistivity survey analysis:

The analysis of data in Appendix A-1 to A-12 and hydro-geological inventory of the existing ground water structure are shown through tables for both Cheerwa and Losing watershed The resistivity values recorded at different locations and different sites for both the watersheds have been presented in graphical form in fig. 4.3 and 4.4.

Table 4.11: Interpreted results of geophysical investigation.

Ground water potential status:

S. No.	Site	Location	Depth (In Mts.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	One	One	19-20	Medium	Very very	Good	180	293

				hard with less fractures	low			
2.		Two	20-22	Fractured saturated med. hard rock	very low	Good	239	330
			26-28	Fractured saturated med. hard rock	very low	Good	220	216

Referring table 4.11 and figure 4.3 the geo-physical study reveals that there is not good possibility of getting good water at the studied area up to 15 m depth. Yet open well can yield better at reasonable depth at around 20-25 m. This was confirmed with the existing wells in the area and site was not selected for pumping test analysis. The data shows shallow and deeper horizons, which are likely to be massive and containing very less or no fracturing and jointing.

Site 2:

Hydrogeology:

The study reveals that the study of hydro-geological inventory of the existing ground water structure in the area, first regional ground water layer occurs in between 14.00 meter to 20.00 meter below ground level. The present yield of water was moderate from existing open well tapping the depth by a suitable pump.

Table 4.12: Interpreted results of geophysical investigation.

S. No.	Site	Location	Depth (Mts.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	Two	One	14-16	Fractured saturated medium hard rock	Low	Good	270	2100

2.	Two	Two	20-22	Medium hard with saturated fractures	Moderately low	Good	450	1000
			28-30	Medium hard with saturated fractures	Moderately low	Good	500	5000

Ground water potential status:

Studying the topographysical, geological, hydrogeological, characteristics and scientific analysis and computation of field data of vertical electrical soundings (table-4.12), the ground water movement occurs along the weathered zone, joints and fractures of rock. The general depth of water below surface varies from 18 Mts. to 25 Mts. Looking to yield potential of ground water in this area the existing well was selected for pumping test analysis considering watershed boundaries.

Site 3:

Hydrogeology:

Geologically the investigated area consists of hard rocks. Generally ground water layers occurs in weathered /fractured /joints at different depth but as per hydrogeological inventory this area is very low saturated at shallow as well as deeper depth due to massive & hard rock. Hydro-geological inventory of the existing ground water structure around the investigated area reveals that the first regional ground water layer occurs in between 18.00 meter to 26.00 meter below ground level in low lying area but water level may vary depending on topography.

Table 4.13: Interpreted results of geophysical investigation.

S. No.	Site	Location	Depth (Mt.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	Three	One	28-30	Very less saturated fractured hard rocks	Very low	Moderate	370	5500
2.		Two	28-30	Very less saturated fractured hard rocks	Very low	Moderate	790	23000

Ground water potential status:

The study of geomorphological, geological, hydrogeological, scientific analysis and computation of field data suggests that two investigated points inside selected area appears to have very low saturation with less chances of good ground water at shallow and deeper horizons upto investigated depth. The resistivity values are very high as shown in table 4.13 & figure 4.3. Thus it was infer that the site is under low potential zone.

Hydrogeological inventory of near by area also indicates that bore holes are very low yielding and non-operating. This inventory also supports present study.

As per interpreted geophysical survey data the investigated points shows that rock becomes hard and less saturated at deeper depth so discharge is not satisfactory. Hence, these sites are not much economically feasible for potential under ground water yielding. Hence, the inference is also confirmed from general survey of the area which reveals that only a few open wells are dugged in this location and are running for few hours only due to low discharge region.

Losing Site 1

Hydrogeology:

The hydrogeology of area reveals that ground water layer occurs in weathered /fractured /jointed rock at moderate and deeper depth and below this ground water has low to moderate saturation due to medium hard rock. The geophysical data (Table – 4.14 & 4.16) of this area shows low to moderate resistivity at moderate & deeper depth due to soft –medium hard rock. Existing open well /tube well/hand pump inventories near and in the investigated area reveals that the present yield of water was moderate and general quality of ground water is good. In this area hand pump on stand was running good. Hydrogeologically the area is moderately saturated. All above results were also supported by the geophysical data. Hydro-geological inventory of the existing ground water structure around the investigated area reveals that the first regional ground water layer occurs below 14.00 meter.

Electrical resistivity survey analysis:

Hydro-geological inventory of the existing ground water structure in the area reveals that the first regional ground water layer occurs below 14 meter.

Table 4.14: Interpreted results of geophysical investigation.

S. No.	Site	Location	Depth (Mts.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	One	One	22-26	Medium hard rock	Low	Good	350	1000

			36-38	Soft medium, hard rock	Moderate	Good	400	370
2.		Two	18-20	Medium hard rock	Low	Good	280	550
			54-56	Soft medium, hard rock	Low – moderate	Good	400	1050

Ground water potential status:

After studying the geomorphological, geological, hydrogeological and computation of scientific analysis of field data of geophysical investigation (Table-4.14 & Figure 4.4) indicates that there is moderate possibility of getting good ground water at the studied area for the construction of tube well. Existing hand pump inventory also suggests there is good ground water below the surface. The investigated area is moderate yielding due to fractured soft to medium hard rock. The data shows shallow and deeper water horizons.

This area lies under study location and the wells for pumping test analysis were selected from the existing open wells keeping in mind the watershed boundaries of Losing watershed and the inference made through geophysical investigation.

Site 2

Hydrogeology:

Hydro-geological inventory of the existing ground water structure in the area reveals that the first regional ground water layer occurs in between 12.00 meter to 18.00 meter below ground level. The present yield of water was moderate. The density of open wells were very low due to the depletion of water table, it means the shallower zones have less water pressure due to thickness of weathering is very less so the area is very low saturated. All the above revelation is also supported by the geophysical data.

Electrical resistivity survey analysis:

Table 4.15: Interpreted results of geophysical investigation.

S. No.	Site	Location	Depth (Mts.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	Two	One	16-18	Medium hard rock with less saturated fractures	Very low	Good	920	720
2.		Two	16-18	Medium hard rock	Low moderate	Good	320	500

Ground water potential status:

After studying the hydrogeological, scientific analysis and computation of field data of vertical electrical soundings (table 4.15 and figure 4.4), the ground water movement occurs along the weathered zone, joints and fractures of rock. The general depth of water below 13 meter while deeper horizons are also fracturing and jointing but the rate of flow is very low. The geophysical investigation indicates that there is very low availability of ground water for agriculture purpose but hand pump can run with low discharge.

Site 3

Hydrogeology:

Hydro-geological inventory of the existing ground water structure in the area reveals that the first regional ground water layer occurs in between 18.00 meter to 26.00 meter below ground level.

Hydrogeologically the area is low saturated and upper zones are highly fractured than lower zones.

Electrical resistivity survey analysis:

Table 4.16: Interpreted results of geophysical investigation.

S. No.	Site	Location	Depth (Mts.)	Formation	Saturation (Expected)	Quality (Expected)	Resistivity (ΩM)	
							True	Absolute
1.	One	One	28-30	Hard rock, very low saturated, fractured	Very low	Good	170	96
			45-50	Hard rock, very low saturated, fractured	Very low	Good	95	53
2.		Two	40-44	Hard rock with less saturated fractures	Very low	Good	100	90

Ground water potential status:

The study of geomorphological, geological, hydrogeological and resistivity soundings inside selected area indicates very low saturation and less chances of good ground water at shallow as well as deeper horizons upto investigated depth (table 4.16 & 4.4).

Geophysical investigated sites in selected area have very poor saturation as indicated by very high resistivity values. Hence, these are not much economically feasible for potential under ground water or it can be stated that sites are not suitable for the ground water exploration because of very low discharge. Hence, on above conclusions the pumping test analysis was not made in this area in the existing open wells.

Based on the study and conclusions of geophysical investigations, the potential sites for ground water yielding were identified and existing open wells were selected for pumping test analysis as mentioned at each site. The investigation analysis shows the existing pattern of ground water availability of whole region. When this investigation is followed by ground water recharge analysis, the combined study may lead to give an appropriate picture of the ground water dynamics. Further, it is evident from this survey that investigations are made at different locations covering a large area, yet there is not too much difference in the geological pattern and potentiality of ground water availability. Thus, recharge analysis made in ensuing sections may serve as a guide line to know the utility and effectuality of implementing soil and water conservation measures and ground water recharge structures under watershed management programme.

4.5 Transmissivity

Transmissivity of selected wells in both the watersheds was estimated by Thies recovery method (1935). Pumping test data were collected for two wells inside the watershed and one well outside watershed. Pumping test data for these wells in Cheerwa watershed are given in table 4.17 to 4.19. Plotting of s'versus t/t' on semilog paper was done with the help of recovery data. Straight lines were fitted for early and late recovery periods separately (Fig. 4.5 to 4.7) It was observed that in Cheerwa watershed average transmissivity was estimated to be 153.5 and 159.7 m^2/day for the well located within and 88.14 m^2/day outside the watershed respectively.

Similarly recovery data for Losing watershed were also collected for two wells inside the watershed and one well outside watershed. The collected information is given in table 4.20 to 4.22. Plotting of residual drawndown s' verses t/t' on semilog paper has been represented in figure 4.8 to 4.10.

In Losing watershed average transmissivity was estimated to be 206.0 and 211.34 m^2/day and 180.63 m^2/day in the wells located within and outside watershed respectively. This shows that transmissivity or recuperation index of the well under treatment of watershed 1.16 times as compared to the well located outside watershed. As the geological formation may be assumed to be same (as analysed earlier), the variation may have been due the construction of Soil & Water Conservation measures. The variation may be on account of intensity of fracturing and weathering of the formation.

These values of transmissivity seem to be in agreement with the values reported by Jat (1990), i.e., 170.72 m^2/day for phyllite formation (recovery method) and lower values than this for quartzite formation (157.02 m^2/day). The low values recorded for outside well may be due to poor fractured zone also.

4.6 Effect of Soil and Water Conservation Measures on Recuperation Rate:

Effect of soil and water conservation measures on recuperation rate was studied and it was presumed that these measures must increase the recuperation rate. Table - 4.23 shows that in Cheerwa watershed, well located within the watershed had higher transmissivity 153.5 m^2/day). The recovery was 89 per cent in 205 minutes as compared to the well located outside the watershed which showed 50.7 per cent recovery in 185 minutes with lower transmissivity value

88.14 m^2/day. The recuperation rate was lower (0.12 m^3/min.) in outside well as compared to inside well (0.22 m^3/min.). Thus, it can infer that certainly the watershed works have proved their utility in quick recuperation of wells.

In case of Losing watershed, the well located within area had transmissivity value 211.34 m^2/day and recovery was 81.0 per cent in 335 minutes. The recovery in well outside area was 51.0 per cent in 350 minutes with transmissivity 180.63 m^2/day (Table-4.30). Further, the recuperation rate was 1.4 times higher in the well of the treated area as compared with untreated area. Thus it can be inferred that due to construction of watershed measures recuperation rate can be expected more in the wells which are under recharge and influence of these works and will attain its static water level in lesser time.

Inter comparison of Cheerwa and Losing watershed indicate higher recuperation rate in case of Cheerwa, this may also be due the fact that in Cheerwa watershed more soil and water conservation works were executed due to no constraint of funds available with that project.

4.7 Effect of Rainfall and Soil and Water Conservation Measures on Groundwater Level Fluctuations:

The water level fluctuations in four selected wells with in the watershed and two wells outside the watershed were recorded for Cheerwa and Losing watershed and are being presented in table 4.24 and 4.25 respectively.

Results revealed that with the occurrence of rainfall the water table in the wells of watershed and outside watershed also rose, both in Cheerwa and Losing watershed. Further, it is indicated that total precipitation in the year 2001 was 515.9 and 543.7 mm respectively in both the watershed and fairly distributed over the whole monsoon period. The trend of water level fluctuations is shown in fig. 4.11 and 4.12 for Cheerwa and Losing 4.13 and 4.14 for Losing watershed respectively.

The rainfall was resulted in net rise in the water column i.e. 7.65 m, 8.0 m, 8.5 m and 9.35 m in well number 1,2,3 and 4 respectively located inside the watershed from June to September for Cheerwa watershed. The net rise in well no. 5 and 6 located outside the watershed was 7.75 m and 7.95 m respectively. Further, total water column depths up to October, 2001 were 5.1 m, 4.35 m, 5.1 m and 5.85 m in well No. 1,2,3 and 4 as compared to 4.25 m and 3.9 m in well no. 5 and 6 (Table 4.24 and Fig. 4.11 & 4.12). This shows that net rise in the wells located in side the watershed is more as compared to wells located outside the watershed. Further, the net available water column after monsoon period was more in the wells of the watershed. The net rise was 2.0 per cent to 20.0 per cent more in the watershed wells. As all the wells are not much farther from each other, it can be inferred that more rise in the water column of watershed wells is the direct effect of soil and water conservation measures due to more conservation of water.

The net rise in water level for Losing watershed was registered as 7.5 m, 9.05 m, 8.8 m and 8.75 m in well No. 1,2,3 and 4 respectively located within watershed area (Table 4.25 & Fig. 4.13 & 4.14). The net rise was 7.15 m and 7.25 m in the wells located outside watershed area. This shows that the net rise was 4.9 per cent to 26.5 per cent more in the watershed wells as compared to well No.5 and 3.4 per cent to 24.08 per cent more as compared to well No.6. Further, the available water column up to October 2001 was 5.9 m, 5.7 m, 6.0 m and 6.75 m in the well No. 1 to 4 respectively which is 52 to 80.0 per cent more as compared to well No. 5 and 21.2 per cent to 43.6 per cent more as compared to well No. 6. Thus it can be concluded that the higher rise in water column during monsoon period and more availability of water column depth after monsoon period in well No. 1 to 4 is due to the implementation of watershed programme. It may also be seen from the Fig. 4.13 and 4.14. That fluctuations were less in the post monsoon season in case of watershed wells as compared to well No. 5 and 6 which may be due to recharging of these wells under soil and water conservation measures.

After the month of September, the precipitation ceases in both the watersheds and resulted in lowering of water table. This is also evident from declining curves (Fig. 4.13 and 4.14).

These results can suitably be confirmed by the study made by Varadan et. Al. (1998) on hydrology and socio economic evaluation of three micro watersheds in Kerla State. The study revealed that recharge of ground water is one of the major advantage due to soil and water conservation programmes in watersheds. They observed mean seasonal water fluctuations of selected wells in treated and untreated watersheds. The observations revealed an abrupt rise in water level during monsoon period indicating the nature of terrain and profile character. Both during pre and post monsoon period the mean water column decreases. The decrease was very low in treated watershed as compared to untreated watersheds wells. The value of decline for treated was 0.2 to 0.5 m where as for untreated the same was 0.2 to 2.0 m.

4.8 Ground water recharge

Ground water recharge was estimated using water fluctuation of well in study area i.e. well number 1 to 4 with in treated and well number 5 to 6 in untreated area. To estimate recharge, the specific yield was measured using analogy of Bousinessq equation.

4.8.1 Estimation of specific yield

Calculation of ground water recharge requires knowledge of aquifer parameters, e.g., storage coefficient (specific yield) and transmissivity. Here, specific yield has been estimated making use of change in water levels in the wells during specific periods. The specific yield is, therefore, calculated for individual wells whose water levels were recorded during monsoon period. Referring table 4.26 shows that specific yield (average) was 2.96 x 10^{-2}, 3.23 x 10^{-2}, 2.69 x 10^{-2}, and 2.78 x 10^{-2} in well No. 1, 2, 3 and 4 respectively located in Cheerwa watershed. The same for the wells located outside the watershed was estimated as 1.34 x 10^{-2} and 1.10 x 10^{-2} respectively (Table 4.27).

Average value of specific yield in Losing watershed was estimated to be 0.75 x 10^{-2}, 0.91 x 10^{-2}, 1.05 x 10^{-2}, and 0.86 x 10^{-2}, in well No. 1,2,3 and 4 respectively (Table-4.28). These wells were located with in watershed while the well located outside watershed have given the value of specific yield as 0.59 x 10^{-2}, and 0.64 x 10^{-2}, respectively (Table-4.29). The variation in the values of specific yield in both the locations must be because of variations in formation characteristics i.e. fracture intensity, hardness etc. Hydro geological analysis of study area showed that wells in Cheerwa watershed had phyllite formation whereas the wells in Losing watershed had quartzite formation (parent rock being sand stone). Quartzite's are known to have lower specific yields than phyllites as reported y Jat (1990). Further, the values of specific yields for weathered phyllites ranges from 1 x 10^{-2} to 3 x 10^{-2}, as reported by NABARD (1984).

4.8.2 Ground water recharge analysis

Ground water recharge was estimated using analytical procedures given in section 3.5.8 the information needed for estimation and computed values are being presented in table 4.30 and 4.31 for Cheerwa and table 4.32 and 4.33 for Losing watershed.

The study showed that wells located in the watershed have recorded recharge due to rainfall from 20.68 per cent (minimum in well No.1) to 77.4 per cent (maximum in well No. 4). The maximum recharge per cent was estimated to be 65.13, 75.2, 71.7 and 77.4 per cent in well No. 1,2,3 and 4 respectively (Table-4.30). Further, average recharge in well No. 1,2,3 and 4 was estimated to be 46.8 mm, 50.0 mm, 46.1 mm and 52.0 mm respectively. The maximum & minimum recharge per cent in well No.5 and 6 was estimated 8.02 to 30.9 per cent and 4.87 to 56.14 per cent respectively (Table 4.31). The average recharge per cent

registered in the watershed wells were 1.99 times to 2.32 times as compared to well No. 5 and 1.97 times to 2.30 times as compared to well No. 6. As well located in side the watershed were under the influence of soil and water conservation practices and showed higher per centage of recharge, this can be inferred that due to adoption of soil and water conservation practices the ground water recharge was increased.

Similarly in Losing watershed maximum recharge was estimated to be 26.93 per cent in well No. 2 and a minimum of 6.67 per cent in well No. 1. The maximum recharge was estimated to be 12.40, 26.93, 21.08 and 19.9 per cent in well No. 1, 2, 3 and 4 respectively, which were located within watershed (Table-4.32). The well No. 5 and 6 located outside watershed-registered recharge from 7.1 to 9.9 and 7.2 to 10.57 per cent respectively (Table-4.33). The maximum recharge per cent for the wells within treated area was more as compared to well of untreated area. Further, it may be estimated from Table 4.32 & 4.33 that average recharge per cent was registered minimum 1.32 times to maximum 2.13 times in well No. 1,2,3 and 4 as compared to well No. 5 and 1.22 times to 1.98 times as compared to well No.6.

The recharge analysis also shows that in Cheerwa watershed rainfall amount during 10.7.01 to 29.7.01 recorded to be maximum 14.52 cm, yet this higher rainfall has resulted in lesser contribution to ground water recharge. It seems that during this interval one rainfall storm of 90 mm of high intensity and short duration had taken place, which may have resulted in higher surface runoff and lesser ground water recharge. However, similar trend was not found in Losing watershed during the period from 4.7.01 to 23.7.01. The maximum rainfall amount in this period was 14.59 cm with storms of 29.5 mm and 71.5 mm, which resulted in more recharge. Since the recharge was estimated for the year 2001 only, these values were weighted for normal rainfall year and the same have been given in parenthesis of these tables.

The values of ground water recharge of the study seems to be in confirmation of recharge values estimated by Athwale (1986) which, was reported to be 50 mm in arid regions with annual rainfall lower than 750 mm.

4.9 Socio-economic and Agricultural Analysis

As per the project report of both the watersheds, it was observed that before the implementation of project the study watersheds suffered from low productivity leading to low farm income and consequently poor investment capacity of the farmers. Off farm activities consist of animal husbandry where outputs were mainly related to production levels in agriculture. The associate problems were moisture stress faced by the crops due to erratic behaviour of rainfall, declining productivity trend, soil erosion due to uncontrolled runoff, poor vegetative cover on non-arable lands, inadequacy of drainage line treatment during high intensity rainfall and lack of alternative employment opportunities.

4.9.1 Status of farm families:

Information were collected during the study regarding farm families, land use pattern, cropping area and cropping intensity, productivity status, additional farm income, economic returns from crop and employment generation for both the watersheds.

The total number of farm families in Cheerwa watershed were 812 and average size of family is 5-7 members. The literacy per centage in the watershed was about 25 (As per Census 1991). The distribution of land holdings in the watershed was as given in table 4.34.

Table 4.34 Number of farm families under different land holdings in Cheerwa watershed.

Size group	**No. of farmers**	**Per centage**
Marginal holdings (0-1 ha)	333	41
Small holdings (1-2 ha)	251	31
Medium holdings (2-4 ha)	154	19
Large holdings (above 4 ha)	49	6
Very large holdings (About 10 ha)	25	3
Total	**812**	**100**

The total numbers of farm families in Losing watershed were 712 and average size of family was 6-7 members. The literacy per cent in the watershed was about 31. The distribution of land holding is given in Table 4.35.

Table 4.35 Number of farm families under different land holdings in Losing watershed.

Size group	**No. of farmers**	**Per centage**
Marginal holdings (0-1 ha)	119	16.71

Small holdings (1-2 ha)	346	48.59
Medium holdings (2-4 ha)	143	20.08
Large holdings (above 4 ha)	104	14.62
Total	**712**	**100.00**

4.9.2 Change in Land Use Pattern

After the evaluation of the project it is seen that there is a phenomenal change in the land use pattern in the project area of Cheerwa watershed, after the implementation of the watershed management programme. The net cultivated area before the commencement of the project was 397.84 ha (1992-93) but with the imposition of soil and water conservation works an additional area of 19.16 ha (previously waste land) has been brought under cultivation up to year 1999-2000. Since start of project, up to the year 1999 an additional area of 210.09 ha, 604.81 ha and 238.1 ha were brought under silvipastoral, pasture and afforestation programme respectively out of the wasteland of the area. The irrigated area increased from 80.0 ha to 102.0 ha due to additional irrigation facilities developed. Number of open wells increased in the area from 30 to 46. Details are given in Table 4.36.

The details of change in land use pattern for Losing watershed are given in Table 4.37. The net cultivated area in the Losing watershed project was 705 ha during start of project but with the imposition of soil and water conservation work 34.5 ha waste land has been brought under cultivation. Up to the year 2000-01 an area of 324.5 ha, 106.0 ha and 145.0 ha were brought under pasture, afforestation and silvipasture respectively, which were earlier panchayat and private wastelands. The irrigated area increased from 85 ha to 107.4 ha due to additional irrigation facilities developed.

4.9.3 Cropped Area and Cropping Intensity

With the implementation of watershed management programme, i.e. soil and water conservation works, increased irrigation facilities, increased moisture status and use of improved seeds and fertilizers, a major area has been brought under cultivation both in kharif as well as in rabi season. The cropping intensity which was 117.38 per cent in the base year has increased to

122.78 per cent after the implementation of the project. The details given in Table 4.38 reveals a major change in the area under maize, wheat, mustard and groundnut while the area under Til and Sugarcane has reduced. Looking to the previous years of drought conditions and the introduction of improved variety of maize, the area under Til has reduced. Further, due to increased irrigation facility in Rabi season wheat crop is sown with improved variety in the area. Musturd, groundnut and sugarcane crops with improved variety were introduced in the area during year 1996-97. As oil seed crop, mustard has become extensively popular due to its drought tolerance and high yield potentiality under dryland conditions (Fig. 4.15 & 4.16).

Area under different crops and cropping intensity for Cheerwa watershed are graphically presented through bar diagram and pie chart in fig. 4.15 and 4.16 respectively.

In Losing watershed (Table 4.39) it was observed that cropping intensity, which was 106.13 per cent in the base year, has increased to 113.18 per cent after the implementation of the project. A major change in the area was noticed under maize, urd, til, wheat, mustard and gram while the area under barley and paddy was reduced. Due to increase in irrigation facilities, there is a significant change in cropped area of wheat, mustard, gram, sugarcane in rabi season. The area under different crops and cropping intensity is shown through bar diagram and pie chart in Fig. 4.17 and 4.18.

4.9.4 Productivity Status:

Due to use of improved seeds, fertilizers, plant protection measures, timely intercultural and other operations and effect of soil and water conservation measures contour bunds and CVH in particular, the crop yield in Cheerwa have been increased significantly than that of the base year (4.40). This is a direct effect of the integrated watershed management approach. The initial average productivity (principal crops) of the cropped area was around 7.18 q/ha in the watershed, which has now risen to 11.81 q/ha (an increase by 1.64 times). The productivity increased by a minimum of 25.0 per cent in green fodder to a maximum of 85.71 per cent in the maize crop. The productivity status was maximum in maize followed by mustard and til which showed an increase of 81.81 and 80.0 per cent respectively. This is on account of leveling of the plots and increased moisture status after construction of contour bunds and contour vegetative hedge in the cultivated area besides improved seeds and use of chemical fertilizer. Crops like groundnut, gram and wheat have also shown good yield potential in the area after implementation of programme, which has become popular in the area. The details of productivity level are shown through bar diagram in fig. 4.19.

Due to affect of soil conservation measures, CVH in particular and use of improved seeds, fertilizer, the crop yields have been almost doubled than that of the base year. The productivity increased by a minimum of 25 per cent in green fodder to a maximum of 150 per cent in the mustard crop. The productivity status followed by mustard is in groundnut and maize, which showed an increase of 123.5 per cent and 108.3 per cent respectively. This is on account of leveling of the plots and increased moisture status after construction of CVH in the cultivated area. The details of productivity level are given in Table 4.41 and Fig. 4.20.

4.9.5 Additional Farm Income:

After detailed analysis it has been found that total net additional income for Cheerwa watershed (Table 4.42 & 4.43) works out as Rs.1450.3 thousand rupees which is average annual additional income in the watershed area after project implementation. Average net additional income per hectare in the area is Rs. 3384.7 which highlights the direct benefits of soil and water conservation works. The maximum return is from maize crop followed by urd, wheat and til.

After detailed analysis in Losing watershed, it was found that total net additional income works out as 2026.7 thousand rupees which is average additional income in the watershed area. Average net additional income per hectare in the area is Rs. 2686.0 which high lights the direct benefits of soil and water conservation works. The maximum return is from maize followed by wheat and black gram and til. The details are given Table 4.44 and 4.45.

4.9.6 Economic Returns from Crop

The economic returns from the crop has been estimated by considering cost of cultivation in present context and return from crops with present market price in both pre and post condition for both watersheds. The minor difference in cost of cultivation in pre and post treatment is subjected to change in variety, more use of fertilizer and pp measures in post condition and this has increased due to increased moisture status and awareness due to watershed programme.

The total net return received from Cheerwa watershed before the project was Rs.806300.0 which has risen to Rs.2256625.0 after the implementation of watershed management programme (an increase by 2.7 times). The total net returns before project implementation from maize, urd, wheat, gram, groundnut and green fodder were Rs. 6512.5, 123900.0, 199950.0, 11000.0, 102600.0 and 141000.0 respectively which has increased to Rs. 521250.0, 310500.0, 375725.0, 27500.0, 261050.0 and 189000.0 respectively which reflects an increment of minimum 1.9 times in wheat to 80 times in maize from total area under respective crops. Further, there was an additional net returns from groundnut, mustard and sugarcane in the area.

It is also seen from the table 4.42 and 4.43 that C.B. ratio under crops has risen maximum from 1.92 to 3.1 in Urd followed by mustard (1.4 to 2.83), in wheat minimum risen in C.B. ratio was seen (1.72 to 1.83). Further, it is also evident from the table that despite of maximum economic return from maize the C.B. ratio was raised just from 1:1 to 1.35.

The total net return from the Losing watershed before the project was Rs. 826190.0 which has risen to Rs. 2852946.5 after the implementation of watershed management programme. The net change in total returns from the area under different crops is estimated to be 3.04 times as that of base year. The total net return from maize, urd, Til, wheat and gram were Rs. 1125204.0, 559650.0, 371925.0, 238480.0 and 75937.5 respectively. This reveals that total net increment was from 1.7 times in wheat to 15.0 times in maize considering the area under respective crops. It is also evident from the table that CB ratio of these crops has also raised from 0.96 to 1.44, 2.04 to 3.29, 1.36 to 2.39, 1.46 to 1.57, and 1.51 to 2.07 respectively. Thus there is significant rise in net return of all the crops in Kharif and Rabi season.

The net incremental return of Rs.1890132.50 from crop production after the implementation of project was estimated (Table 4.42 & 4.43). Thus, due to increased income through crop production the farmers have now derived better social status and livelihood after the implementation of watershed management programme.

The same type of results have also been reported by Hazara and Singh (1988) who had carried out a similar kind of evaluation study of Tejpura watershed, Jhansi and reported that due to imposition of soil and water conservation measures, viz., contour and field bunding, gully plugging, check dams across seasonal nallas and diversion channel the crop intensity increased from 83 to 156 per cent. They further reported that initial average productivity level was raised from 0.55 t/ha to 1.43 t/ha (an increase by 2.6 times) after the implementation of soil and water conservation works. The range of increased productivity was 110-289 per cent over the base yields where highest productivity was associated with wheat followed by mustard.

The similar study made by Pandey et. Al. (1998) confirms the results of this study as well, as their study made in semi arid tropics region of Gujarat state under two watersheds revealed the sustainability of the project which infer\erred that the net returns through agriculture were not only increased by 2.3 to 2.4 times but it also had fair distribution across the community. It was also reported that land use intensity in two locations namely Navamota and Rebari increased from 91 to 100 and 77 to 97 per cent over base period. This reflects the effectiveness of the watershed management programme on cropping system.

Further the results obtained through this study are also in concurrence with the results of the study made by S. Arul G. Nanasekar (2000) in Tamilnadu state under interface forestry project. He reported that at all three locations under study the net sown area increased due to availability of increased cultivable land as a result of soil and moisture conservation programmes. The increment was reported to be in the rage of 23.8 to 51.2 per cent considering all three locations. The main soil and water conservation works taken were check dams, gully plugging, continuous contour trenches, stone wall barrier, field bunding and percolation tanks. It was also reported that due to this programme there were changes in cropping pattern and yields. Crops like paddy, banana, sugarcane yielded higher and fetch higher incomes. Similar pattern was observed for oilseed crops also.

4.9.7 Employment generation:

The selected respondent of both the watersheds were categorized into six categories based on the occupation they are engaged in. The categories were farming, Labour + farming, business + farming, independent profession + farming, service + farming and business + independent profession + farming.

The status change in employment generation during pre and post project scenario in study area is given in the table-4.46 & 4.47.

These table shows that out of six categories identified there has been phenomenal change in shifting of profession in category II i.e. labour + farming in both the watersheds. The increment was by 3 and 6 per cent respectively in Cheerwa and losing watersheds. This increment may rightly be understood as shifting has been made from farming to this category because of more employment generation due to implementation of watershed projects in both areas, which provided the employment opportunities (mandays generated) and also reduction in farming categories drought of past few years.

Further a very nominal increment has also been observed in independent profession + Farming (Category-IV) which may be due to income generation and economic upliftment carried by some profession i.e. dairy, agro based entrepreneurship and thus independent profession has attracted the people of the area.

4.10 Performance of LSCD on silt deposition:

Both the watersheds were treated with this measure. In Cheerwa watershed 540 stone wall terraces in arable lands and 1080 loose stone check dams in non-arable lands for drainage line treatments were constructed whereas in Losing watershed 600 stone wall terrace and 800 loose stone check dam were made. Out of these, a representative treated area was selected to measure the actual silt deposited behind these structures i.e. on upstream side of the structure. The actual dimension viz length, width and height (difference between upstream and downstream height) at the upstream side of these check dams were measured and are tabulated in Appendix-B. It is observed that in Cheerwa watershed a total volume of 324.78 m^3 silt has been deposited which indicates that in all 4235.0m^3 silt was deposited in total treated area. Thus rate of silt deposition was found to be 1.08 m^3/ha/year along these structures.

In losing watershed the total amount of silt collected in the selected area was found to be 294.63 m^3, which indicates that total amount of 4410 m3 of silt, was deposited in total area. This reveals that the rate of silt deposition in the area was 1.36 m^3/ha/year along this measure.

The results indicate that the stonewall terrace in arable lands and loose stone check dams in non-arable lands proved successfully for the purpose of silt trap. By constructing LSCDs in non-arable land it could be easily seen that in trapped silt behind these structure, grass production programme or tree plantation can easily be taken which would have not been possible otherwise. Thus this measure is really worthwhile in such conditions.

4.11 Effect of SWC measures on soil moisture status:

As far as functional utility of soil and water conservation measure is concern it is to be constructed for conserving moisture and increasing moisture status in the soil. The soil samples in treated and untreated area were collected simultaneously and were anlysed for study area. The table 4.47 shows that average moisture status in treated area was 20.54% and 17.88 per cent in Cheerwa and Losing watershed respectively. This shows that in Cheerwa and Losing watersheds the moisture status was higher by 5.8 and 11.2 per cent as compared to untreated area. Considering this increment in moisture status it can be infer that during monsoon season the moisture in soil profile could be maintained for a longer period resulting into delayed wilting stage. Thus the purpose of soil moisture conservation measure i.e. contour vegetative hedge, earthen bund, contour trench and staggered trench is proved.

4.12 Afforestation programme:

The afforestation and silvipastoral programme was undertaken in Cheerwa and Losing watershed to meet the fuel and fodder requirement of the local people. For the purpose various tree species i.e. Neem, Babul, Kala Siras, Soobabul, Jungle Jalebi, Kumtha, Shisham, Bamboo, Gulmohar, Kachnar, Karanj, Eucalyptus, and Parkinsonia were planted in the Cheerwa and Losing watershed. The observation to know the survival percentage of these trees was made in the year 2001 through representative sampling. The trees were planted like the year 1997 i.e. till the end of project year. It can be revealed from the table 4.49 that out of various tree planted in the area Babul (51%), Kumtha (45%) and Neem (44%) are the most survived plants in Cheerwa. This may be due to the fact that these species are able to sustain even in low rainfall conditions. The performance of Soobabul and Kala siras was also found to be satisfactory under such conditions. Based on these data it was infer that the area is most suited for the tree species belonging to babul family.

Further, in Losing the most survived plant species were Eucalyptus (60%) followed by Neem (55%), Babul (50%) and Jungle Jalebi (50%). The losing area is characterized by much undulating topography and hence rainwater availability limits the plant survival, therefore plants like Eucalyptus survived with the maximum per centage as this species can draw water from deeper profiles and can sustained in low water availability.

Based on data available it was also suggested to plant bamboo in the valleys region of the watershed, as they survived better in valley areas and fetch good economic value.

Overall, it could be revealed that afforestation programme proved its worth in the watershed development plan made for both study areas.

4.13 Pasture Development:

The samples of dry grass production in 1 m^2 area were taken in both Cheerwa and Losing watersheds. After the implementation of the project the average grass production (mainly Seran and Sali) in the watershed area was found to be 1.35 & 1.60 tons per hectare (Table 4.50) from the land which was completely denuded before the implementation of the project in these watersheds respectively. The grass seeds of local variety were sown in notches.

It is worth while to mentioned here that average productivity which is achievable in the study area is up to 2.5 ton/ha but due to steepy slope, undulating topography and over exploited degraded land, the productivity could reach only to the aforesaid results. Looking to the condition of the study area, this grass productivity is satisfactory.

In development and management of pasturelands, particularly on Government lands (Common property resources), the participation of beneficiaries has been found very encouraging. The beneficiaries are managing their areas by constituting the User's Societies and have developed a system to maintain these areas on a sustainable basis. The grazing is not encouraged and they are following the cut and carry system and also encouraging the stall feeding system in the area. Further, they have decided to develop a system of controlled grazing after 5 years of the treatment. The increased grass production is also assigned to improved moisture status caused due to construction of trenches on the denuded lands, which conserved the runoff water and helped in stabilizing the pastures.

4.14 Suggested conservation measures for the study area

The appropriate soil and water conservation measures for every watershed plan are designed on the basis of rainfall, land use capability classification and topography of the area, which acts as the most important variables including inclination towards the adoption of technology by the people of the area. Based on the study and results obtained, the design of most appropriate soil and water conservation measures, which may be adopted for Southern Rajasthan, are discussed below. The cost of each such measure may differ from place to place depending upon availability of local material and indigenous technology.

4.14.1 Puerto Rico Terraces

It is very common practices in the area that farmers used to cultivate sloping lands which is having slope even more than 6% and where contour bunding is not suitable. To check soil erosion and for better moisture conservation Puerto Rico Terraces of dry stone may be proposed along the contours. It is very popular and purposeful soil and water conservation measures in Southern Rajasthan as stones are easily available in the area and it is also a very stable structure.

Recommended cross section of Puerto Rico Terraces is related to its width and height. The study suggest width of the structure as 0.6 m and height as 0.45 m for above structure to be stable.

4.14.2. Contour Bunding

In the area where average slope is less then 6 per cent and annual rainfall is low, for efficient moisture conservation and to check erosion contour bunds are proposed to be constructed along the contours. This structure is widely adopted by the farmers in the area where sufficient soil depth is available in field to conserve adequate amount of rain water. It was also revealed that farmers with small land holdings are reluctant to adopt this measure due to loss of land, therefore small cross section of this structure be proposed. This should strictly be constructed on contour. The cross section of contour bund found to be successful in the areas with following dimensions.

Top width – 040m, Bottom width –0.80 m, Height 0.80 m, Slide slope 1.5:1.

4.14.3. Stone Wall Terraces

It is revealed that in this hilly region stone wall terracing is most appropriate and adoptable practice of developing terraces by putting stone wall barriers across the slope in the cultivated valleys. These stone walls will act as a barrier to check the further soil loss and also to make the land leveled by continuous depositing of soil. In Southern Rajasthan most part of the cultivated land is available in the valley portion in which these structure are constructed to check the erosive velocity of runoff and to conserve moisture. A stable cross section of SWT emerged out of study relates all the dimensions to height of the terrace found ground level. It is suggested that SWT should have foundation as 40 per cent of height of terrace and bottom width as twice the depth of foundation, whereas top width should be same as depth of foundation.

4.14.4 Loose Stone Check Dams:

During the study it was observed that a slight modification in constructing approach of this measure is required. It must be designed on the concept that on the upper reaches the runoff concentration will be less because of less catchments area whereas for lower reaches runoff concentration will be more, therefore rather constructing uniform cross sectional area of check dam from top to bottom of the drain it should be divided in to upper, middle and lower reaches. It is proposed to be constructed for drainage line treatment particularly for non arable valleys to check the erosive velocity of runoff and to conserve moisture for establishment of vegetative cover. They can not be any branded specification regarding this structure due to the reason that cross section of drain varies from place to place.

4.14.5 V-ditch:

V-ditches are constructed on contours by excavating a trench and forming bund on down stream of the trench. The interval between the two adjacent trenches are so designed that the quantity of water coming from intervening area in V-ditch is not more than 0.06 m^3.It was observed that it must be constructed in the non-arable areas where slope is less than 20 per cent to achieve desired results. The general cross section may be kept as 0.06 m^2 with top width as 0.60 m. However the depth will vary depending upon slope and available soil depth.

4.14.6 Contour trenches:

For regeneration of degraded land and effective insitu rainwater conservation it was revealed that contour trenches has been found most suitable measures upto the slope of 30 per cent in Southern Rajasthan. Contour trench break the slope length, reduce the velocity of flowing runoff, retard scouring action and help in conserving moisture. The land slope be kept main consideration for this structure based on which cross section be kept 0.09 m^2 having width and depth as 0.30 m.

4.14.7 Staggered trenches:

For insitu conservation of rain water in the highly denuded and degraded lands where slope is more than 30 per cent these trenches are proposed to be constructed at horizontal interval of 10m. It was indicated that in highly sloppy area it is very common and useful structure for Southern Rajasthan for conserving moisture and developing pasture on the waste lands as topography of this region is very undulating. The length of the staggered trench be kept as 4.0 m with depth and width as 0.30 m. The distance between two staggered trenches in the row is kept 4.0 m.

In both contour and staggered trenches, consideration of horizontal interval is also important for the structure to be effective. Therefore, while constructing these structure HI be maintained based upon topographical condition.

4.14.8 Contour vegetative hedge:

It was observed that survival of different vegetative barriers was poor though constructed on contours. The reason being the erratic behaviours of rainfall in past few years. The measure was constructed at approximately 40m horizontal interval but at some places cline to intervene of farmer they it is constructed at field boundary giving variation in H.I. Further, beneficiaries have given a positive opinion about the performance of this measure in terms of benefit viz. reduction in erosion in crease in moisture and increased crop yield.

In general the measure was found to be satisfaction with few suggestions such as that plant material be of good quality, planting be done when sufficient moisture available, provision of watering be made and size of bund be increased with a provision of waste weir write a safe disposal of water.

4.14.9 Silvi pastoral system

Silvi pastoral development is one of the major activity in study watersheds in general. It has been executed in both private and common lands. It was analyzed that average survival of the trees was not much encouraging though few plants survival better. It was observed that grass productivity of the area was increased to that of bare year, which are due to the cause of insitu moisture conservation. In general in the study area babul was found to be most adaptable species along with Neem, Shisham, Subabul and Bamboo. The discussion with farmers and performance of measure lead to the conclusion that timely planting of tree saplings and over seeding of grass seeds be made just with the onset of monsoon. The six of “V” ditch be increased and be aligned on contours strictly LSCD be constructed at lesser I.I. It was also reported by the beneficiaries that proper stone fencing be made for protection of their areas and repair be made every 2-3 years.

Table 4.37: Change in land use pattern before and after the project, losing watershed.

S. No.	Particulars	Area	
		Before the project implementation (ha)	After the project implementation (ha)
1.	Arable lands	705	739.5
2.	Unirrigated including fallow Irrigated area	620 85	597.6 107.4
3.	Non-arable lands	657	622.50
4.	Panchayat land not suited for cultivation	159.08	-
5.	Private waste land	262.0	-
6.	Government waste land	188.92	-
7.	Area not available for development	47.00	47.00
8.	Pasture	-	324.50
9.	Afforestation	-	106.0
10.	Silvi pastoral	-	145.0
	Total Geographical area	1362.00	1362.00

Table-4.39: Area – Losing watershed under different crops and cropping intensity before and after the implementation of the project.

Crop	Before implementation the project (ha)	After the implementation of the project	Per cent increase/ decrease
Kharif:			
Maize	**471**	**492**	**4.45**
Urd	**58**	**78**	**34.48**
Til	**72**	**87**	**20.83**
Paddy	**10**	**8**	**-20.0**
Groundnut	**10**	**12**	**20**
Green fodder	**23.2**	**28**	**20.69**
Chillies	**18**	**21**	**16.6**
Total	**662.2**	**726**	
Rabi:			
Wheat	**48**	**54.2**	**12**
Barley	**16**	**12.3**	**-23.12**
Mustard	**7.0**	**18.5**	**164.3**
Gram	**8.0**	**13.5**	**68.75**

Green Fodder	**1.2**	**5.0**	**316**
Vegetables (Chilli)	**2.0**	**3.5**	**+75**
Total	**84**	**109**	
Cropping intensity	**106.13**	**113.18**	

Table 4.41: Productivity status of different crops in Losing watershed.

Crop	Before implementation the project (ha)	After the implementation of the project	Per cent increase/ decrease
Kharif:			
Maize	**6.0**	**12.5**	**108.33**
Urd	**4.0**	**6.5**	**62.5**
Til	**2.0**	**3.5**	**75.00**
Paddy	**8.0**	**11.5**	**43.75**
Groundnut	**4.25**	**9.5**	**123.52**
Green fodder*	**380**	**475**	**25**
Chillies	**25**	**35**	**40**
Rabi:			
Wheat	**12**	**18.5**	**54.16**
Barley	**15**	**15.0**	**00.00**
Mustard	**3**	**7.5**	**150.0**
Gram	**4**	**7.25**	**81.25**

Green fodder*	**400**	**525**	**31.2**

***Continuing crop whole year.**

Table 4.38: Area under different crops and cropping intensity before and after the implementation of project: Cheerwa watershed.

S. No.	Crop	Area before project (ha)	Area after project (ha)	Per cent increase/ decreased
	Kharif:			
1.	Maize	260.5	278	6.72
2.	Urd	42	46	9.52
3.	Til	22.5	17.5	-22
4.	Groundnut	19	23	21.05
5.	Green Fodder*	33	35.5	7.5
6.	Sugarcane*	5	3.5	-30.0
7.	Vegetable (Chilly)	6	7	16.6
	Total	388	410.5	
	Rabi:			
8.	Wheat	43	56.5	31.39
9.	Mustard	16	22.5	40.62
10.	Gram	5	5	0

11.	**Sugarcane***	**5**	**3.5**	**-30.0**
12.	**Barley**	**7**	**10**	**42.8**
13.	**Green fodder***	**3**	**4**	**33.3**
	Total	**79**	**101.5**	
	Cropping Intensity	**117.38**	**122.78**	

***Continuing crop whole year.**

Table 4.40: Productivity status of different crops before and after the implementation of project: Cheerwa watershed.

S. No.	Crop	Yield (q/ha) Before	Yield (q/ha) After	Per cent increase
1.	Maize	7.0	13.0	85.71
2.	Urd	4.0	6.5	62.5
3.	Til	2.5	4.5	80.0
4.	Groundnut	6.5	11.5	76.9
5.	Green Fodder	400	500	25.0
6.	Chillies	23.5	31.0	31.91
7.	Wheat	14.0	22.5	37.7
8.	Mustard	5.5	10.0	81.81

9.	**Gram**	**5.0**	**8.5**	**70.0**
10.	**Sugarcane**	**350**	**475**	**35.71**
11.	**Barley**	**13.0**	**18.0**	**38.46**
12.	**Green fodder**	**450**	**525**	**16.66**

Table 4.36: Change in Land use pattern before and after the implementation of project: Cheerwa watershed.

S. No.	**Crop**	**Before project (ha)**	**After project (ha)**
1.	**Arable land**	**397.84**	**417.0**
2.	**Unirrigated including fallow** **Irrigated**	**317.84** **80.0**	**297.84** **102.0**
3.	**Non-arable land**	**1072.2**	**1053.0**
4.	**Panchayat Land**	**213.0**	**-**
5.	**Government revenue waste land**	**346.2**	**-**

6.	**Private waste land**	**513.0**	**-**
7.	**Pasture**	**-**	**604.81**
8.	**Habitation and land not available for development**	**110.0**	**110.0**
9.	**Silvi pasture**	**-**	**210.09**
10.	**Afforestation**	**-**	**238.10**
	Total	**1580.0**	**1580.0**

Table-4.46: Occupational change of farm family before and after the project in Cheerwa watershed.

S. No.	Occupation	Per cent of sampled family adopting particular occupation	
		Before	After
1.	Farming	24.0	20.0
2.	Labour + Farming	50.0	53.0
3.	Business + Farming	11.0	13.0
4.	Independent + profession + Farming	5.0	8.0

5.	**Service + Farming**	**8.0**	**4.0**
6.	**Business + Independent profession + Farming**	**2.0**	**2.0**

Table 4.47: Occupational change of farm family before and after the project in losing watershed.

S. No.	**Occupation**	**Per cent of sampled family adopting particular occupation**	
		Before	**After**
1.	**Farming**	**35.0**	**30.0**
2.	**Labour + Farming**	**42.0**	**48.0**
3.	**Business + Farming**	**9.0**	**10.0**
4.	**Independent + profession + Farming**	**4.0**	**5.0**
5.	**Service + Farming**	**7.0**	**6.0**
6.	**Business + Independent**	**3.0**	**1.0**

	profession + Farming		

Appendix –B_1 Dimensions of sediment deposition on U/S side of check dams

Location: Cheerwa watershed

Sample No.	Length (m)	Width (m)	Height (m)	Volume of silt deposition (m^3)
1.	3.0	1.85	0.45	2.50
2.	3.0	2.00	0.4	2.4
3.	2.0	1.75	0.70	2.45
4.	2.0	2.0	0.75	3.0
5.	1.5	3.0	0.35	1.57
6.	5.0	3.00	0.65	9.75
7.	2.0	2.6	0.9	4.68
8.	1.75	1.25	0.65	1.421
9.	4.5	4.0	1.0	18.0
10.	4.0	2.00	0.65	5.2
11.	2.5	1.50	0.7	2.62
12.	2.5	1.0	0.5	1.25

Sample No.	Length (m)	Width (m)	Height (m)	Volume of silt deposition (m^3)
13.	3.0	2.5	0.8	6.0
14.	4.5	3.0	0.60	8.1
15.	3.0	2.50	0.55	4.12
16.	2.0	3.0	0.45	2.7
17.	3.0	2.00	0.65	3.9
18.	8.0	5.00	0.75	30
19.	4.0	3.00	0.55	6.6
20.	6.0	1.5	0.65	5.85
21.	3.0	3.5	1.00	10.5
22.	6.0	1.5	0.75	6.75
23.	3.0	2.50	0.75	5.62
24.	8.0	5.0	0.75	30.0
25.	7.0	6.0	0.55	23.1
26.	11.0	7.0	0.5	38.5
27.	5.0	3.0	0.4	6.0
28.	2.0	3.0	0.75	4.5
29.	1.5	1.0	0.4	0.6
30.	5.0	3.0	0.55	8.25
31.	5.0	8.0	0.30	12.00
32.	6.0	4.5	0.70	18.9
33.	4.0	1.5	0.35	2.1
34.	5.0	2.0	0.18	1.80
35.	5.0	2.0	0.45	4.5
36.	3.0	1.50	0.80	3.6
37.	3.5	2.0	0.8	5.6
38.	4.0	2.5	0.6	6.0
39.	5.0	3.0	0.45	6.75
Total				**324.78**

Table 4.48: Moisture content (%) in treated and untreated areas in study watersheds.

Name of watershed	Area	Moisture content (%)

		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Cheerwa	**Treated**	**20.1**	**20.5**	**21.0**	**19.5**	**21.6**	**20.54**
	Untreated	**19.0**	**19.5**	**20.9**	**19.0**	**18.6**	**19.4**
Losing	**Treated**	**18.3**	**17.2**	**17.80**	**18.5**	**17.6**	**17.88**
	Untreated	**15.0**	**15.6**	**15.25**	**16.5**	**17.5**	**15.97**

Table-4.49: Average survival per centage of various tree species in Cheerwa and Losing watersheds.

S. No.	Tree species	2001	2001
1.	Neem	44.0	55.0
2.	Babul	51.0	50.0

3.	Kala Siras	37.0	NP
4.	Soobabul	25.0	NP
5.	Jungle Jalebi	28.0	50.0
6.	Kumtha	45.0	NP
7.	Shisham	27.0	30.0
8.	Bamboo	NP	55.0
9.	Gulmohar	NP	32
10.	Kachnar	NP	40
11.	Eucalyptus	NP	60
12.	Parkinsonia	NP	55

NP = Not planted

Table: 4.50 Performance of the pasture development work under study area.

Sample area = 1 m x 1 m = 1m^2

	Sample of average grass productivity, grams					
Location	**I**	**II**	**III**	**IV**	**V**	**Average t/ha**
Cheerwa watershed	120.0	125.0	203.0	100.0	130.0	1.35
Losing water shed	175.0	145.0	160.0	155.0	165.0	1.6

Table-4.20:Pumping test data for well no.1 inside losing watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	170	-	3.05
2	172	86	3.00
4	174	43.5	2.96
6	176	29.33	2.93
10	180	18.0	2.90
15	185	12.33	2.88
20	190	5.5	2.85
25	195	7.8	2.75
30	200	6.6	2.72
38	208	5.47	2.69
45	215	4.77	2.65
55	225	4.0	2.62
70	240	3.43	2.58
90	260	2.88	2.55
110	280	2.54	2.50
140	310	2.21	2.40
170	340	2	2.20
200	370	1.85	2.00
260	430	1.65	1.89
320	450	1.53	1.75
390	560	1.43	1.65

Table-4.22 Pumping test data for well no. 5 outside losing watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	225	-	3.0
2	227	113.5	2.99
4	229	57.25	2.98
6	231	38.5	2.96
8	233	29.12	2.95
10	235	23.5	2.94
12	237	19.75	2.93
15	240	16.0	2.91
20	245	12.25	2.88
25	250	10.0	2.85
35	260	7.43	2.79
45	270	6.0	2.73
55	280	5.09	2.66
65	290	4.46	2.60
75	300	4.0	2.54
95	320	3.37	2.46
115	340	2.96	2.35
140	365	2.60	2.26
165	390	2.36	2.13
200	425	2.12	2.03
235	460	1.96	1.89
290	515	1.77	1.71
350	575	1.4	1.47

Table-4.21: Pumping test data for well no. 2 inside losing watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	86	-	1.59
2	88	44	1.52
4	90	22.5	1.45
6	92	15.33	1.41
9	95	10.55	1.36
12	98	8.16	1.33
15	101	6.73	1.31
18	104	5.77	1.25
22	108	4.90	1.20
26	112	4.30	1.17
33	119	3.60	1.08
38	124	3.26	1.02
48	134	2.79	0.97
59	145	2.46	0.91
70	156	2.23	0.88
85	171	2.01	0.82
100	186	1.86	0.76
115	201	1.75	0.71
135	221	1.64	0.67
165	251	1.52	0.62
200	286	1.43	0.53
235	321	1.36	0.44
335	421	1.26	0.30

Table-4.17:Pumping test data for well no.1 inside Cheerwa watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	90	-	1.8
3	93	31.0	1.6
5	95	19.0	1.55
9	99	11.0	1.48
13	103	7.92	1.40
20	110	5.5	1.28
30	120	4.0	1.17
40	130	3.25	1.05
50	140	2.8	0.95
60	150	2.5	0.88
70	160	2.28	0.81
85	175	2.06	0.72
100	190	1.9	0.54
115	205	1.78	0.40
130	220	1.69	0.30
145	235	1.62	0.28
175	265	1.51	0.24
205	295	1.44	0.19

Table-4.18: Pumping test data for well no. 2 inside Cheerwa watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	150	-	5.13
2	152	76	5.04
6	156	26	4.90
10	160	16	4.78
15	165	11	4.60
21	171	8.14	4.41
28	178	6.36	4.27
38	188	4.95	4.12
48	198	4.13	4.02
58	208	3.59	3.92
70	220	3.14	3.84
85	235	2.76	3.72
100	250	2.5	3.63
115	265	2.30	3.57
145	295	2.03	3.35
175	325	1.86	3.25
205	355	1.73	3.00
235	385	1.64	2.78
265	415	1.57	2.71
315	465	1.48	2.50
375	525	1.4	2.22

Table-4.19: Pumping test data for well no. 5 outside Cheerwa watershed.

Time since pumping stopped t' minutes	Time since pumping started t=tp+t' minutes	Ratio t/t'	Residual draw down (m)
0	185	-	-
2	187	93.5	3.35
4	189	47.25	3.32
6	191	31.83	3.25
8	193	24.12	3.10
10	195	19.5	3.0
12	197	16.41	2.95
15	200	13.33	2.90
18	203	11.27	2.85
22	207	9.40	2.81
27	212	7.85	2.75
32	217	6.78	2.68
40	225	5.62	2.65
50	235	4.7	2.61
65	250	3.84	2.56
80	265	3.31	2.49
100	285	2.85	2.44
120	305	2.54	2.37
150	335	2.23	2.32
185	370	2.0	2.15
220	405	1.84	2.09
270	455	1.68	2.02
320	505	1.57	1.84
370	555	1.50	1.79
430	615	1.43	1.65

Table-4.26: Estimation of specific yield of wells in Cheerwa watershed

S. No.	ho(m)	h(m)	T (days)	α (%)	Average specific yield, %
Well No.1					
1.	8.25	6.8	11	1.75(1.75 x 10^{-2})	(2.96x10^{-2})
2.	6.8	5.55	12	1.69(1.69 x 10^{-2})	
3.	5.55	3.35	16	3.15(3.15 x 10^{-2})	
4.	3.35	1.35	20	4.54(4.54 x 10^{-2})	
5.	1.35	0.6	22	3.68(3.68 x 10^{-2})	
Well No.2					
1.	8.5	6.8	11	2.02(2.02 x 10^{-2})	(3.23x10^{-2})
2.	6.8	5.2	12	2.23(2.23 x 10^{-2})	
3.	5.2	3.1	16	3.23(3.23x 10^{-2})	
4.	3.1	1.25	20	4.54(4.54 x 10^{-2})	
5.	1.25	0.5	22	4.16(4.16 x 10^{-2})	

S. No.	ho(m)	h(m)	T(days)	α (%)	Average specific yield
Well No.3					
1.	9.4	7.65	11	1.87 (1.87 x 10^{-2})	2.69 x 10^{-2}
2.	7.605	6.25	12	1.68 (1.68 x 10^{-2})	
3.	6.25	4.00	16	2.78 (2.78 x 10^{-2})	
4.	4.00	1.9	20	3.72 (3.72 x 10^{-2})	
5.	1.9	0.9	22	3.39 (3.39 x 10^{-2})	
Well No.4					
1.	10.25	8.35	11	1.86 (1.86 x 10^{-2})	2.78 x 10^{-2}
2.	8.35	6.75	12	1.77 (1.77 x 10^{-2})	
3.	6.75	4.25	16	2.89 (2.89 x 10^{-2})	
4.	4.25	2.0	20	3.76 (3.76 x10^{-2})	
5.	2.0	0.9	22	3.62 (3.62 x 10^{-2})	

Table-4.30: Ground water recharge as percent of rainfall in Cheerwa watershed.

Well No.	Period	Rainfall (cm)	h (cm)	Pi (Syxh) (cm)	R, %
Well No. 1					
1.	31.5.01-11.06.01	4.56	145.0	2.53	55.4 (68.4)*
2.	12.6.01-23.06.01	7.39	125.0	2.11	28.5 (35.18)
3.	24.06.01-09.07.01	10.64	220.0	6.93	65.13(80.41)
4.	10.07.01-29.07.01	14.52	200.0	9.08	62.5 (77.17)
5.	30.07.01-20.08.01	13.34	75.0	2.76	20.68(25.53)
		Average 46.47%, (57.37)			
Well No. 2					
1.	31.05.01-11.06.01	4.56	170.0	3.43	75.2 (92.8)
2.	12.06.01-23.06.01	7.39	160.0	3.56	48.1 (59.39)
3.	24.06.01-09.07.01	10.64	210.0	6.78	63.7 (78.6)
4.	10.07.01-29.07.01	14.52	185.0	8.39	57.7 (71.2)
5.	30.07.01-20.08.01	13.34	75.0	3.12	23.3 (28.76)
		Average 48.98 %, (60.47)			
Well No. 3					
1	31.5.01-11.06.01	4.56	175	3.27	71.7 (88.5)
2	12.6.01-23.06.01	7.39	140	2.35	31.7 (39.14)
3	24.06.01-09.07.01	10.64	225	6.25	58.7 (72.4)
4	10.07.01-29.07.01	14.52	210	7.81	53.7 (66.30)
5	30.07.01-20.08.01	13.34	100	3.39	25.4 (31.36)
			Average 48.24 (59.56)		
Well No. 4					
1.	31.05.01-11.06.01	4.56	190	3.53	77.4(95.5)
2.	12.06.01-23.06.01	7.39	160	2.33	38.2 (47.16)
3.	24.06.01-09.07.01	10.64	250	7.22	67.8 (83.71)
4.	10.07.01-29.07.01	14.52	225	8.46	58.26(71.93)
5.	30.07.01-20.08.01	13.34	110	3.98	29.8 (36.79)
			Average 54.28 (67.02)		

*** Figure in parenthesis indicates calculated values of recharge for normal rainfall year.**

Table-4.27: Estimation of specific yield of wells outside Cheerwa watershed.

S. No.	ho(m)	h(m)	T (days)	α (%)	Average specific yield, %
Well No.5					
1	11.5	10.2	11	1.09 (1.09×10^{-2})	1.34×10^{-2}
2	10.2	8.9	12	1.13 (1.13×10^{-2})	
3	8.9	7.0	16	1.50 (1.50×10^{-2})	
4	7.0	4.7	20	1.99 (1.99×10^{-2})	
5	4.7	3.75	22	1.02 (1.02×10^{-2})	
Well No.6					
1	13.7	11.8	11	1.35 (1.35×10^{-2})	1.10×10^{-2}
2	11.8	10.3	12	1.13 (1.13×10^{-2})	
3	10.3	8.7	16	1.05 (1.05×10^{-2})	
4	8.7	6.7	20	1.30 (1.30×10^{-2})	
5	6.7	5.75	22	0.69 (0.69×10^{-2})	

Table-4.31: Ground water recharge as percent of rainfall outside Cheerwa watershed.

Well No.	Period	Rainfall (cm)	h (cm)	Pi (Syxh) (cm)	R, %
Well No. 5					
1	31.5.01-11.06.01	4.56	130	1.41	30.9 (38.15)*
2	12.6.01-23.06.01	7.39	130	1.46	19.7 (24.32)
3	24.06.01-09.07.01	10.64	190	2.85	26.7 (32.96)
4	10.07.01-29.07.01	14.52	230	4.57	31.4 (38.77)
5	30.07.01-20.08.01	13.34	105	1.07	8.02 (9.9)
		Average 23.34 %,(28.81)			
Well No.6					
1	31.05.01-11.06.01	4.56	190	2.56	56.14(69.31)
2	12.06.01-23.06.01	7.39	150	1.69	22.86(28.22)
3	24.06.01-09.07.01	10.64	160	1.68	15.78(19.48)
4	10.07.01-29.07.01	14.52	200	2.6	17.90(22.10)
5	30.07.01-20.08.01	13.34	95	0.65	4.87(6.01)
		Average 23.51 %, (29.02)			

*** Figure in parenthesis indicates calculated values of recharge for normal rainfall year.**

Table-4.28: Estimation of specific yield of wells in Losing watershed

S. No.	ho(m)	h(m)	T(days)	α (%)	Average specific yield, %
Well No. 1					
1.	16.2	14.5	16	0.69(0.69 x 10^{-2})	
2.	14.5	13.5	18	0.58(0.58 x 10^{-2})	0.75x10^{-2}
3.	13.05	10.8	19	1.0(1.0 x 10^{-2})	
4.	10.8	9.7	18	0.60(0.60 x 10^{-2})	
5.	9.7	8.7	12	0.90(0.90 x 10^{-2})	
Well No. 2					
1.	17.0	15.15	16	0.72(0.72 x 10^{-2})	
2.	15.15	13.55	18	0.62(0.62 x 10^{-2})	0.91x10^{-2}
3.	13.55	10.55	19	1.31(1.31 x 10^{-2})	
4.	10.55	9.05	18	0.85(0.85 x 10^{-2})	
5.	9.05	7.95	12	1.08(1.08 x 10^{-2})	
Well No. 3					
1.	15.25	13.35	16	0.83 (0.83x10^{-2})	1.05 x 10^{-2}
2.	13.35	11.7	18	0.73(0.73x10^{-2})	
3.	11.7	9.25	19	1.23(1.23x10^{-2})	
4.	9.25	7.6	18	1.09(1.09x10^{-2})	
5.	7.6	6.45	12	1.36(1.36x10^{-2})	
Well No. 4					
1.	17.35	15.45	16	0.72(0.72x10^{-2})	0.86 x 10^{-2}
2.	15.45	14.05	18	0.53(0.53x10^{-2})	
3.	14.05	11.40	19	1.10(1.10x10^{-2})	
4.	11.40	9.85	18	0.81(0.81x10^{-2})	
5.	9.85	8.60	12	1.13(1.13x10^{-2})	

Table 4.32 Ground water recharge as percent of rainfall in Losing watershed.

Well No.	Period	Rainfall (cm)	h (cm)	Pi (Syxh) (cm)	R,%
Well No. 1					
1.	1.6.01-16.6.01	9.46	170	1.18	12.40 (14.52)
2.	16.6.01-4.7.01	7.58	135	0.79	10.32 (12.07)
3.	4.7.01-23.7.01	14.59	225	2.25	15.52 (18.15)
4.	23.7.01-10.8.01	9.96	110	0.66	6.67 (7.80)
5.	10.8.01-22.8.01	7.4	100	0.9	12.16 (14.22)
			Average, 11.41 %,(13.33)		
Well No. 2					
1.	1.6.01-16.6.01	9.46	185	1.33	14.05 (16.43)
2.	16.6.01-4.7.01	7.58	160	1.0	13.19 (`15.43)
3.	4.7.01-23.7.01	14.59	300	3.93	26.93 (31.5)
4.	23.7.01-10.8.01	9.96	150	1.27	12.75 (14.9)
5.	10.8.01-22.8.01	7.4	110	1.19	16.08 (18.8)
			Average, 16.60%,(19.42)		
Well No. 3					
1	1.6.01-16.6.01	9.46	190	1.58	16.70 (19.53)
2	16.6.01-4.7.01	7.58	165	1.20	15.83 (18.52)
3	4.7.01-23.7.01	14.59	245	3.01	20.63(24.13)
4	23.7.01-10.8.01	9.96	165	1.79	17.97 (21.02)
5	10.8.01-22.8.01	7.4	115	1.56	21.08(24.66)
			Average 18.44%, (21.57)		
Well No. 4					
6.	1.6.02-16.6.01	9.46	190	1.37	14.5 (16.96)
7.	16.6.01-4.7.01	7.58	140	0.74	9.8 (11.46)
8.	4.7.01-23.7.01	14.59	265	2.91	19.9(23.2)
9.	23.7.01-10.8.01	9.96	155	1.25	12.56 (14.69)
10.	10.8.01-22.8.01	7.4	125	1.41	19.05 (22.08)
				Average 11.39 (13.32)	

*** Figure in parenthesis indicates calculated values of recharge for normal rainfall year.**

Table-4.29: Estimation of specific yield of wells outside Losing watershed.

S. No.	ho(m)	h(m)	T (days)	α(%)	Average specific yield, %
Well No. 5					
1	18.5	16.95	16	0.54(0.54x10^{-2})	0.59 x 10^{-2}
2	16.95	15.70	18	0.43(10.43x10^{-2})	
3	15.70	13.7	19	0.72(0.72x10^{-2})	
4	13.7	12.35	18	0.58(10.58x10^{-2})	
5	12.35	11.35	12	0.70(0.70x10^{-2})	
Well No. 6					
1	17.8	16.15	16	0.61(0.61x10^{-2})	0.64 x 10^{-2}
2	16.15	14.8	18	0.49(0.49x10^{-2})	
3	14.8	12.75	19	0.78(0.78x10^{-2})	
4	12.75	11.50	18	0.58(0.58x10^{-2})	
5	11.50	10.55	12	0.72(10.72x10^{-2})	

Table-4.33: Ground water recharge as percent of rainfall outside Losing watershed.

Well No.	Period	Rainfall (cm)	h (cm)	Pi (Syxh) (cm)	R,%
Well No. 5					
1	1.6.01-16.6.01	9.46	155	0.83	8.8 (10.29)*
2	16.6.01-4.7.01	7.58	125	0.54	7.1(8.30)
3	4.7.01-23.7.01	14.59	200	1.44	9.9(11.58)
4	23.7.01-10.8.01	9.96	135	0.78	7.83(9.16)
5	10.8.01-22.8.01	7.4	100	0.70	9.46(11.06)
			Average, 8.62 %,(10.08)		
Well No. 6					
1	1.6.02-16.6.01	9.46	165	1.0	10.57(12.36)
2	16.6.01-4.7.01	7.58	135	0.66	8.7(10.17)
3	4.7.01-23.7.01	14.59	205	1.6	10.9(12.75)
4	23.7.01-10.8.01	9.96	125	0.72	7.2(8.42)
5	10.8.01-22.8.01	7.4	95	0.68	9.1(10.64)
			Average 9.29%, (10.86)		

*** Figure in parenthesis indicates calculated values of recharge for normal rainfall year.**

Table 4.1:Morphological characteristics of watershed under study.

S. No.	Characteristics	*Estimated value*	
		Cheerwa watershed	**Losing watershed**
	Linear aspects:		
1.	**Area**	**1580.0 ha**	**1362.0 ha**
2.	**Perimeter**	**18560 m**	**14000 m**
3.	**No. of stream order**		
	I	**190**	**60**
	II	**88**	**24**
	III	**25**	**9**
4.	**Stream length (L^{-}_{u})**		
	I	**29040 m**	**21000 m**
	II	**20000 m**	**8750 m**
	III	**9680 m**	**3500 m**
5.	**Bifurcation Ratio**		
	$B.R._1$	**2.16**	**2.5**
	$B.R._2$	**3.52**	**3.11**
	Average	**2.84**	**2.80**
6.	**Stream length ratio**		
	RL_1	**0.67**	**0.96**
	RL_2	**0.60**	**0.94**
	Average	**0.63**	**0.95**
	Aerial aspects:		
7.	**Form factor**	**0.36**	**0.54**
8.	**Shape factor**	**2.77**	**1.83**
9.	**Circulatory ratio**	**0.576**	**0.87**
10.	**Elongation ratio**	**0.68**	**0.83**
11.	**Drainage density**	**3.71 km/Sq.km.**	**2.44 km/Sq.km.**
12.	**Constant of channel maintenance**	**0.27**	**0.40**
	Relief aspects:		
13.	**Relief**	**270m**	**180 m**
14.	**Relief ratio**	**0.042**	**0.036**
15.	**Relative relief**	**1.45**	**1.28**
16.	**Stream frequency**	**0.19 per ha**	**0.068 per ha**
17.	***Ruggedness number***	**1001.7**	**439.2**

18.	Geometric number	238.1	122.0

Table 4.2: Data for development of rating curve, Cheerwa watershed.

Stage (Cm)	*Average stage, cm*	Cross section area, m^2	*Velocity, m/sec.*	Duration, minutes	Discharge, m^3/Sec.
0-10	5	0.1	0.2	9	.02
10-20	15	0.3	0.47	4.5	0.14
20-30	25	0.5	1.0	3.0	0.50
30-40	35	0.7	1.37	3.0	0.96
40-60	50	0.1	2.1	1.5	2.1
60-80	70	1.4	3.07	9.0	4.3
80-70	75	1.5	3.3	10.5	5.0
70-50	60	1.2	2.58	9.5	3.1
50-30	40	0.8	1.62	16.5	1.3
30-20	25	0.5	1.0	13.5	0.50
20-10	15	0.3	0.46	18.0	0.14
10-5	7.5	0.15	0.26	13.5	0.04
5-0	2.5	0.05	0.2	45	0.01

Table 4.3 Data for development of rating curve Losing watershed.

Stage (Cm)	*Average stage, cm*	Cross section area, m^2	*Velocity, m/sec.*	Duration, minutes	Discharge, m^3/Sec.
0-10	5	0.15	0.4	9	0.06
10-20	15	0.45	1.0	4.5	0.45
20-30	25	0.75	1.6	4.5	1.20
30-40	35	1.05	2.14	3.0	2.25
40-55	47.5	1.425	2.80	6.0	3.99
55-70	62.5	1.875	3.8	10.5	7.29
70-60	65	1.95	4.0	7.5	7.8
60-40	50	1.5	2.9	13.5	4.4
40-20	30	0.9	1.88	24.0	1.71
20-10	15	0.45	1.0	36.0	0.45
10-5	7.5	0.225	0.53	24.0	0.12
5-0	2.5	0.075	0.4	52.5	0.03

Table 4.4:Observation at silt observation post (SOP), Cheerwa watershed year 2000

S. No.	Date	Rainfall (mm)	Runoff, m^3	Soil loss, (t/ha)
1.	13.5.2000	37.2	2440.3	0.134
2.	9.6.2000	61.2	3512.8	0.299
3.	13.7.2000	30.8	2273.04	0.117
4.	14.7.2000	46.6	382.12	0.27
5.	15.7.2000	14.8	1334.96	0.081
6.	21.7.2000	21.5	1692.48	0.098
7.	22.7.2000	30.6	2509.2	0.159
8.	11.8.2000	33.8	2702.3	0.072
9.	14.8.2000	43.2	3365.2	0.19
10.	6.9.2000	20.0	1623.6	0.093
	Total Rainfall	439.9	25275.0	1.51

	for the season			

Table 4.5:Observation at silt observation post (SOP), Cheerwa watershed year 2001

S. No.	*Date*	Rainfall, (mm)	Runoff, m^3	Soil loss, (t/ha)
1.	8.6.2001	23.8	1170.9	0.035
2.	9.6.2001	17.0	975.8	0.038
3.	14.6.2001	16.9	866.1	0.029
4.	15.6.2001	21.2	1216.8	0.05
5.	16.6.2001	29.4	1988.9	0.084
6.	3.7.2001	67.0	5494.0	0.22
7.	9.7.2001	21.6	1239.8	0.045
8.	10.7.2001	17.8	1094.7	0.042
9.	11.7.2001	90.0	8118.0	0.44
10.	12.7.2001	18.8	1695.7	0.06

11.	**7.8.2001**	**32.0**	**1836.8**	**0.064**
12.	**13.8.2001**	**28.0**	**1607.2**	**0.053**
13.	**16.8.2001**	**12.6**	**619.9**	**0.022**
14.	**17.8.2001**	**38.4**	**2519.0**	**0.11**
	Total Rainfall for the season	**515.9**	**30443.6**	**1.29**

Table 4.9: Runoff estimation through curve number method Cheerwa watershed.

Year 2000				**Year 2001**		
S. No.	**Date**	**Rainfall (mm)**	**Runoff Depth, mm**	**Date**	**Rainfall (mm)**	**Runoff depth, mm**
1.	**13.5.2000**	**37.2**	**13.4**	**16.6.2001**	**29.4**	**0.9**
2.	**9.6.2000**	**61.2**	**0.58**	**3.7.2001**	**67.0**	**1.4**
3.	**14.7.2000**	**46.6**	**6.8**	**11.7.2001**	**90.0**	**34.0**
4.	**15.7.2000**	**14.8**	**0.9**	**12.7.2001**	**18.8**	**2.4**
5.	**14.8.2000**	**43.2**	**5.2**	**17.8.2001**	**38.4**	**3.4**

	Total		**26.3**	**Total**		**42.1**

Table 4.6: Observation at silt observation post (SOP), Losing watershed year 2000

S. No.	*Date*	Rainfall, (mm)	Runoff, m^3	Soil loss, (t/ha)
1.	12.5.2000	36.2	9333.7	0.133
2.	9.6.2000	77.8	17194.1	0.288
3.	3.7.2000	31.4	6939.5	0.103
4.	13.7.2000	20.6	4932.0	0.074
5.	14.7.2000	36.2	10667.1	0.160
6.	22.7.2000	25.0	6906.3	0.075

7.	11.8.2000	48.4	11053.1	0.165
8.	14.8.2000	20.1	6663.2	0.076
9.	6.9.2000	19.4	5359.3	0.061
10.	23.9.2000	21.2	5466.1	0.066
	Total Rainfall for the season	454.3	84517.4	1.2

Table 4.7: Observation at silt observation post (SOP), Losing watershed year 2001

S. No.	Date	Rainfall, (mm)	Runoff, m^3	Soil loss, (t/ha)
1.	15.6.2001	19.5	4309.5	0.044
2.	16.6.2001	27.2	6211.6	0.067
3.	3.7.2001	56.5	14151.6	0.153

4.	**9.7.2001**	**29.5**	**7606.2**	**0.080**
5.	**10.7.2001**	**13.4**	**3948.6**	**0.048**
6.	**11.7.2001**	**71.5**	**21595.7**	**0.263**
7.	**12.7.2001**	**14.6**	**4248.4**	**0.053**
8.	**7.8.2001**	**23.0**	**5083.0**	**0.071**
9.	**10.8.2001**	**48.2**	**13137.0**	**0.130**
10.	**13.8.2001**	**26.4**	**5834.5**	**0.065**
11.	**17.8.2001**	**28.2**	**644.0**	**0.068**
12.	**5.10.2001**	**31.4**	**6939.5**	**0.072**
	Total Rainfall for the season	**543.7**	**99240.2**	**1.08**

Table-4.10: Runoff estimation through curve number method, Losing watershed.

Year 2000				**Year 2001**		
S.	**Date**	**Rainfall**	**Runoff**	**Date**	**Rainfall**	**Runoff**

No.		(mm)	depth, mm		(mm)	depth, mm
1.	12.5.2000	36.2	1.32	16.6.2001	27.2	4.84
2.	9.6.2000	77.8	1.95	9.7.2001	29.5	6.05
3.	14.7.2000	36.2	1.31	11.7.2001	71.5	16.56
4.	3.7.2000	31.4	0.45	12.7.2001	14.6	0.31
5.	13.7.2000	20.6	1.93	13.8.2001	26.4	4.44
6.	21.7.2000	21.4	2.23	17.8.2001	28.2	0.12
7.	11.8.2000	48.4	5.09			
	Total		14.28	Total		32.32

Table-4.23 Response of wells under soil and water conservation treatments

Particulars	Wells of Cheerwa		Wells of Losing	
	Within watershed	Outside watershed	Within watershed	Outside watershed
Type of formation	Phyllite	Phyllite	Quartzite	Quartzite
Discharge (m^3/day)	499.4	360.88	461.64	230.0
Duration of pumping tp, minutes	90.0	185.0	86.0	225.0
Drawdown, m	1.8	3.35	1.59	3.0
Recovery				
Per cent	89.4	50.7	81.0	51.0
Time, minutes	205.0	185.0	335.0	350.0
$T_{avg.,}$ m^2/day	153.5	88.14	211.34	180.63
Recuperation rate, m^3/min	0.22	0.12	0.07	0.052

Appendix B_2 : Sediment deposition on up stream of check dams, Losing watersheds.

Sample No.	Length (m)	Width (m)	Height (m)	Volume of silt deposition (m^3)
1.	5.0	3.5	1.2	21.0
2.	3.0	2.20	0.65	4.29

3.	**2.75**	**1.8**	**0.5**	**2.47**
4.	**2.5**	**1.20**	**0.30**	**0.90**
5.	**4.5**	**3.5**	**0.75**	**11.81**
6.	**3.5**	**2.0**	**0.85**	**5.95**
7.	**5.0**	**2.5**	**0.80**	**10.0**
8.	**1.5**	**1.0**	**0.45**	**0.675**
9.	**4.35**	**1.6**	**0.28**	**1.94**
10.	**4.45**	**2.3**	**0.32**	**3.27**
11.	**5.5**	**3.0**	**0.45**	**7.425**
12.	**9.5**	**5.5**	**0.60**	**31.35**
13.	**6.5**	**4.0**	**0.40**	**10.40**
14.	**8.5**	**4.5**	**0.30**	**11.475**
15.	**6.5**	**2.1**	**0.75**	**10.23**
16.	**2.5**	**2.0**	**0.85**	**4.25**
17.	**4.0**	**3.0**	**0.50**	**6.00**
18.	**8.0**	**4.0**	**0.75**	**24.0**
19.	**1.5**	**1.0**	**0.35**	**0.525**
20.	**2.5**	**0.75**	**0.45**	**0.84**
21.	**2.0**	**3.0**	**0.30**	**1.80**
22.	**1.35**	**2.20**	**0.20**	**0.594**
23.	**5.0**	**3.15**	**1.0**	**15.75**
24.	**7.0**	**4.50**	**0.30**	**9.45**
25.	**4.0**	**2.0**	**0.35**	**2.80**
26.	**4.0**	**1.0**	**0.20**	**0.80**
27.	**6.25**	**1.5**	**0.75**	**5.85**
28.	**8.0**	**3.35**	**0.65**	**17.42**
29.	**5.5**	**3.0**	**0.20**	**3.30**
30.	**3.0**	**1.0**	**0.15**	**0.45**
31.	**2.9**	**1.5**	**0.60**	**2.61**
32.	**6.0**	**4.0**	**0.70**	**16.80**
33.	**5.0**	**1.50**	**0.30**	**2.25**
34.	**2.0**	**2.0**	**0.20**	**0.8**
35.	**2.0**	**3.0**	**0.15**	**0.9**
36.	**1.5**	**1.0**	**0.60**	**0.9**
37.	**9.5**	**7.0**	**0.50**	**33.25**
38.	**6.2**	**1.8**	**0.20**	**2.232**
39.	**5.0**	**1.2**	**0.80**	**4.80**
40.	**3.5**	**2.2**	**0.40**	**3.08**
	Total			**294.636**

Table-4.24: Fluctuations of water level in selected wells of Cheerwa watershed

Well No.	**Depth of well 'm'**	**Water levels from top 'm' on different dates (Inside watershed)**							
		31.5.01	**11.6.01**	**23.6.01**	**9.7.01**	**29.7.01**	**20.8.01**	**20.9.01**	**20.10.01**
1	9.00	8.25	6.80	5.55	3.35	1.35	0.6	2.05	3.90
2	9.10	8.5	6.80	5.20	3.10	1.25	0.50	2.0	4.75
3	10.10	9.4	7.65	6.25	4.0	1.9	0.90	2.9	5.0
4	11.25	10.25	8.35	6.75	4.25	2.0	0.90	3.35	5.40

Well No.	**Depth of well 'm'**	**Water levels from top 'm' on different dates (Outside watershed)**							
		31.5.01	**11.6.01**	**23.6.01**	**9.7.01**	**29.7.01**	**20.8.01**	**20.9.01**	**20.10.01**
5	12.0	11.50	10.20	8.9	7.0	4.70	3.75	5.75	7.75
6	14.5	13.70	11.80	10.30	8.70	6.70	5.75	7.70	10.6

Table-4.25: Fluctuation of water level in selected wells of Losing watershed

Well No.	Depth of well 'm'	Water levels from top 'm' on different dates (Inside watershed)								
		1.6.01	**16.6.01**	**4.7.01**	**23.7.01**	**10.8.01**	**22.8.01**	**15.9.01**	**28.9.01**	**28.10.01**
1	17.9	16.2	14.5	13.05	10.8	9.7	8.7	10.0	11.2	12.0
2	18.5	17.0	15.15	13.55	10.55	9.05	7.95	9.85	11.85	12.8
3	16.5	15.25	13.35	11.7	9.25	7.6	6.45	7.90	9.65	10.5
4	19.5	17.35	15.45	14.05	11.40	9.85	8.60	10.05	11.9	12.75

Well No.	Depth of well 'm'	Water levels from top 'm' on different dates (Outside watershed)								
		1.6.01	**16.6.01**	**4.7.01**	**23.7.01**	**10.8.01**	**22.8.01**	**15.9.01**	**28.9.01**	**28.10.01**
5	20.0	18.5	16.95	15.70	13.7	12.35	11.35	13.5	15.0	16.25
6	18.8	17.8	16.15	14.8	12.75	11.5	10.55	12.10	13.20	14.10

LITERATURE CITED

Anonymous (1988). "Evaluation of structures research highlights". Annual report on Central Soil and Water Conservation Research and Training Institute, Dehradoon, 99: 8-9.

Anonymous (1998). "Compendium on Action plan of KVKs (Zone-VI), Rajasthan Agricultural University, Bikaner : 8-10.

Ashok kumar & Savita Tomar (1998), "Prioritisation of sub watershed for water resource development in USRI watershed Giridih Bihar – A case study". Proceedings of international conference on watershed management and conservation, 8-10 Dec., 1998, Delhi : 20-30.

Athwale RN (1966),"Hydrological basis of a strategy for scheduling supplementary irrigation to areal crops in dry land agriculture. Paper presented at Seminar on water management the key to development of agriculture, Indian National science academy, New Delhi April 28-30, 1986, ICRISAT, conference paper no. CP-299: 1-31.

Bhardwaj S.P. and Pradeep Dogra (1997). "Watershed management models for Himalayas Shivaliks and Aravallis". Indian Journal of Soil Conservation, 25(1) : 1-8.

Dorge S.K.and S.P. Wankhede (1987). "Salient features of Nala bunding works in Maharashtra State". Indian Journal of Soil Conservation, 15(3): 32-37.

E. Suburayalu, A.L. Narayanan, R. Mohan and R. Poonguzhalan (1998). "Geomorphologic Instantaneous hydrograph (GIUH) of watershed". Proceedings of International Conference of Watershed Management and Conservation, 8-10 Dec., 1998, Delhi : 538-557.

Gawande, (1992). "Evaluation of ground water potential in small Agricultural watershed during low rainfall years". Indian Water Resources, 12(3, 4): 177-188.

Goel, P.K., and H.B.Singh (1996). "Impact of soil conservation measures on ground water availability". Indian Journal of Soil Conservation, 24(1) : 19-24.

Hadda M.S., K.L. Khera and S.S. Kukal (2000), "Soil and Water Conservation practices and productivity in North-Western sub mountaineous tract of India". Indian Journal of Soil Conservation, 28 (3) : 187-192.

Hazara CR and DP Singh (1988)," Efficient crop production through girl and water conservation an watershed basis at Tejpura, Jhansi, Rangelands resource and management, proceedings of the National Rangeland symposium, IGFRI, Jhansi, November 9-12, 107-114

Hemalatha, B., S. Surekha and N. Nagaraja (1996). "A study on knowledge level of farmers about watershed". Karnataka Journal of Agricultural Sciences, 9 (4) : 666 - 669.

Jat M.L. (1990), estimation of aquifer parameter in selected hydro geological formations of Udaipur. Unpublished ME thesis, SWCE deptt. CTAE, Udaipur 187 & 210.

Kale, S.P., M.N.Gund, A.G. Durgude and R.B. Pawar (1992). "Effect of conservation measures and cropping systems on the soil and water conservation and the biomass production in different micro watershed". Indian Journal of Soil Conservation, 22 (1, 2) : 70-74.

Kale, S.R., V.G. Salvi and P.V. Varade (1993). "Runoff and soil loss as affected by different soil conservation measures under *Elusine caracana* (Ragi) in latritic soils, west coast Konkan region (Maharashtra)". Indian Journal of Soil Conservation, 21(2) : 11-15.

Khatik G.L., R.S. Kurothe & H.B. Singh (1997). "Impact of operational research project on agricultural Production through integrated watershed management". Indian journal of soil conservation, 25(2) : 157-161

Koppad A.G., K. Manjappa and A.M. Chandrashekharaiah (2001). "Impact of different conservation measures on rehabilitation on degraded lands and agriculture productivity". Indian Journal of Soil Conservation, 29 (2) : 148-151.

Kumar Dilip, P.K. Gupta and Suraj Bhan (1991). "Effect of in- situ moisture conservation practices and fertilizer on root characteristics and yield of rainfed maize". Indian Journal of Soil Conservation, 21(2): 22-24.

Manoj Kumar Ray (1998)," estimation of runoff from daily rainfall from selected watersheds of Udaipur region" An unpublished ME thesis , RAU, Bikaner.

Malikarjunappa Gauda, M.L. Maurya and M.,D.Belgaumi (1992). "Impact of water harvesting structures (nala bund) on ground water recharge". Indian Journal of Soil Conservation, 20 (3) : 65-71.

M. Madhu, A.K. Sikka, K.P. Tripathi, R. Raghupati and D.V. Singh (2001). "Contour staggered Trenching and cover crop for soil and water conservation in new tea plantations in the Nilgiris". Indian Journal of Soil Cons. 29 (1) : 1-6.

Mishra P.J. and B. Sahu (2001). “Comparative performance of vegetative barriers in North-Eastern Ghat of Orrisa”. Indian Journal of Soil Conservation, Vol. 29(1), 50-52.

Mishra V.K., D.H. Ranade and Ram K. Gupta (1997). “Comparative evaluation of vegetative soil and water conservation measures based on overall performance index”. Indian Journal of soil conservation, 25 (2) : 103-105.

Mishra R.V.(1994). “Development of sediment prediction models for the watersheds of Chambal Catchment based on Geomorphic and climatological characteristics”. An unpublished M.E. thesis, CTAE, Udaipur.

Mittal, H. K. and Jaspal Singh (1993). “Effect of water harvesting structure on ground water recharge- A case study”. Proceedings of international conference on Environmental management and geo water aspects, Rotterdam, Held in NSW, Australia, 8-11 February : 461-465.

Mukesh Chand and Suraj Bhan (2000). “Effect of Vegetative barriers on erosion losses, soil properties and yield of Sorghum”. Indian Journal of Soil conservation, 28 (3) : 250-252.

NABARD, (1984) . Norms for ground water assessment Based upon report of the ground water estimation committee, 1-13.

N. Subba Rao and R. Pratap Reddy (2001). “Assessment of Ground water yield using electrical resistivity approach”. Proceeding of the national seminar on ground water resources, Department of Geology, MLS University, Udaipur, Feb. 2000,1 (1) : 83-86.

Paliwal B.S. and Meeta Khilnani (2001). “Electrical Resistivity data to assess aquifer parameters for better interpretation of hydrogeology, A study of the Nagaur region, Rajasthan”. Proceeding of the national seminar on ground water resources, Department of Geology, MLS University, Udaipur, Feb. 8-12, 2000, 1(1) : 48-67.

Patnaik U.S. & Alok Sikka (1987). “Bunding and leveling in Agricultural land”. Indian Journal of Soil Conservation, 15 (3) : 51.

Patil, R.G. (1990). “A study of water table fluctuations based on observation wells”. Thesis submitted to Division of Agricultural Engineering, New Delhi.

Paroda R.S. (2000). “Policy support essential”. Article published in the Hindu, Survey of Indian Agriculture. 17 - 20.

Pawade, M.N. (1981). "Water balance of Agricultural Watersheds". Indian journal of Dryland Agriculture Research Development. 3 (2) : 236- 237.

Pendke, M. S., S.N. Jadhav and P.G. More (1997). "Socio-economic evaluation of watershed development works in Ghodegaon watershed". Journal, New Agriculturist. 8 (1) : 37 - 41.

Pendke M.S. (1990). "Impact evaluation of soil conservation measures in selected watersheds of Udaipur district". An unpublished M.E. thesis, CTAE, Udaipur.

Pendke,M.S. and K.P. Gore (1997). "Evaluation of regional ground water potential in watershed". Journal of Maharashtra Agricultural University, 24 (3) : 296 - 298.

Phadnawis, A. N. Birajdar, J. M., Nangre, M. L. and, Asmatoddin, M., (1998) "Resource management in a rainfed watershed (Podal singi Maharashtra)". Indian Journal of Soil Conservation, 21 (1) : 43 - 50.

Prasad S.N., Ratan Singh, Chandra Prakash, D.H. Rao, H. Gadekar, V.S. Katiyar, Arjun Prasad and R. Roghupathy (1997). "Impact of watershed management on runoff water resource development and productivity of arable lands in south eastern Rajasthan". Indian Journal of soil conservation, 25 (1) : 68 -72.

Ranade D.H., L.K. Jain, Ram K. Gupta and D.K. Mccool (1997). "Comparative performance of mechanical vegetative soil conservation measures in vertisols". Indian Journal of Soil Conservation, 25 (3) : 182-185.

Sharma, K. D. (1986). "Runoff behaviour of water harvesting microcatchments". Agricultural Water management, 11, 137-144.

Sharma K.D. and A.K. Kalla (1980). "Effect of nala bunding on Vidhyan sand Stone aquifer in Western Rajastan". Indian Journal of Soil Conservation, 88 (2) : 44 - 49.

Singh, R.A. (1997). "Evaluation of rainwater conservation technologies in ravinous catchment". Indian Journal of soil conservation, 25 (I) : 73-76.

Singh, S. (1995). "Quantitative analysis of watershed geomorphology using remote sensing techniques". Annals of arid zone, 34: 243-251.

S. Arun Gnana Sekhar (2000),"Moisture marvel" Watersheds news, 15(4), 33-37

Singh G (1981). “Manual of soil and water conservation practices of India”, C.S.W.R.T.I., Dehradoon, ICAR, Bulletin BOT – 1310 : 10.

Singh P.K. (2000). “Watershed Management (Design and Practices)”. Book published by e-media publications, Udaipur, India : 9-10.

Sinha et al (1998), "Use of geophysical techniques in Gamharia Nala watershed management programme”. Proceedings of international conference on watershed management and conservation organized by ……. 8-10 Dec. 1998, Delhi : 491-501.

Subudhi, C. R. and P. C. Senapati (1996). “Runoff and soil loss under different vegetative measures in Kalahandi districts of Orrisa”. Indian Journal of soil conservation, 24 (2) : 177-180.

Subudhi C. R. (1995). “Relationship among hydrological and geomorphological parameters in upper damodar valley”. Indian Journal of Soil Conservation, 23 (3), 205-207.

Varadan Km, M Nazimuddin, Babu Mathew, Kokkal & P.K. Pradeep Kumar (1998),” Hagdrologic and socio economic evaluation of watershed development in western ghat regions of Kerala-India-A case study. Proceedings of International conference on watershed management & girl conservation 8-10 Dec. New Delhi, 225-233.

Venugopal M.R., E.J. James and N.V.M. Unni (1996). “Relationship between forest cover and drainage density in a typical rainforest. An investigation using satellite data”. Proceedings of water resources planning and management, Printed in Netherlands, 295-302.

Wodeyar J.K., Rajan Patil and S.C. Puranaik (2001). “Geological, geomorphological and hydrogeological studies of Kandra Basin, Panhala taluka, Kolhapur district, Maharashtra”. Proceeding of the national seminar on ground water resources, Department of Geology, MLS University, Udaipur, held in from 8-12 Feb. 2000, (1)1 : 139-142.