WATER HARVESTING PLANS FOR A HARD LATERITE TERRAIN – A CASE STUDY

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PROJECT REPORT

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DECLARATION

We here by declare that this project report entitled "**Design of Staggered Trenches for a Hard laterite Terrain and its Positioning using Geographic Coordinates** " is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this project report entitled entitled "**Design of Staggered Trenches for a Hard laterite Terrain and its Positioning using Geographic Coordinates** " is a record of project work done jointly by **Nimitha B, Vini Babu and Sreekanth J** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to them.

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SYMBOLS AND ABBREVIATIONS

M Km^3	Million kilometre cube
M ha-m	Million hectare metre
M ha	Million hectare
m^3	metre cube
mm	millimeter
M tonnes	Million tonnes
%	percentage
t/ha	tonnes / ha
cm	centimetre
Mm^3	Million cubic metre
m	metre
et al	and other people
Kg	Kilogram
,	minute
ie	that is
º	Degree
"	second
ha	hectare
R A R S	Regional Agricultural Research Station
U. S	United States
AMC	Antecedent Moisture Condition
GIS	Geographic information system
GPS	Global positioning system
ILWIS	Integrated land and water information system
W	Well
cm/hr	centimetre/hour
cm^3	centimetre cube
cm/s	centimetre/second
Vs	versus

m^2	square metre
Km	kilo metre

Introduction

INTRODUCTION

Land and water are the two important natural endowments, which are crucial life supporting elements and need to be properly utilised for increasing the productivity and improving economic conditions of rural people. Water is essential for all forms of life and is the fundamental resource for human survival. It helps in the socio-economic development as well as for maintaining intact eco systems. Consequent to rising water demand, it is rapidly becoming a rare resource. The imbalance between demand and supply, resource degradation and competition calls for new approaches for water management and water harvesting techniques. The total quantity of water in the world is estimated to be about 1386 M km^3. About 96.5 % of this water is contained in the oceans as saline water. Some of the water on the land accounting to about 1 % of the total water is also saline. Thus only about 35 M km^3 of fresh water is available and 24.4 M km^3 is contained in frozen state as ice in polar regions and on mountaintops as glaciers. 70 % of the fresh water consumed worldwide is used for irrigation. In a single growing season a plant may absorb 2000 times as much as its yield. Only 20 % of fresh water is being utilized for industrial purposes.

India accounts for 16 % of the world's human population and nearly 30 % of cattle with only 2-4 % of the land area and 4 % of the water resources. Even if the full irrigation potential is exploited, about 50 % of the country's cultivated area will remain un- irrigated, particularly with the current irrigation efficiency. The availability of water per season per year is about $2200m^3$ for India and about 800 m^3 for southern states.

But the demand of water for agricultural purposes is estimated to increase to produce increasing quantities of food, horticultural products and raw materials for industry. The requirement of water by different sectors by 2025 is estimated to be 105 M ha m, but the share of water for agriculture is expected to reduce from the present level of 85 % to 71 % by 2025. The demand of water for agriculture is estimated to increase from 50 M ha m in 1985 to 70 M ha m in 2050. During the same period, the demand of water for non-agricultural use will multiply four fold from 7 M ha m to 28 M ha m.

While increase in water table and water logging in an area of about 5.76 M ha is the problem in canal and tank irrigated areas along with secondary salinization, receding water table at a rate as high as one metre annually along with underground water pollution in many states are the haunting problems in well irrigated areas. The water use efficiency in Indian agriculture, at about 30 to 40 % is one of the lowest in the world against 65 % in China. The International Water Management Institute forecasts that by 2025, 33 % of India's population will live under absolute water scarcity conditions. The per capita water availability, in terms of average utilizable water resources in the country, has dropped drastically from 6008 m^3 in 1947 to 2200 m^3 and is expected to dwindle to 1450 m^3 by 2025.

The International Conference on Water and the Environment, Dublin and the United Nations Conference on Environment and Development, the Earth Summit at Rio De Janeiro, both held in 1992, the Millennium Summit 2000 and the Earth Summit in 2002, have all drawn the World's attention to this crisis.

India's water resources are substantial. The average annual rainfall is about 1150 mm, but it is unevenly distributed from 100mm in Rajasthan to 11000 in Chirappunji – erratic and fails. The total surface flow is about 195 M ha m of which 69 M ha m is the utilizable water. The available ground water for irrigation is about 36 M ha m of which about 11.5 M ha m is utilized.

The gross irrigated area from surface and ground water is 97 M ha m. the total storage available in the country is about 18 M ha m even if all the structures under construction and contemplated in the coming years are completed, the total capacity will be only about 37.5 M ha m.

The National Commission on Integrated Water Resource Development has assessed that about 450 M tonnes of food grains will be required by 2050. In 2050 the cropping intensity should be about 150 % and the percentage of irrigation to gross cropped area about 50 %. The productivity per unit area of almost all crops especially the main crops like paddy, cotton, and pulses are far below the world average and wheat yield is just equal to world average.

The overall efficiency obtained is about 35 – 40 % in surface water and 60 – 65 % in ground water. The productivity of irrigated land is about 1.5 to 4.0 tonnes / ha for crops averaging about 2.5 t/ha as compared to an available target of more than 5 t/ha because of inefficiency in management and improper operation of irrigation system. Though participatory irrigation management is accepted in principle by all Governments, more than 60% of irrigation water is used only for rice and wheat crops in India and 40 % for other crops. Though the small and marginal farmers are about 80% of total number, their operation area is about 35% and the rest belong to medium or large holding farmers.

India's average rainfall, about 119.4 cm, when considered over geographical area of 328 M ha amounts to 400 M ha m. Out of this about 70 M ha m is lost to the atmosphere. In Kerala, the mean annual rainfall received is 300 cm. The total number of rainy days is 126. The undulating topography is the main reason for water loss to the seas. A state which started off with more than 50,000 M cubic m of fresh water in its 44 rivulets, 900 odd ponds and 120 days of 300 cm rainfall, has water stress in at least one third of its inhabitants.

In rural areas, 70 % or more of the inhabitants depend on well water, which is polluted by intestinal coliforms, which is undoubtedly caused by the leach pits and deep pits for disposing human excreta. Tanker water supplies are pressed in to service at an exorbitant cost to the exchequers and have become a small industry, which is difficult to dispense with. Water is turning out to be the limiting factor in the Kerala development experience, having potential to overturn many of the social achievements we are proud of.

The fresh water year has seen coalition of planners, academicians, and media persons seriously looking at the various facts of the emerging water divide in Kerala. Today the serious scarcity and more seriously scarcity amidst plenty syndrome of drinking water converts situation to a crisis. Large-scale abuse of water resources takes place by the modern developmental activities. Rainwater harvesting and recharging is the technology developed for collecting and storing of rainwater from local land surface, rock catchments and roof using jars or pots or underground methods to overcome the crisis.

Presently, besides traditional measures, large number of moisture conservation measures like check dams, trenches and other structure including ponds has come up for multiple uses. This includes control of erosion, harvesting and storing water for agricultural rehabilitation of degraded lands. The best option is conserving water in the soil profile at each point of geographical area and small impounding at gullies, vallies, ponds etc. Generally, water supply systems are composed of components namely catchment area, conveyance and collection systems. They can be done in lakes, depressions, flood plain reservoirs, village ponds, tanks, dead quarries etc.

A typical soil form of Kerala is the laterite. It is widely distributed over the central region of Kerala. In fact the soil type , laterite, was first discovered at a place called Angadippuram in Malappuram district of Kerala. The soil type is characterised in high rainfall areas with high infiltration rate.

Laterites are widely distributed in the semi humid and humid inter tropical regions of the globe and in fossil state are found in drier climates and sometimes even in a temperate climate. Because of its unique occurrence in tropics where high temperature and abundant precipitation are prevalent, laterites do not accumulate organic matter except under special conditions. Hardened laterite contains relatively high concentration of iron. The chief and visible morphological feature of laterite profiles is the presence of an indurate horizon, which changes irreversibly to an ironstone hard pan on exposure to air and sun. Erosion removes surface horizon, exposing the layers in which sesquioxides have accumulated leading them to hardening. The mechanism of laterisation involves iron which initially mobilised, gets immobilised developing crystallinity and continuity of crystalline phase, entrapping the soft kaolinite material .The whole process is favoured by environmental conditions like alternate rainy and dry seasons, which will promote relative accumulation of iron. Physical and chemical constraints in crop production occur due to laterisation. Physical constraints include susceptibility to erosion, low water holding capacity and drought stress. Chemical constraints include deficiency of organic matter, Nitrogen, Potassium, Calcium, Magnesium and low cation exchange capacity.

Liming and application of necessary quantity of fertilizers eliminate these constraints. Vegetation is yet another important measure widely used to reduce laterisation. Water is thus required to enhance vegetal cover, which reduces the hard pan formation.

Present study is conducted at Chelloor near Kuttipuram in Malappuram district where severe scarcity of drinking water prevails. The place is a hilly region with hard laterite covering the hilltop where little recharge occurs. This occurs in most parts of Malappuram and Calicut districts. The rainfall contributes little to the ground water with the result that the wells remain dry for most part of the year. Thus there occurs a very high scarcity of drinking water. Due to the presence of hard laterite on the surface, the water is not infiltrated down and whole water is lost as runoff. Laterisation resulted in the formation of hardpan. The infiltration rate of surface layer is very less. Mechanical manipulation is required in deeper layers.

Main objectives of study are

1. Field topographic survey
2. Estimating existing runoff and infiltration rate
3. Design of staggered trenches
4. Positioning of trenches using geographic co-ordinates

Review of Literature

REVIEW OF LITERATURE

Water is the fundamental resource for human survival, socio-economic development and for maintaining intact ecosystems. The source of water on earth is precipitation. Even though the term precipitation denotes all forms of water such as rainfall, snowfall, hail, frost and dew that reaches the earth from the atmosphere, the predominant form of precipitation in India is rainfall. Most of the rainfall is lost as surface runoff, evaporation, and interception. Hence for meeting water demands of existing society, insitu water harvesting is considered to be the best option.

Harvesting local rainwater and reusing it for life saving irrigation is a usual practice in India. Modern technologies for obtaining and using water are chiefly with the exploitation of river system and the development of ground water by wells, bore holes etc.

One method to try outside the big river system is to collect rainwater immediately after it falls and before a large evaporation occurs. The principle of collecting and using precipitation from a small catchment area is termed as rainwater harvesting. This has to be planned depending upon topography, soil type, rainfall and other meteorological data. The term was first used in Australia by H.J. Geddes, to denote the collection and storage of any farm water either runoff or creek flow for irrigation use.

2.1 Importance of water harvesting

Land pressure is increasing day by day due to population growth, causing the use of more and more marginal lands for agriculture. During rainy season, water availability can be ensured at minimum investment. Water harvesting is a substitute and is important in response to water scarcity. It proves to be more costly.

2.2. Water harvesting techniques

They include wide range of methods, based on the following three basic points:

1. Sources of water available
2. Required storage duration
3. Intended use of harvested water

On the basis of these points, techniques are

1. Roof harvesting
2. Runoff harvesting

2.3Runoff harvesting:

Runoff is induced by completely or partly sealing the soil surface by using chemicals like gelatinous materials or oily substances that seal soil pores, or by artificially compacting the soil surface of catchments area. It may be short term or long term.

2.3.1Short term techniques:

2.3.1.1. Contour bund:

It involves the construction of bunds on contours of catchments area. These bunds hold the surface runoff in surrounded space of two adjacent bunds. The height of contour bund ranges from 0.3 m to 1.0 m length from 10m to few hundred meters.

2.3.1.2 Semi-circular hoop:

This structure consists of an earthen embankment, constructed in the shape of semi circle furnished on a contour. The water contributed from the area is collected with in the hoop to a maximum depth equal to the height embankment. The height of the hoop is from 0.1 to 0.5 m. these are used for irrigation of grasses, fodder, shrubs or trees etc.

2.3.1.3 Rock catchments or quarry reservoir:

They are the exposed rock surfaces for collecting runoff water. When rainfall occurs on exposed rock surface, it takes the form of runoff very rapidly because there is little loss. The runoff is drained towards lowest point called as storage tank. The area of catchments may vary from a hundred square meter to few thousand square metres.They can serve as reservoirs for storing water. With the modification of catchments area or linkage with nearby channels, the capacity can be increased where the volume of runoff water is calculated to be in excess of present storage capacity. The area at the periphery of individual quarries may be shaped in form of gently sloping catchments.

2.3.1.4 Ground catchments:

A large area of ground is used as catchments for runoff yield. The runoff is diverted in to a storage tank, where it is harvested. The ground is cleared of vegetation and compacted very well. They are road catchments, which is used for different purposes such as for the collection of runoff water for irrigation of vegetables and to collect water for storing purposes. They were used since 4000 years ago in places where annual crops and some drought tolerant species were grown.

2.4 Principles of water harvesting structure design

In many regions, local thumb rules were used for designing the structures. For hydrological design, a more or less universal criteria is followed which is basically the ratio of catchment area to cultivated area. The value varies from 1:5 to 1:40, depending on rainfall magnitudes and distribution, runoff coefficient and water requirement of existing crops to be irrigated.

$$\text{Ratio} = \frac{CR - DR}{DR \times RC \times EF}$$

CR = Crop water requirements

DR = Design rainfall

RC = Runoff coefficient

EF = Efficiency factor

One way of classifying methods of water conservation is by comparing rainfall with crop requirements. Accordingly the three practices to be followed are;

1. Where precipitation is less than crop requirements, the strategy includes land treatment to increase runoff in to cropped areas, allowing for water conservation and the use of drought tolerant crops with suitable management practices.
2. When precipitation is equal to crop requirements, the strategy is local conservation of precipitation, maximum storage with in the soil profile and storage of excess runoff for the subsequent use.
3. When precipitation is in excess of crop requirements, strategy is to reduce rainfall erosion, to drain surplus runoff and store it for subsequent use.

Design rainfall is probably less than long term average rainfall in order to give better crop in low rainfall years, while excess can overflow in wet years. Runoff coefficient is the percentage of rainfall which becomes runoff. Efficiency reflects the difference between rainfall distribution and the water requirements of crop. Different practices are widely adopted in soil and water conservation.These can be approached through agronomic and engineering procedures. Engineering measures differ with location, slope of land, soil type, amount and intensity of rainfall.

Agronomic practices:

1. Contour cultivation
2. Strip cropping
3. Cover cropping
4. Inter cropping
5. Mulching
6. Zero tillage

Mechanical practices:

1. Contour bunding
2. Contour trenches
3. Bench terracing
4. Staggered trenching
5. Crescent bunding
6. Check dams

2.5 Soil and water conservation measures:

Soil and water are the most vital natural resources for the survival of mankind. Proper management of natural resources like soil,water and vegetation is a pre requisite for sustained productivity. For increased water and soil conservation, various measures such as land form treatments, water ways and drainage channels, field bunds, vegetative barriers, storage of excess water through construction of dug out ponds, cropping intensity increase etc were under taken.

A study was conducted in doon valley by Arora, Y.K and Mohan, S.C.(1994).In doon valley,attempts were made to enhance the productivity of lemon and sweet orange through land shaping and in situ moisture conservation by adopting moisture conservation measures.

The major effect on soil moisture indicated that it gets depleted rapidly in all treatments by the beginning of April and remarkably more rapid thereafter, but full polythene maintained soil moisture at higher level (18.1%) in root zone (0-30 cm) towards May end. Effects on yield and tree growth indicate that grass mulch cover on surface in V-shaped micro catchment had maximum survival(74.6%) for the establishment of orchard in degraded land. Fruit quality was found to be better in case of grass mulching and can hence be recommended.Various insitu water harvesting techniques implemented in command area increased moisture content ion soil profile which inturn increases the crop yield of bajra,wheat and mustard by 45%,27%,59% respectively. Mechanical measures include staggered contour trenching, percolation embankment and vegetative measures.

P.C.Tyagi and B.P.Joshi (1994) conducted a study in western Himalayan region. Runoff and soil loss are acute resulting in impoverished land and low crop production. Conservation measures are therefore necessary to control soil erosion and retain maximum possible moisture in the soil.mainly the measures adopted are agronomic and mechanical.

V.N.Sharda and S.S.Shrimala (1994) conducted a study on water harvesting and recycling in northern hilly regions. These regions though receives sufficient annual rainfall, its temporal and spatial variations frequently result in moisture stress conditions during critical stages of plant growth. Proper design of harvesting structures involves adequate analysis of rainfall amount,intensity and its distribution such that maximum water is available by end of monsoon. To avoid pond silting,area should be vegetated properly and soil conservation measures like contour cultivation,terracing,check dams etc should be adopted.

Chanappa(1994) conducted a study on insitu moisture conservation in arid and semi arid topics. The approach was to reduce runoff by adopting various interterrace management practices including land smoothening to avoid local depressions, adoption of vegetative bunds on contour and frequent intercultivation. The principle behind is to increase infiltration by reducing runoff rate, temporarily impounding water on soil surface. Red soils are shallow and light , where level terraces and contour bunds were reported functioning satisfactorily.

Singh et al (1994) conducted a study on resource management for sustained production in Aravali region .Staggered contour trenches of size 2.5m x 0.45m x 0.45m at spacing in the same direction and 2.5m apart in rows has proved as first line of defence for sediment control .Digging of contour trenches on hilly slopes is a major mechanical soil and water conservation measure to reduce runoff and soil loss and to favour quick growth of trees and grasses. The trenches act as sediment trap mini structure and reduce runoff and peak discharge apart from improving the moisture regime of the improverished soil. The number of such trenches depends on type of soil and degree of slope.

Sastry et al (1994) conducted a study on mass erosion and its control. Contour trenches break the velocity of runoff and store some part of it in them, improving the moisture availability. Generally trenches may be dug with cross section of 0.3mx0.3m. Staggered trenches may be made upto 15m in length with interspace between them. Recurence interval of 5 to 10 years.

Rana (1998) conducted a study on evaluation and vegetative measures for gully control in Kandi region of Himachal Predesh. It included temporary checkdams of loose boulders, gabion and brushwood which gave varied performance in gully control.The gabion checkdams were observed to be much efficient than loose boulder or brushwood checkdam. The brushwood checkdams were the least efficient as they decayed and were subjected to termite attack.Grasses like vetiver, *Saccharum munja*, bushes like Ipomea cornea and trees like Iacacia catechu and Leucaena leucophela have been observed suitable for the region.

Singh et al (1998) conducted a study on remote sensing and GIS techniques for prioritization of water sheds in upper machkund watershed in Andra Pradesh.The climate of area is mostly sub humid tropics with mean annual rainfall of 1055 mm.The demarcation of watershed and sub watershed was done using visual interpretation of geo coded IRS – IB and prints. By using GIS, hydro geomorphology, land use, land cover and slope maps were combined to generate erosion intensity maps

A study was conducted by Madhu et .al (2001) on the effect of contoured staggered trenching and cover crops of beans in conserving soil and water. The mean of three years data revealed that soil and water conservation efficiency was higher in combination of CST and cover crop of beans and CST.

Titala and Shiyani(2001) studied on economic impact of water harvesting structures. The structures of Raj samadhiyala of the North-Saurashtra Agro-climatic zone is one of the most admired water harvesting structures due to its higher water benefits. The impact of water harvesting structures on cropping pattern of farmers,crop yields and income of farmers,inequality between income of beneficiaries was evaluated.

Yadhav et al(2001) conducted a study on different technology of water harvesting in some of the water deficit cities of India. An integrated system of rain water harvesting can be designed for a city,in which rain water harvesting at the domestic and neighbourhood level can be combined with other techniques at the city level for recharging the aquifer which will augment the net availability of fresh water for consumption.

Athavale (2003) conducted a study on better water conservation measures in some parts of Madhya Pradesh. As a measure to combat water shortages, harvesting of rainwater and runoff is practised. This practice has certainly been successful in raising the shallow water table at many places and farmers have been able to give supplemental irrigation to Kharif crops, secondary irrigations to rabi crops. About 33% of the domestic supply in cities is also met through tapping of ground water by dug wells or tube wells.

A study was conducted by Vijay Kumar and Arun Goel (2005) on the potential of geographic information system in water resource management. The proper management of water resource project requires storage and retrieval of data and information for quick analysis. The study was to explore the capabilities of GIS which will be useful in solving several problems of water resources. It has been found that various functionalities of DEM, map overlay, terrain mapping digitization, network analysis etc can be utilized in the planning, decision making and management of water resources in an efficient manner.

The principle behind is to increase infiltration by reducing runoff rate, temporarily impounding water on the soil surface to increase opportunity time for infiltration and modifying land configuration for inter plot water harvesting. The present approach to reduce runoff by adopting various inter terrace management practices include land smoothening to avoid local depressions, adoption of small section or vegetative bunds on contour, contour sowing, opening ridges or furrows across the slope.

2.6 Contour trenching:

In land capability classification some lands have severe limitations by virtue of which they are not suitable for cultivation. The limitations may be in terms of higher slope, severe erosion, stoniness, rockiness, etc. Such lands are referred as non agricultural lands, denuded or waste lands, which cannot be easily converted into cultivable form.

It is an excavated trench along a uniform level across the slope of the land in the top portion of catchments. Bunds are formed downstream along the trenches with material taken out of them. More favourable moisture conditions are thus created to accelerate the growth of planted trees. Contour trenches break the velocity of runoff. The rainwater percolates through the soil slowly and travels down and benefits land in middle and lower sections of catchment.

2.6.1 Design:

Plants are planted on the trench side of the bunds along the berms. Trenches are not more than 15m long and are generally staggered. In the cross section they rarely exceed 0.3 x 0.3 m. Trenches must run perfectly level. Contour trenches are excavated at suitable intervals (depending upon the slope of land) and their cross sections are designed to collect and convey the runoff from the interspace between the successive trenches and this determines the size of the trench. Side slopes of trenches are 1:1 or 0.5:1 depending on nature of soil. These trenches are meant to intercept the runoff and convey it to a vertical disposal drain excavated at suitable intervals along natural folds at valley without causing erosion.

2.6.2 Graded Trenches

These are identical to contour trenches except in that they are excavated with longitudinal bed grade. These trenches are suited to areas receiving high annual rainfall.

2.6.3 Staggered trenches

These are excavating trenches of shorter lengths in a row along the contour with interspace between them. Suitable vertical intervals between the rows are restricted to impound the runoff expected from above, without overflow. In the alternate row, the trenches will be located directly below one another. The trenches in successive rows will be staggered, with the trenches in the upper row and the interspace in the lower row being directly below each other. The length of the trench and the interspace between the trenches in the same row may be suitably arrived at, so that there will be no long unprotected or interrupted slope to cause unexpected runoff and erosion. As the trenches are not continuous, no vertical disposal drain is excavated. The cross section area of these trenches will be designed to collect the runoff expected from intense storms at recurrence interval of 5 to 10 years.

Contour and staggered trenches are widely adopted in Tamil Nadu. These are adopted in high rainfall hilly areas of lands with slopes steeper than 33% or any slope with badly eroded soil. Instead of contour trenching, graded contour trenches have been suggested. The trenches are limited in length to about 450 m. The trenches are located as below according to slopes:

Table 1. Trench spacing for different slopes

Category	Slope	V.I (m)
Gentle slopes	5 -10	13.5 - 19.5
Medium slopes	10 -25	6 –13.5
Steep slopes	> 25	1.25

The length of staggered contour trench will be 3m to 3.65 m while the interspace between the trenches in the same row will be only 2.4 to 3m. The trenches will be trapezoidal in cross section with 0.3m-to 0.45m-bottom width, side slope of 0.5:1 to 1:1. The bund will have about 0.15m free board out of 1.02m. In addition, planting the area with fast growing tree and grass species is also done.

2.7 Agronomic measures

Some agronomic management practices which assist nature's never ending efforts to recloth the soil are

2.7.1 Sowing

The natural methods are not sufficient due to the high pressure on the land or the successive disturbance to the site which can be vegetated with either sowing or planting the germinated seedlings in the large areas are prone to competition from aggressive weeds, pest, diseases, wild animals and rodents etc requires intensive management. The sowing should be done in already prepared trenches, patches and strips. Especially, in areas subject to erosion, it is profitable to plant the seed either in prepared patches or on the berm of trenches. Sowing methods are;

2.7.1.1 Strip sowing:

The strips are spaced at 3-4m, depending upon the species to be established. The strips are either continuous or broken, depending upon the configuration or topography. The broken strips are practiced in undulating topography, where these are staggered. The main advantage of strip sowing is that it involves comparatively less soil working, smaller quantity of seed and lesser cost in weeding operations. Seeds are either dibbled or drilled in the prepared strips.

2.7.1.2 Patch sowing:

Square or circular patches of 20 cm or 30 cm diameter are prepared, the soil is worked and the seeds are sown. This can be practised in sites where weed intensity is low. The common spacing between patches is 3m x 3m.This involves skilled personnel in laying out and stacking.

2.7.1.3 Pit sowing:

In localities with low rainfall, pits of 45cm x 45cm x 45cm are dug sowing done on the filled up pits. It provides good worked up soil for roots penetration and moisture conservation. The cost of soil working is high.

2.7.1.4 Trench or ridge sowing:

In arid areas, trenches of 1.5m x 45cm x 45cm are dug at 3m spacing staggered on contour. The soil excavated is piled on the down hill slope along the trench length. The seeds are either sown on berm of the trenches or in diagonally half filled trenches. In high rainfall areas, this process runs the risk of inducing sedimentation in the reservoirs.

2.7.1.5 Mound sowing:

It is subjected to water logged areas and scrapping the soil and raising it to 60 cm height prepare mounds. Sowing is to be done on such mounds. For successful planting, Seth (1960) advocates that the central core of the mound should be filled with good soil mixed with well rotten farmyard manure or mixed to 2 Kg of gypsum.

2.7.1.6 Time of sowing:

It is imperative to complete the soil working before the onset of rains. The best sowing time is the first shower of rain.

2.7.1.7 Depth of sowing:

The seed should be covered with soil .in case of smaller seeds, light soil cover may suffice. The cover should not exceed the diameter of the seed.

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Materials and Methods

MATERIALS AND METHODS

Chelloor experiences an acute shortage of water during the summer months. The hard laterite nature of the soil on the hilltop permits little infiltration in to the soil. Hence most of the rainfall obtained is lost as runoff and little part of it is contributed to ground water by recharge. Even though most of the houses own more than one well they remain dry during the summer. Further deepening of the wells are not possible as they lie upon the granite. Studies indicate the need for harvesting the runoff and recharging it to the soil for replenishing the ground water potential of the area. The present study was undertaken to design a scientific runoff harvesting technique for proper recharge of the rainfall that was lost as runoff.

This chapter describes the materials and methods adopted for the study.

3.1 Location of study

The study was undertaken in the Chelloor area of Kuttippuram Gramapanchayat in Malappuram district. It is situated at 10°51' North latitude and 76° 1' East longitude.

3.2 Experimental Details

3.2.1 Reconnaissance survey and selection of suitable site

The hilltop is having almost 5 ha of barren land where laterisation had occurred due to prolonged exposure to sun. The soil is seen only in a few patches between hard, black coloured laterite rock. There are about 250 families living along the slopes of the hill, severely affected by drought in the months of March, April and May. The area was found suitable for water harvesting as it was on the topmost region and could be easily availed for the purpose. A picture of the area is shown in plate 1.

3.2.2 Rainfall data

Daily rainfall depth for the year 2005 was obtained from the meteorological observatory of K C A E T, Tavanur, Malappuram district. Rainfall data for the past fifteen years, ie. from 1991 to 2004 was collected from the observatory of R A R S , Pattambi.

3.2.3 Catchment area and Contour survey

The area of the catchment was determined by topographic survey. Contours of the catchment area were plotted for a grid size of 10 m x 10 m. The contours were plotted with a suitable contour interval. SURFER 6, which plots the contour using interpolation technique, was used for the purpose.

3.2.4 Depth of Soil

The depths of soil at different positions of the field were found out using screw auger. The procedure is depicted in Plate 1

3.3 Vegetation

The whole area is almost barren with only a few species of shallow rooted grasses growing during the favourable seasons.

3.4 Depth of runoff

The runoff was computed by the curve number method. It estimates storm wise direct runoff . The method is based on the potential maximum retention of the catchment, ie, the antecedent moisture condition and physical characteristics of the catchment.

This method assumes that the ratio of direct runoff Q to the rainfall depth minus the initial losses (P- Ia) is equal to the ratio of actual retention of rainfall to the S value,

$$\frac{Q}{P - I_a} = \frac{P - Q - I_a}{S}$$

To simplify the above equation, considering the condition of the region. Ia can be taken as 0.3 S . So the equation may be reduced to ;

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

where;

Q - Direct Runoff depth

P - Rainfall depth

I_a - Initial abstraction

S - Potential maximum retention

And $Q = 0$ when $P \leq 0.3S$

By using this equation, if we have values of P and S known then the value of Q can be calculated. The retention capacity, S of the catchment can be predicted using curve number (CN) defined by the U.S soil Conservation Service (1969), given as

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

The value of CN varies from minimum of zero for most permeable surface to maximum of 100 for impervious surface. The value of CN for different land use conditions and hydrologic soil groups are applied to the antecedent moisture conditions II and applied to the antecedent moisture conditions III and I with correction factors. The antecedent moisture condition for the area was determined by the five day total antecedent rainfall. The limits of AMC I, II and III are shown in the table given in Appendix I.

After determining the soil type, initially the curve number for the entire catchment for AMC II was determined. The curve number for AMC I and AMC III were obtained from a table with CN for AMC I and AMC III corresponding to CN for AMC II. The table is shown in the Appendix II. Using the values for CN obtained from the curve the daily runoff was computed. The runoff obtained is in depth basis.

3.5 Water table contour

Water table contours are lines joining points having equal water table elevations. The procedure for drawing water table contours involved measuring the water table depths using a tape from the ground surface. The locations and ground surface elevations of ten wells in the area were obtained by tacheometric surveying. Then the elevations of water table were calculated by substracting the water table depth from the ground surface elevation. Water table contours were plotted in SURFER 6 by giving well locations in co-ordinate system and corresponding water table elevations as input data. The software uses interpolation technique to draw the contours. Water table contours were drawn for three months, July, September and December 2005.

3.6 Soil properties

3.6.1 Infiltration rate

Infiltration rate of the soil was calculated on an undisturbed surface of the soil in the area using double ring infiltrometer. Infiltration rate of soil after excavating the soil to a depth of thirty centimetre from the ground surface was also calculated.

The experimental setup consisted of two metallic cylinders of 2mm rolled steel. The cylinders were 30 cm long. The cylinder from which the infiltration measurements were taken was 30 cm in diameter. The outer cylinder, which was used to form the buffer pond was about 60 cm in diameter. The cylinders were driven to a depth of 15 cm in to the soil using a falling weight type hammer striking on a metallic sheet placed on the top of the cylinder.

After driving the cylinders vertically downward in to the soil to the required depth, the metallic sheet was removed. The hook gauge was then placed. Water was then filled to a depth of 10 cm in the outer as well as inner ring. The recession in the water level was recorded during the time intervals of 5, 10, 15, 25, 45, 60, 75, 110 and 130 minutes after filling water. Both the cylinders were refilled up to the initial level after every reading was taken. Infiltration rates were then calculated for each of the time intervals.

3.6.2 Determination of permeability of soil

The permeability of soil at fully saturated condition is taken as the lateral rate of flow. For determining the lateral rate of flow constant head permeability test was adopted.

An undisturbed soil specimen was taken using a core cutter. This soil specimen was used for the experiment. The soil sample was placed in the permeameter. The constant head reservoir was attached to the drainage cap of the permeameter and water was allowed to flow out from the drainage base for some time such that a steady state of flow is established. The air vent was opened for de-airing the soil sample. The water was allowed to flow under constant head for a specific time interval and water discharged corresponding to the specific time interval was collected in the graduated jar. The head causing the flow was measured. The experiment was repeated under two different heads. The coefficient of permeability was calculated using the equation ;

$$k = \frac{Q \cdot L}{T \cdot h \cdot A}$$

where,

k = Coefficient of permeability (cm / sec)

Q = Quantity of water flowing in time interval t (cm^3)

L = Length of soil sample (cm)

T = Time interval (sec)

h = Head causing the flow (cm)

A = Area of cross section of soil sample (cm^2)

3.6.3 Test Pit

To determine the seepage from the pits in the actual field condition, a test pit of standard size was made and the depth of water percolating from the pit was monitored at constant time intervals after filling it up to the top. The steady state obtained was selected as the constant rate of outflow from the pit.

3.7 Design of Staggered trenches

From the evaluation of soil properties it was seen that the infiltration rate of the undisturbed soil surface was very less. But the infiltration rate of the soil thirty centimetres below the ground surface is relatively high. Any recharge is, hence, possible only by causing the rainwater to infiltrate this permeable part of soil profile by removing the overlying soil. Also the water is to be retained over the soil for a time equal to the time of infiltration. Hence contour trenches, which satisfies both the requirements, was selected for the purpose of runoff harvesting. Since it is a high rainfall area staggered form of contour trenches were decided to be adopted. The design of staggered trenches involved the following.

3.7.1. Rainfall Analysis

The staggered trenches were designed for runoff from a rainfall with a return period of five years. The rainfall with a return period of five years was obtained by rainfall frequency analysis. The purpose of frequency analysis of an annual series is to obtain a relation between the magnitude of the event and its probability of exceedence. The frequency analysis was done with fifteen years' rainfall data from 1991 to 2005.The empirical technique of plotting position was used for the analysis.

The annual extreme series of the daily rainfalls for the years 1991 to 2005 were arranged in descending order of magnitude and an order number 'm' were assigned for each. Thus for the first entry m = 1, for the second entry m = 2 and so on till the last event for which m = 15. The probability P of an event equaled to or exceeded is given by Weibull formula ;

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

The recurrence interval T ;

$$T = 1/P = (N+1)/m$$

The exceedence probability of the event obtained by this empirical formula is called plotting position. Having calculated P (and hence T) for all the events in the series, the variation of rainfall magnitude was plotted against the corresponding T on a semi-log paper. From this plot, the rainfall corresponding to a recurrence of five years was found out.

3.7.2 Rainfall - Runoff correlation

The runoff corresponding to the rainfall of five year return period was obtained by Rainfall – Runoff correlation. The procedure adopted was to fit a linear regression line between rainfall values (P) and runoff values (R) and to accept the result if the correlation coefficient is nearer unity. The equation for straight line regression between runoff R and rainfall P is;

$$R = aP + b$$

And the values of the coefficients ‘a’ and ‘b’ are given by

$$a = \frac{N \sum PR - (\sum P)(\sum R)}{N(\sum P^2) - (\sum P)^2}$$

And,

$$b = \frac{\sum R - a\sum P}{}$$ in which ;

N

N - number of sets of observations R and P

The coefficient of correlation ‘r’ was calculated as

$$r = \frac{N(\sum PR) - (\sum P)\sum(R)}{\sqrt{[N(\sum P^2) - (\sum P)^2] \times [N(R^2) - (\sum R)^2]}}$$

A value of $0.6 < r < 1.0$ indicates good correlation. Then the value of runoff depth corresponding to the rainfall of five years return period was taken from the plot.

3.7.3 Runoff volume

The total volume of runoff from the catchment was determined by multiplying the runoff depth obtained in section 3.7.2 by the total catchment area obtained in section3. 2.3

3.7.4 Pit dimensions and spacing

Suitable pit dimensions in the range of standard pit dimensions that are usually selected for the design of staggered trenches were adopted for the design. The depth of the pit was selected after studying the infiltration rates of the soil at different depths. The pit to pit spacing in a row was so selected that the vegetation proposed can effectively grow in the space with the water percolating from the pits available in their root zone.

3.7.5 Design of Bund

A bund, with trapezoidal cross sectional area, was proposed to be provided on the downward side of the trench with suitable species of grass growing on it. The bund was so designed that the volume of excavation of soil was equal to the volume of the bund.

The height of bund was selected based on the root zone depth of the grass species growing on it.

3.7.6 Number of pits and spacing of the rows

Number of pits and the row to row spacing of pits were designed in such a way that a fixed percentage of the total runoff corresponding to the rainfall with five year return period can be harvested in the pits. The number of pits and spacing required to harvest different percentages of the runoff were calculated and an optimum number and spacing which was practically and economically feasible was selected.

Number of pits is obtained as follows

$$N = \frac{\text{Total volume of runoff}}{\text{Volume of a single pit}}$$

Volume of excavation

$$V = \text{Volume of runoff to be harvested}$$

Area contributing to one pit is given by

$$A = \frac{\text{Total area of the catchment}}{\text{Number of pits}}$$

The distance between the pits in alternate rows is given by

$$L = \frac{\text{Area contributing to one pit}}{\text{Length of a pit}}$$

Distance between rows $R = L/2$

Depth of runoff that can be fully harvested

$$D = \frac{\text{Volume of the pit}}{\text{Catchment area of each pit}}$$

3.7.7 Water conservation efficiency

Water conservation efficiency is the ratio of depth of harvested runoff to the depth of total runoff. Water conservation efficiency was calculated for depths corresponding to different percentages of the peak runoff volume and the design providing a water conservation efficiency of 50 % was chosen.

$$\text{Water conservation efficiency} = \frac{\text{Depth of harvested runoff}}{\text{Total Runoff depth}}$$

3.8 Positioning of the staggered trenches

GIS (Geographic Information system)and GPS (Global Positioning System) were made use of in locating the positions of the staggered trenches along the contours. The latitudes and longitudes of a few known points, including the bench mark were first obtained using the GPS e-Trex. The map of the area with contours and grid points prepared in SURFER 6 was imported in to the GIS software ILWIS 3.3 as a segment map. The map was then geo-referenced by LATLON , using the latitudes and longitudes obtained using e-Trex. Then the latlon co-ordinates of different points on each contour was obtained from the map. This can be transferred to the ground using the GPS

Results and Discussion

RESULTS AND DISCUSSION

The results of the studies conducted for the design of staggered trenches to enhance the ground water potential of the laterite catchment of Chelloor area are presented in this chapter. The design of the staggered trenches and its positioning is also discussed.

4.1 Annual rainfall depth

The depth of rainfall for the year 2005 was obtained as 282.6 cm. The daily rainfall depths for the year are given in tables 2 to 13.

4.2 Contour survey and Catchment Area

The suitable area selected after the reconnaissance survey was surveyed starting from a ridge. Square grids of 10 m x 10 m were established in a portion of the total area and the elevations of the corners of the grids with respect to an arbitrary benchmark were obtained by levelling. Another portion of the field was surveyed using theodolite. The total area of the catchment was obtained as 4.69 ha. The contour map of the area with the boundary and grid points is shown in Fig. 1. The average slopes of the area were obtained as 3.2 % in North South direction and 1.8 % in East West direction.

4.3 Depth of soil

The depth of loose soil was measured using screw auger at different locations of the entire catchment area. The soil depth varied from 0 to 1.5 m. Most of the area had a very thin layer of loose soil of the order 5 to 15 cm, wiping off the chance of any vegetation establishing there. The vegetation of the area comprises only shallow rooted grass varieties growing after the rains.

4.4 Depth of runoff

The annual average runoff depth was calculated as per the procedure mentioned in section3.4 .For applying the method the Hydrologic soil group, vegetative cover, land use pattern and the antecedent moisture conditions of the region were determined.

4.4.1 Hydrologic Soil Group

The presence of an impermeable hard pan on the surface of the soil was observed. Hence it was concluded that the soil belonged to the hydrologic soil group

4.4.2 Vegetative Cover

The area has no vegetation except for a few species of shallow rooted grasses growing during the rainy season and is subjected to grazing. The hydrologic condition is, hence, poor

.4.4.3 Present Land Use practices

The area is put to no use other than grazing and transportation.

4.4.4 Curve Number

The Curve Number for the area was selected from the table given in Appendix III showing Land Use pattern, hydrologic condition and hydrologic soil group. The land use was poor and hydrologic soil group D. Under these conditions the curve number 91 was selected for the area for AMC condition II. From the conversion table given in Appendix II the CN values for AMC conditions I and III were obtained as 80 and 97 respectively.

4.4.5 Rainfall data

The rainfall data was collected from the meteorological observatory of K C A E T Tavanur for computation of runoff using the formula ;

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

The initial abstraction I_a was selected as 0.3 from table given in Appendix IV. Using the formula runoff was computed on a daily basis. The tables 1 to12 shows the computed values of runoff corresponding to daily rainfall depths and curve numbers.

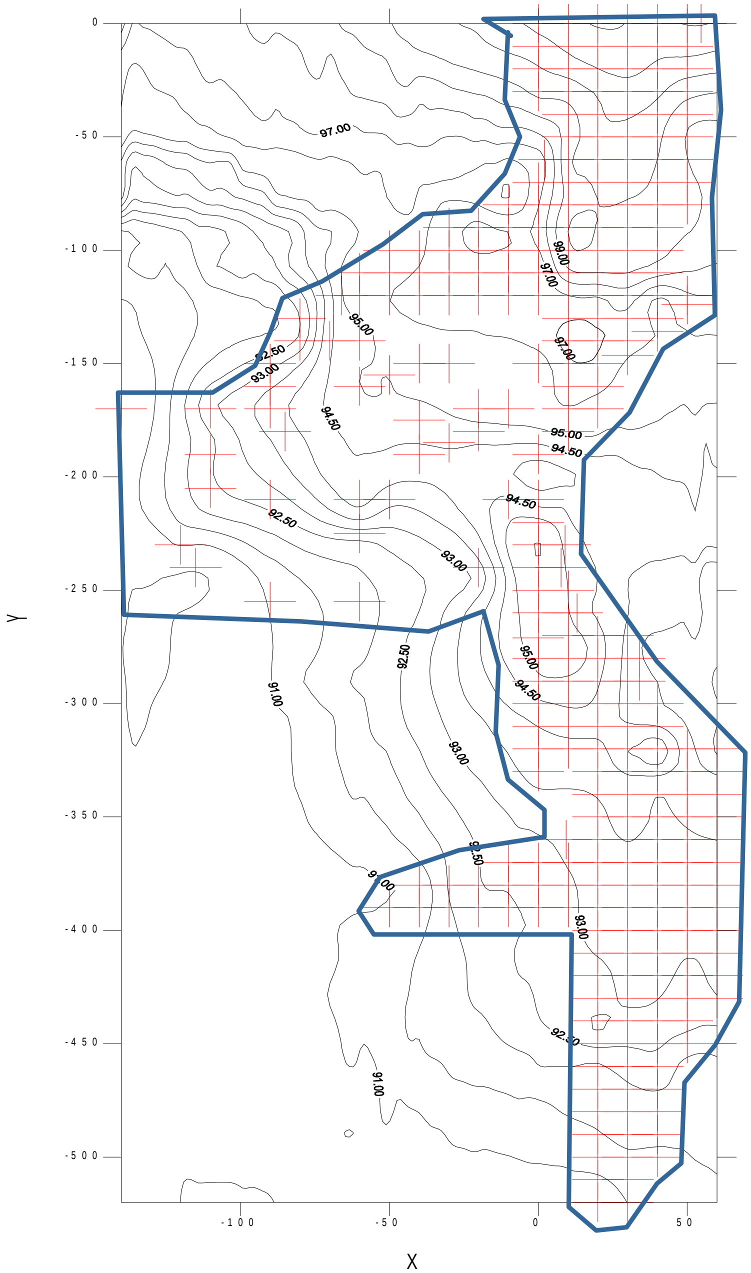


Fig 1. Boundary map with grid points and contours

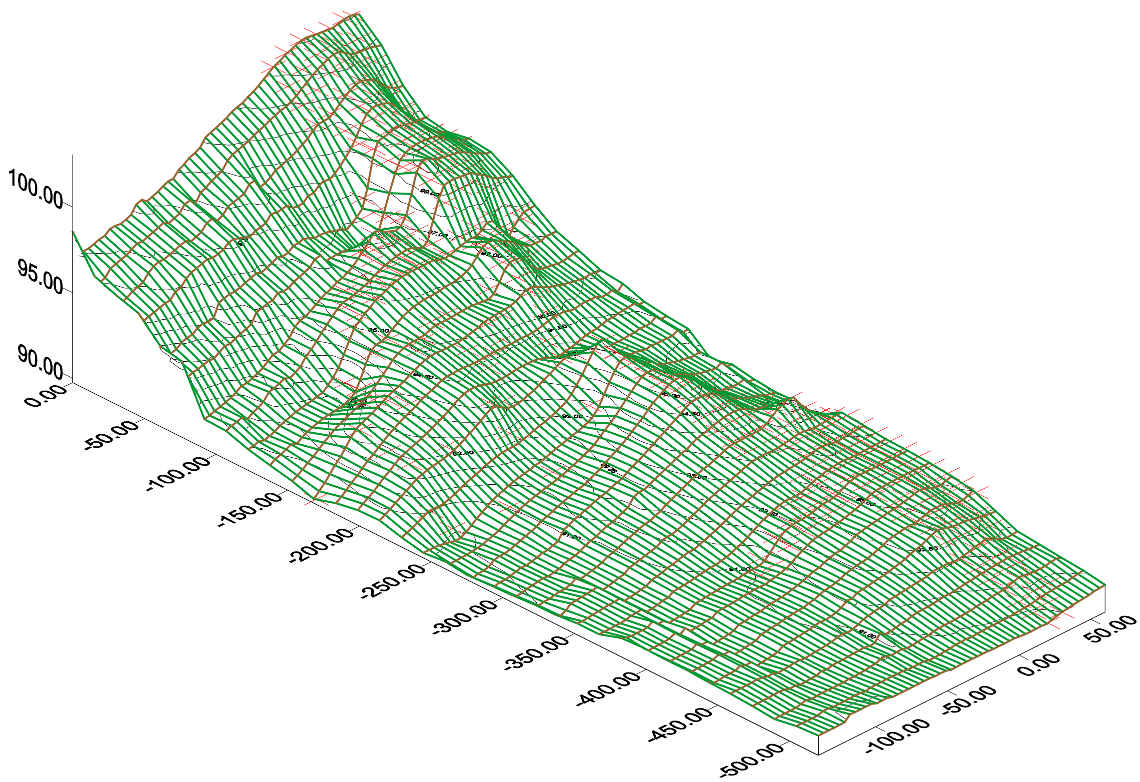


Fig 2. Surface plot of the area

Table 2. Runoff for the month of January 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
1/1/05	0	0	80	6.35	0
1/2/05	0	0	80	6.35	0
1/3/05	0	0	80	6.35	0
1/4/05	0	0	80	6.35	0
1/5/05	0	0	80	6.35	0
1/6/05	0	0	80	6.35	0
1/7/05	0	0	80	6.35	0
1/8/05	0	0	80	6.35	0
1/9/05	0	0	80	6.35	0
1/10/05	0	0	80	6.35	0
1/11/05	0	0	80	6.35	0
1/12/05	0	0	80	6.35	0
1/13/05	0	0	80	6.35	0
1/14/05	0	0	80	6.35	0
1/15/05	0	0	80	6.35	0
1/16/05	0	0	80	6.35	0
1/17/05	0	0	80	6.35	0
1/18/05	0	0	80	6.35	0
1/19/05	0	0	80	6.35	0
1/20/05	0	0	80	6.35	0
1/21/05	0	0	80	6.35	0
1/22/05	0	0	80	6.35	0
1/23/05	0	0	80	6.35	0
1/24/05	0	0	80	6.35	0
1/25/05	0	0	80	6.35	0
1/26/05	0	0	80	6.35	0
1/27/05	0	0	80	6.35	0
1/28/05	0	0	80	6.35	0
1/29/05	1	0.1	80	6.35	0
1/30/05	2.4	0.24	80	6.35	0
1/31/05	1.2	0.12	80	6.35	0
Total	4.6	0.46			0

Table 3. Runoff for the month of February 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
2/1/05	0	0	80	6.35	0
2/2/05	0	0	80	6.35	0
2/3/05	0	0	80	6.35	0
2/4/05	0	0	80	6.35	0
2/5/05	0	0	80	6.35	0
2/6/05	0	0	80	6.35	0
2/7/05	0	0	80	6.35	0

2/8/05	0	0	80	6.35	0
2/9/05	0	0	80	6.35	0
2/10/05	0	0	80	6.35	0
2/11/05	0	0	80	6.35	0
2/12/05	0	0	80	6.35	0
2/13/05	0	0	80	6.35	0
2/14/05	0	0	80	6.35	0
2/15/05	0	0	80	6.35	0
2/16/05	0	0	80	6.35	0
2/17/05	0	0	80	6.35	0
2/18/05	0	0	80	6.35	0
2/19/05	0	0	80	6.35	0
2/20/05	0	0	80	6.35	0
2/21/05	0	0	80	6.35	0
2/22/05	0	0	80	6.35	0
2/23/05	0	0	80	6.35	0
2/24/05	0	0	80	6.35	0
2/25/05	0	0	80	6.35	0
2/26/05	0	0	80	6.35	0
2/27/05	0	0	80	6.35	0
2/28/05	0	0	80	6.35	0
Total	0	0			0

Table 4. Runoff for the month of March 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
3/1/05	0	0	80	6.35	0
3/2/05	0	0	80	6.35	0
3/3/05	0	0	80	6.35	0
3/4/05	0	0	80	6.35	0
3/5/05	0	0	80	6.35	0
3/6/05	0	0	80	6.35	0
3/7/05	0	0	80	6.35	0
3/8/05	0	0	80	6.35	0
3/9/05	0	0	80	6.35	0
3/10/05	0	0	80	6.35	0
3/11/05	0	0	80	6.35	0
3/12/05	0	0	80	6.35	0
3/13/05	0	0	80	6.35	0
3/14/05	0	0	80	6.35	0
3/15/05	0	0	80	6.35	0
3/16/05	0	0	80	6.35	0
3/17/05	0	0	80	6.35	0
3/18/05	0	0	80	6.35	0
3/19/05	0	0	80	6.35	0
3/20/05	0	0	80	6.35	0
3/21/05	0	0	80	6.35	0
3/22/05	0	0	80	6.35	0
3/23/05	0	0	80	6.35	0

3/24/05	0	0	80	6.35	0
3/25/05	0	0	80	6.35	0
3/26/05	0	0	80	6.35	0
3/27/05	0	0	80	6.35	0
3/28/05	0	0	80	6.35	0
3/29/05	0	0	80	6.35	0
3/30/05	0	0	80	6.35	0
3/31/05	0	0	80	6.35	0
Total	0	0			0

Table 5. Runoff for the month of April 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
4/1/05	0	0	80	6.35	0
4/2/05	0	0	80	6.35	0
4/3/05	32	3.2	80	6.35	0.449867
4/4/05	1	0.1	97	0.785567	0.004478
4/5/05		0	97	0.785567	0
4/6/05	37.6	3.76	97	0.785567	2.957942
4/7/05	1	0.1	97	0.785567	0.004478
4/8/05	1	0.1	97	0.785567	0.004478
4/9/05		0	97	0.785567	0
4/10/05		0	97	0.785567	0
4/11/05		0	97	0.785567	0
4/12/05	0.4	0.04	80	6.35	0.295488
4/13/05		0	80	6.35	0
4/14/05		0	80	6.35	0
4/15/05	32	3.2	80	6.35	0.449867
4/16/05		0	97	0.785567	0
4/17/05		0	97	0.785567	0
4/18/05		0	97	0.785567	0
4/19/05		0	97	0.785567	0
4/20/05	7.3	0.73	97	0.785567	0.241598
4/21/05	3.4	0.34	91	2.512088	0.011227
4/22/05		0	91	2.512088	0
4/23/05	4.1	0.41	91	2.512088	0.00353
4/24/05		0	91	2.512088	0
4/25/05		0	91	2.512088	0
4/26/05	1.3	0.13	80	6.35	0.249443
4/27/05		0	80	6.35	0
4/28/05		0	80	6.35	0
4/29/05		0	80	6.35	0
4/30/05		0	80	6.35	0
Total	121.1	12.11			4.672396

Table 7. Runoff for the month of June

Date	P(mm)	P(cm)	CN	S	R(cm)
6/1/05	4.5	0.45	97	0.785567	0.079542
6/2/05		0	97	0.785567	0
6/3/05		0	97	0.785567	0
6/4/05	2	0.2	97	0.785567	0.00222
6/5/05	38.8	3.88	97	0.785567	3.074199
6/6/05		0	97	0.785567	0
6/7/05	5.3	0.53	97	0.785567	0.120026
6/8/05	10.2	1.02	97	0.785567	0.45168
6/9/05	28.3	2.83	97	0.785567	2.065756
6/10/05	8.2	0.82	97	0.785567	0.303371
6/11/05	0.3	0.03	97	0.785567	0.024539
6/12/05	29	2.9	97	0.785567	2.132216
6/13/05	4	0.4	97	0.785567	0.057362
6/14/05		0	97	0.785567	0
6/15/05	31	3.1	97	0.785567	2.322835
6/16/05	107.1	10.71	97	0.785567	9.821746
6/17/05	45	4.5	97	0.785567	3.677651
6/18/05	44.8	4.48	97	0.785567	3.658122
6/19/05	56	5.6	97	0.785567	4.7564
6/20/05	50.8	5.08	97	0.785567	4.245425
6/21/05	29	2.9	97	0.785567	2.132216
6/22/05	17	1.7	97	0.785567	1.022352
6/23/05	0.2	0.02	97	0.785567	0.028992
6/24/05	8	0.8	97	0.785567	0.289336
6/25/05	29	2.9	97	0.785567	2.132216
6/26/05	2.9	0.29	97	0.785567	0.019227
6/27/05	6.8	0.68	97	0.785567	0.208957
6/28/05	22	2.2	97	0.785567	1.475501
6/29/05	7.2	0.72	97	0.785567	0.234966
6/30/05	61.1	6.11	97	0.785567	5.258901
Total	648.5	64.85			49.59576

Table 8. Runoff for the month of July

Date	P(mm)	P(cm)	CN	S	R(cm)

7/1/05	42.8	4.28	97	0.785567	3.463045
7/2/05	46.2	4.62	97	0.785567	3.7949
7/3/05	23	2.3	97	0.785567	1.56805
7/4/05	64.1	6.41	97	0.785567	5.554997
7/5/05	33.3	3.33	97	0.785567	2.543218
7/6/05	5	0.5	97	0.785567	0.104188
7/7/05	1	0.1	97	0.785567	0.004478
7/8/05	107	10.7	97	0.785567	9.811794
7/9/05	66	6.6	97	0.785567	5.742693
7/10/05	16.1	1.61	97	0.785567	0.943008
7/11/05	5.8	0.58	97	0.785567	0.147985
7/12/05	3	0.3	97	0.785567	0.02199
7/13/05	2.8	0.28	97	0.785567	0.016623
7/14/05	3	0.3	97	0.785567	0.02199
7/15/05		0	97	0.785567	0
7/16/05	13.1	1.31	97	0.785567	0.685674
7/17/05	28.8	2.88	97	0.785567	2.113213
7/18/05	10.5	1.05	97	0.785567	0.474989
7/19/05	9.2	0.92	97	0.785567	0.375856
7/20/05	9.8	0.98	97	0.785567	0.42099
7/21/05	1.6	0.16	97	0.785567	1.06E-05
7/22/05	10	1	97	0.785567	0.436278
7/23/05	6.7	0.67	97	0.785567	0.202589
7/24/05	22.8	2.28	97	0.785567	1.5495
7/25/05	3.6	0.36	97	0.785567	0.041644
7/26/05	10.8	1.08	97	0.785567	0.498533
7/27/05	17.8	1.78	97	0.785567	1.093549
7/28/05	41	4.1	97	0.785567	3.287831
7/29/05	27	2.7	97	0.785567	1.942726
7/30/05	70	7	97	0.785567	6.138216
7/31/05	24.1	2.41	97	0.785567	1.670421
Total	725.9	72.59			54.67098

Table 9. Runoff for the month of August

Date	P(mm)	P(cm)	CN	S	R(cm)
8/1/05	47	4.7	97	0.785567	3.873135
8/2/05	36.4	3.64	97	0.785567	2.841895
8/3/05	9	0.9	97	0.785567	0.361071
8/4/05	5	0.5	97	0.785567	0.104188
8/5/05	6.2	0.62	97	0.785567	0.171624
8/6/05	0	0	97	0.785567	0
8/7/05	0	0	97	0.785567	0
8/8/05	10.2	1.02	91	2.512088	0.088423
8/9/05	5.2	0.52	91	2.512088	0.000122
8/10/05	7	0.7	91	2.512088	0.014407
8/11/05	2	0.2	91	2.512088	0.041389
8/12/05	0	0	91	2.512088	0
8/13/05	32	3.2	91	2.512088	1.396816
8/14/05	19.8	1.98	97	0.785567	1.273902

8/15/05	55	5.5	97	0.785567	4.658016
8/16/05	22.8	2.28	97	0.785567	1.5495
8/17/05	0.8	0.08	97	0.785567	0.008394
8/18/05	11.8	1.18	97	0.785567	0.578559
8/19/05	0	0	97	0.785567	0
8/20/05	0	0	97	0.785567	0
8/21/05	0	0	97	0.785567	0
8/22/05	0	0	91	2.512088	0
8/23/05	0	0	80	6.35	0
8/24/05	2.4	0.24	80	6.35	0.199417
8/25/05	0	0	80	6.35	0
8/26/05	0	0	80	6.35	0
8/27/05	0	0	80	6.35	0
8/28/05	0	0	80	6.35	0
8/29/05	0	0	80	6.35	0
8/30/05	0	0	80	6.35	0
8/31/05	13.8	1.38	80	6.35	0.001873
Total	286.4	28.64			17.16273

Table 10. Runoff for the month of September

Date	P(mm)	P(cm)	CN	S	R(cm)
9/1/05	0	0	91	2.512088	0
9/2/05	0	0	91	2.512088	0
9/3/05	23.2	2.32	91	2.512088	0.763016
9/4/05	42.1	4.21	97	0.785567	3.394864
9/5/05	7.2	0.72	97	0.785567	0.234966
9/6/05	45.6	4.56	97	0.785567	3.73626
9/7/05	87.6	8.76	97	0.785567	7.883051
9/8/05	26.4	2.64	97	0.785567	1.886129
9/9/05	16.2	1.62	97	0.785567	0.951782
9/10/05	138.2	13.82	97	0.785567	12.92003
9/11/05	40	4	97	0.785567	3.19065
9/12/05	6	0.6	97	0.785567	0.159671
9/13/05	7.4	0.74	97	0.785567	0.248278
9/14/05	12	1.2	97	0.785567	0.594826
9/15/05	0	0	97	0.785567	0
9/16/05	0	0	97	0.785567	0
9/17/05	0	0	91	2.512088	0
9/18/05	25.4	2.54	91	2.512088	0.912537
9/19/05	9.4	0.94	97	0.785567	0.390774
9/20/05	33.9	3.39	97	0.785567	2.60089
9/21/05	0.8	0.08	97	0.785567	0.008394
9/22/05	0	0	97	0.785567	0
9/23/05	0	0	97	0.785567	0
9/24/05	0	0	97	0.785567	0
9/25/05	0	0	97	0.785567	0
9/26/05	0	0	80	6.35	0
9/27/05	0	0	80	6.35	0
9/28/05	0	0	80	6.35	0

9/29/05	0	0	80	6.35	0
9/30/05	0	0	80	6.35	0
Total	521.4	52.14			39.87612

Table 11. Runoff for the month of October

Date	P(mm)	P(cm)	CN	S	R(cm)
10/1/05	0	0	80	6.35	0
10/2/05	0	0	80	6.35	0
10/3/05	0	0	80	6.35	0
10/4/05	0	0	80	6.35	0
10/5/05	13	1.3	80	6.35	0.000141
10/6/05	0.6	0.06	91	2.512088	0.094572
10/7/05	0	0	91	2.512088	0
10/8/05	0	0	91	2.512088	0
10/9/05	22	2.2	91	2.512088	0.684563
10/10/05	49.2	4.92	97	0.785567	4.088543
10/11/05	2.9	0.29	97	0.785567	0.019227
10/12/05	50.25	5.025	97	0.785567	4.191477
10/13/05	3.75	0.375	97	0.785567	0.047311
10/14/05	8.1	0.81	97	0.785567	0.296333
10/15/05	1.2	0.12	97	0.785567	0.00184
10/16/05	0	0	97	0.785567	0
10/17/05	0	0	97	0.785567	0
10/18/05	0	0	91	2.512088	0
10/19/05	1.7	0.17	80	6.35	0.230476
10/20/05	4.4	0.44	80	6.35	0.124801
10/21/05	0	0	80	6.35	0
10/22/05	18.9	1.89	80	6.35	0.055151
10/23/05	9	0.9	97	0.785567	0.361071
10/24/05	1.4	0.14	97	0.785567	0.000381
10/25/05	3.1	0.31	97	0.785567	0.024907
10/26/05	0.6	0.06	97	0.785567	0.013699
10/27/05	0	0	97	0.785567	0
10/28/05	10.2	1.02	91	2.512088	0.088423
10/29/05	5.6	0.56	91	2.512088	0.00129
10/30/05	0	0	91	2.512088	0
10/31/05	4	0.4	91	2.512088	0.004353
Total	209.9	20.99			10.32856

Table 12 . Runoff for the month of November 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
11/1/05	31	3.1	91	2.512088	1.320522
11/2/05	0.5	0.05	97	0.785567	0.016911
11/3/05	18.2	1.82	97	0.785567	1.129363
11/4/05	0	0	97	0.785567	0

11/5/05	2.6	0.26	97	0.785567	0.011915
11/6/05	17.2	1.72	97	0.785567	1.040095
11/7/05	58	5.8	97	0.785567	4.953317
11/8/05	0	0	97	0.785567	0
11/9/05	0	0	97	0.785567	0
11/10/05	1	0.1	97	0.785567	0.004478
11/11/05	0	0	97	0.785567	0
11/12/05	0	0	97	0.785567	0
11/13/05	9.5	0.95	80	6.35	0.016982
11/14/05	0	0	80	6.35	0
11/15/05	0	0	80	6.35	0
11/16/05	0	0	80	6.35	0
11/17/05	0	0	80	6.35	0
11/18/05	0	0	80	6.35	0
11/19/05	0	0	80	6.35	0
11/20/05	0	0	80	6.35	0
11/21/05	0	0	80	6.35	0
11/22/05	0	0	80	6.35	0
11/23/05	0	0	80	6.35	0
11/24/05	0	0	80	6.35	0
11/25/05	2.6	0.26	80	6.35	0.19103
11/26/05	0	0	80	6.35	0
11/27/05	0	0	80	6.35	0
11/28/05	0	0	80	6.35	0
11/29/05	0	0	80	6.35	0
11/30/05	0	0	80	6.35	0
Total	140.6	14.06			8.684612

Table 13. Runoff for the month of December 2005

Date	P(mm)	P(cm)	CN	S	R(cm)
12/1/05	0	0	80	6.35	0
12/2/05	0	0	80	6.35	0
12/3/05	0	0	80	6.35	0
12/4/05	17	1.7	80	6.35	0.027271
12/5/05	0	0	91	2.512088	0.125604
12/6/05	0	0	91	2.512088	0.125604
12/7/05	0	0	91	2.512088	0.125604
12/8/05	0	0	91	2.512088	0.125604
12/9/05	0	0	91	2.512088	0.125604
12/10/05	0	0	80	6.35	0
12/11/05	0	0	80	6.35	0
12/12/05	0.3	0.03	80	6.35	0
12/13/05	0	0	80	6.35	0
12/14/05	0	0	80	6.35	0
12/15/05	0	0	80	6.35	0
12/16/05	0	0	80	6.35	0
12/17/05	0	0	80	6.35	0
12/18/05	0	0	80	6.35	0

12/19/05	0	0	80	6.35	0
12/20/05	0	0	80	6.35	0
12/21/05	0	0	80	6.35	0
12/22/05	0	0	80	6.35	0
12/23/05	0	0	80	6.35	0
12/24/05	0	0	80	6.35	0
12/25/05	0	0	80	6.35	0
12/26/05	0	0	80	6.35	0
12/27/05	0	0	80	6.35	0
12/28/05	0	0	80	6.35	0
12/29/05	0	0	80	6.35	0
12/30/05	0	0	80	6.35	0
12/31/05	0	0	80	6.35	0
Total	17.3	1.73			0.655293

Total Rainfall = 282.6 Total Runoff = 196.3cm

4.5 Water table Contour

Ten wells of the area were selected for the water table study. The depth to water table was monitored on monthly basis. The depth to water table for the ten wells for the months February 2005 to January 2006 are shown in table 14, all depths being in metres. The names of the owners of the ten wells are given in the Appendix V .

Table 14. Water table depths, in m, of wells in the area

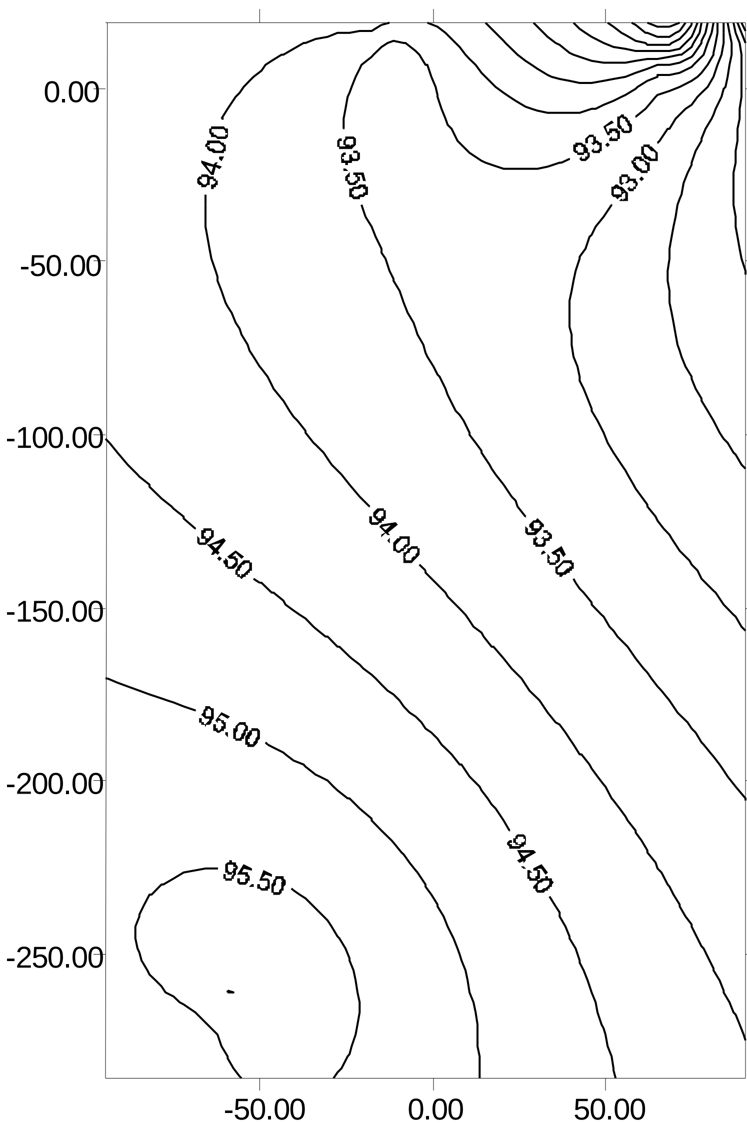
`

Well	Feb ‘05	Mar ‘05	Apr ‘05	May ’05	Jun ‘05	July ‘05	Aug ‘05	Sep ’05	Oct ‘05	Nov ’05	Dec ‘05	Jan ‘06
W1	13	--	--	12.6	10.4	10.2	10.8	12.7	12.85	12.87	12.84	12.9
W2	--	--	--	--	6.42	6.4	7.35	8.7	8.9	8.94	--	--
W3	--	--	--	--	4.86	4.7	5.16	5.3	5.3	5.35	5.54	--
W4	--	--	--	-	3.68.	3.65	3.93	4.1	4.16	4.22	4.35	--
W5	7.85	7.79	7.88	7.75	6.84	6.7	7.01	7.54	7.59	7.64	7.69	7.78
W6	10.76	10.79	10.8	10.7	9.6	9.5	9.94	10.35	10.4	10.4	10.55	10.6
W7	7.67	7.69	7.73	7.66	6.75	6.55	6.76	7.3	7.37	7.42	7.51	7.55
W8	8.54	8.2	8.3	8.15	7.02	6.96	7.24	7.75	7.9	8.1	8.3	8.37
W9	8.5	8.6	8.75	8.35	7.25	7.2	7.85	8.1	8.24	8.35	8.4	8.5
W10	10.2	10.4	10.54	9.68	8.65	8.4	8.82	9.6	9.75	9.8	9.9	10.2

The well locations and ground surface elevation for the wells obtained by tacheometric survey are given in table 15 . The plot of water table contours for three month is shown in figures 3, 4 and 5. Wells nearer to areas without hard pan showed better yield. The effects of any recharge measure done on the area can be evaluated by comparing the then water table data with the present values

Table 15. Location and ground elevation of the wells

WELL No:	X co-ordinate (m)	Y co-ordinate (m)	Elevation (m)
W1	65	4.54	104.1
W2	69	18.75	104.2
W3	88	16.46	96.7
W4	90.5	19.25	94.2
W5	-11.5	10	99.86
W6	-17.6	19.23	103.7
W7	-51	-273	102.4
W8	-67	-271.5	102.3
W9	-61.5	-264.3	103.3
W10	-94.2	-286	103.6



0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-50.00
0.00
50.00
94.00
93.50
93.50
93.00
94.00
93.50
94.50
95.00
94.50
95.50

fig 3. Water table contour map for July 2005

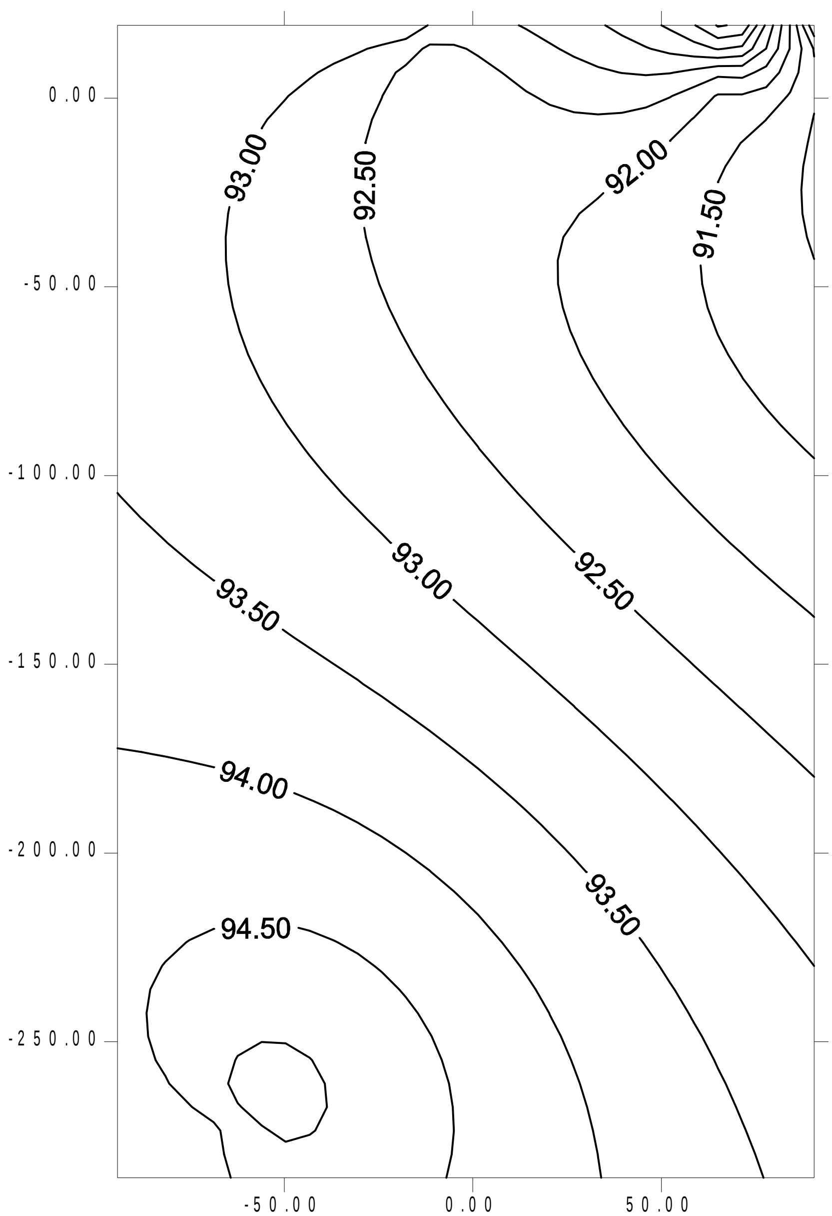
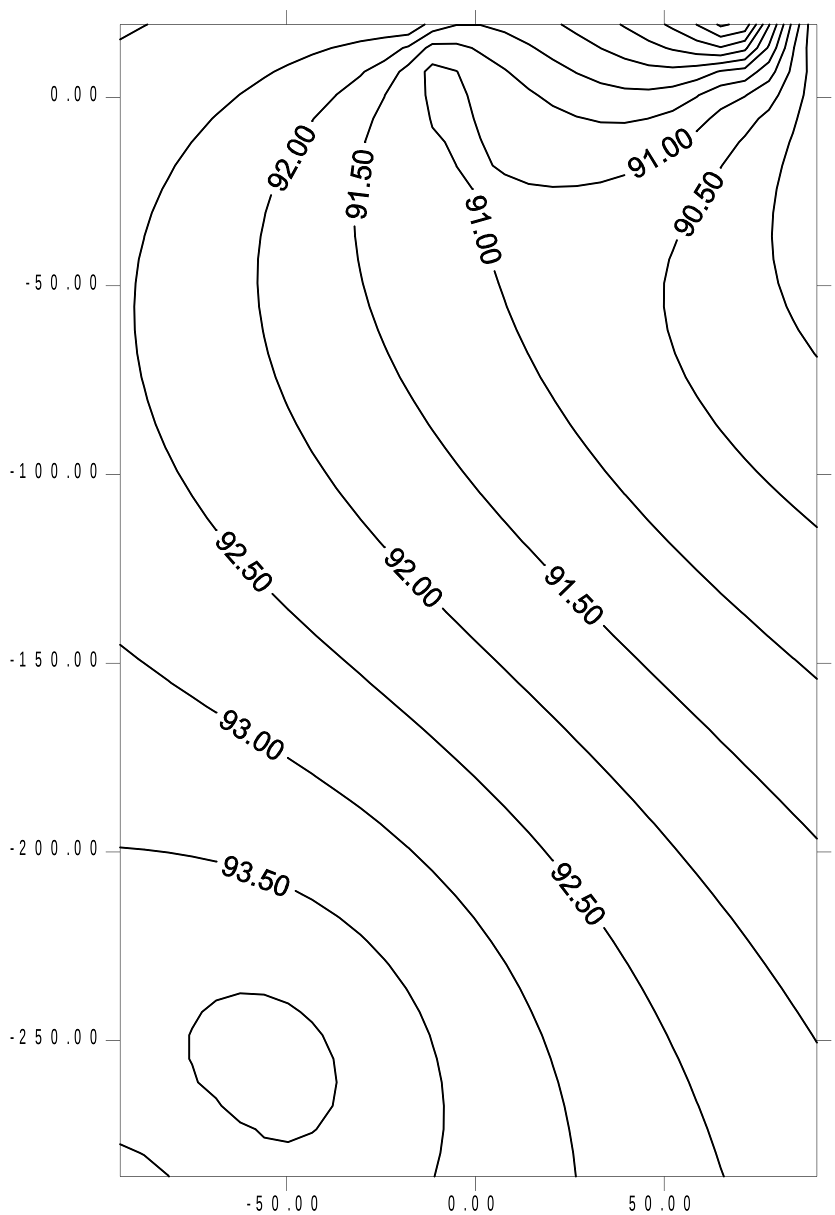


fig 4. Water table contour map for Sep. 2005



0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-50.00
0.00
50.00
92.00
91.50
91.00
91.00
90.50
92.50
92.00
91.50
93.00
93.50
92.50

fig 5. Water table contour map for Dec. 2005

4.6 Soil Properties

4.6.1 Infiltration rate

The infiltration rate of the undisturbed soil surface was calculated as per the procedure mentioned in section3.6.1. Tables 16 and 17 shows the experimental data collected and the calculated infiltration rate. The infiltration rate became constant at 130 minutes and corresponding value of average infiltration (0.3 cm/hr) was considered as the infiltration rate of the soil. The infiltration rate of the soil was found very low. This is due to the presence of a hard pan on the surface of the soil. Test was carried out after excavating 30 cm of soil from the ground surface. The results showed a higher rate of infiltration from that layer (4.8 cm/hr).

Table 16. Results of Double ring infiltrometer test on undisturbed soil surface

Elapsed time (min)	Depth of water surface from reference point (cm)		Infiltration during the period (cm)	Average infiltration rate (cm/hr)
	Before filling	After filling		
0	-	15	0	0
5	15	15	0	0
10	15	15	0	0
15	15	15	0	0
25	15	15	0	0
45	15	15	0	0
60	15	15	0	0

75	14.9	15	0.1	0.1
90	14.9	15	0.1	0.2
110	14.9	15	0.1	0.3
130	14.9	15	0.1	0.4

Table 17. Results of Double ring infiltrometer test on 30 cm deep soil.

Elapsed time (min)	Depth of water surface from reference point (cm)		Infiltration during the period (cm)	Average infiltraton rate (cm/hr)
	Before filling	After filling		
0	-	15		-
5	14.55	15	0.45	5.4
10	14.55	15	0.45	5.4
15	14.1	15	0.5	6
25	13.35	15	0.9	5.4
45	13.85	15	1.65	4.9
60	13.85	15	1.15	4.6
75	13.85	15	1.15	4.6
90	13.8	15	1.2	4.8
110	13.4	15	1.6	4.8
130	13.4	15	1.6	4.8

4.6.2 Permeability of the soil

Permeability of the soil was estimated using the procedure mentioned in 10.2. The results of constant head permeability test are given in Table 17. The values obtained are similar to moderately permeable soils. Average value of coefficient of permeability was found to be 3.924 cm/hr. Hence the outflow from the surface area is not having much variation from that of base area. The r

Length of soil sample = 12.73 cm

Diameter of soil sample = 10.97 cm

Cross sectional area of soil sample = $94.6 cm^2$

Table 18. Results of constant head permeability test

Trial No:	1	2
Head, h (cm)	110.4	112.8
Time T (sec)	120	120
Quantity Q(cm^3)	83	85
Coefficient of permeability $K = \frac{Q.L}{T h A}$ cm/s	9.9×10^{-4}	9.95×10^{-4}

4.7 Test pit

A pit of size 3m x 0.4m x 0.3m , one that is usually adopted for the design of staggered trenches was made in the soil. The experimental data obtained were as shown in the table 6. The steady state outflow from the pit was obtained as 3.6 cm/hr.

Table 19. Outflow from the test pit

Time (min)	Depth of water infiltrated (cm)
0	
5	2
10	2.7
15	3.5
20	4
25	5.4
30	6.0
35	6.75
40	7.3
45	7.5
50	7.8
55	8.15
60	8.45

4.8 Design of staggered trenches

4.8.1 Rainfall analysis

Frequency analysis was done with 15 years' rainfall data (1991 to 2005) as per the procedure mentioned in 11.1. Table 19 shows the one day maximum rainfall for all the years. The ranking of the events and calculation of their recurrence interval using Weibull's formula are shown in table 20.The rainfall depth corresponding to five year return period was obtained by plotting rainfall depth against corresponding recurrence interval. The graph is shown in Fig 6.

Table 20. Annual extreme series of rainfall

Year	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
Rainfall (cm)	12.37	10.2	9.75	9.46	10.08	8.06	19.2	9.26	10.98	14.3	12.7	11.37	9.73	14.95	11.26

Table 21. Recurrence interval using Weibull's formula

Rank m	Rainfall cm	Recurrence interval T = (N +1)/m
1	19.12	16
2	14.95	8
3	14.3	5.333333
4	12.37	4
5	12.3	3.2
6	11.37	2.666667
7	11.26	2.285714
8	10.98	2
9	10.2	1.777778
10	10.08	1.6
11	9.75	1.454545
12	9.73	1.333333
13	9.46	1.230769
14	9.26	1.142857
15	8.06	1.066667

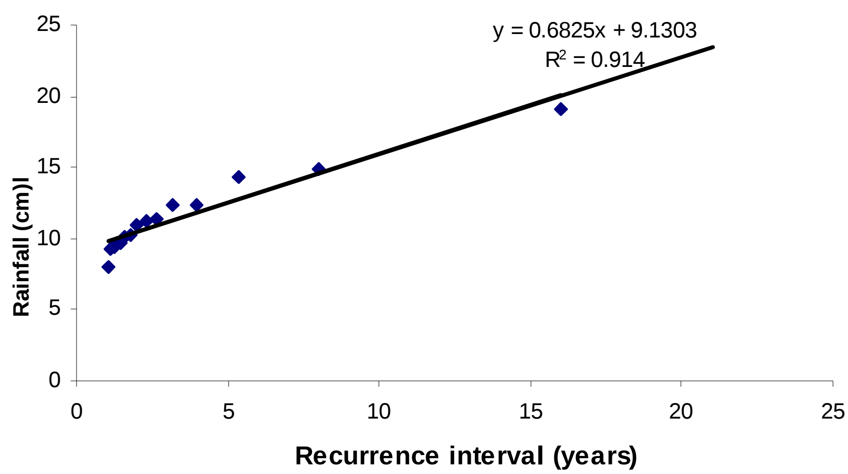


Fig 6. Rainfall Vs Recurrence interval

From the plot the value of rainfall corresponding to a recurrence interval of five years was obtained as 12.54 cm.

4.8.2 Rainfall – Runoff correlation

The daily depths of runoff were plotted against the corresponding depths of rainfall on a monthly basis for the months having considerable rainfall. The runoff corresponding to a rainfall of 12.54 was obtained from each curve. The obtained values were 7.24 cm (May), 11 cm (June), 11.2 cm (July), 9.5 cm (August), 11.12 cm (September), 9.2 (October) and 9.25 cm (November). Since most of the rains occurs in the monsoon and runoff corresponding to the month of July was the highest, the value of runoff 11.2 cm was chosen for the design. The values of ‘a’ and ‘b’ as per the procedure 11.2 is given in table 22.

Table 22. Values of ‘a’ and ‘b’

Month	a	b
May	0.5741	0.0415
June	0.8999	-0.292
July	0.9245	-0.4012
August	0.7701	-0.1579
Septembr	0.907	-0.2472
October	0.748	-0.1733
November	0.7427	-0.0586

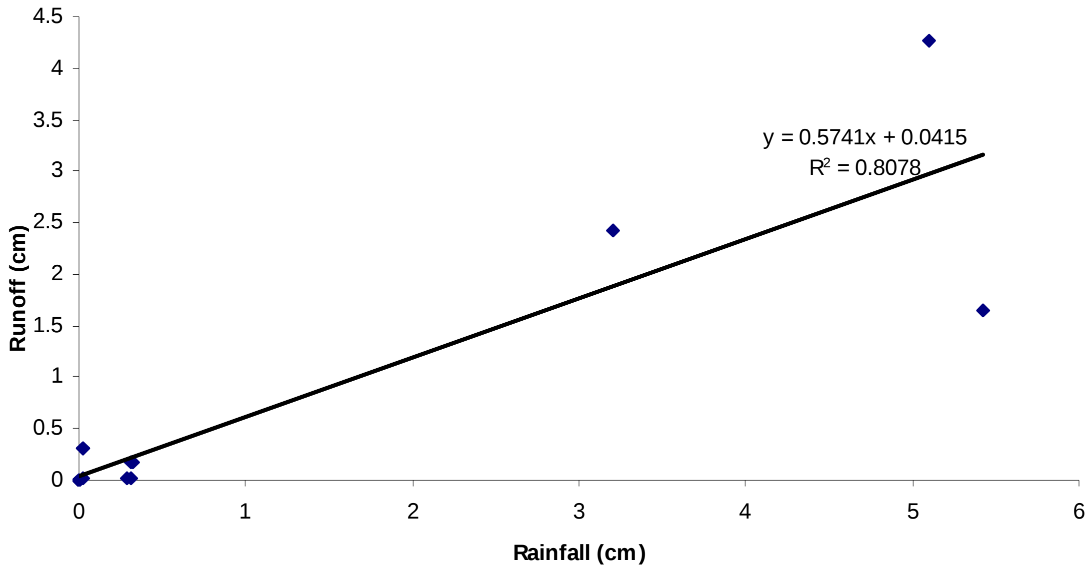


Fig 7. Runoff –Rainfall correlation for May 2005

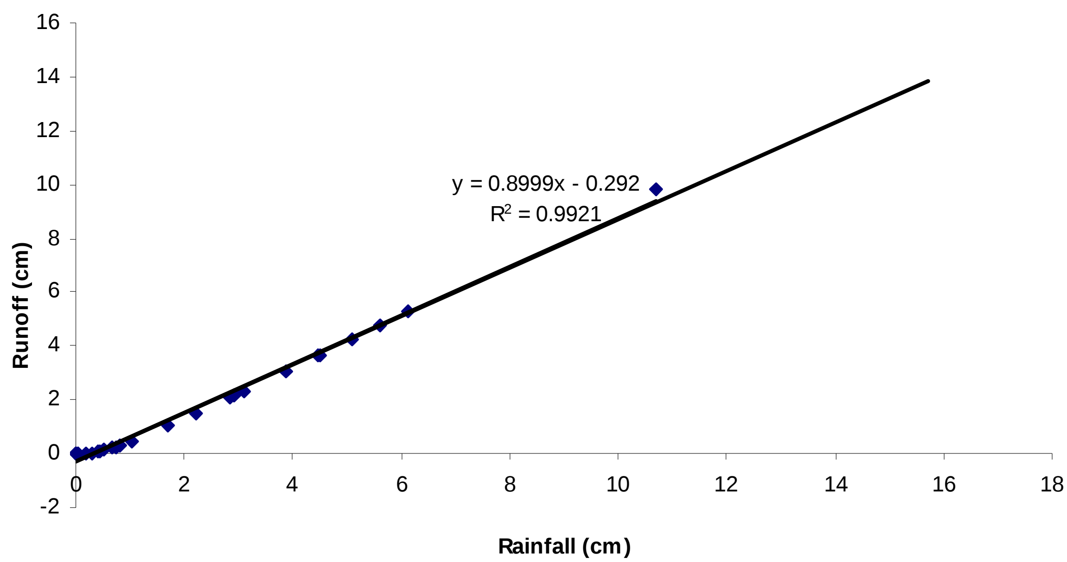


Fig 8. Runoff – Rainfall correlation for June 2005

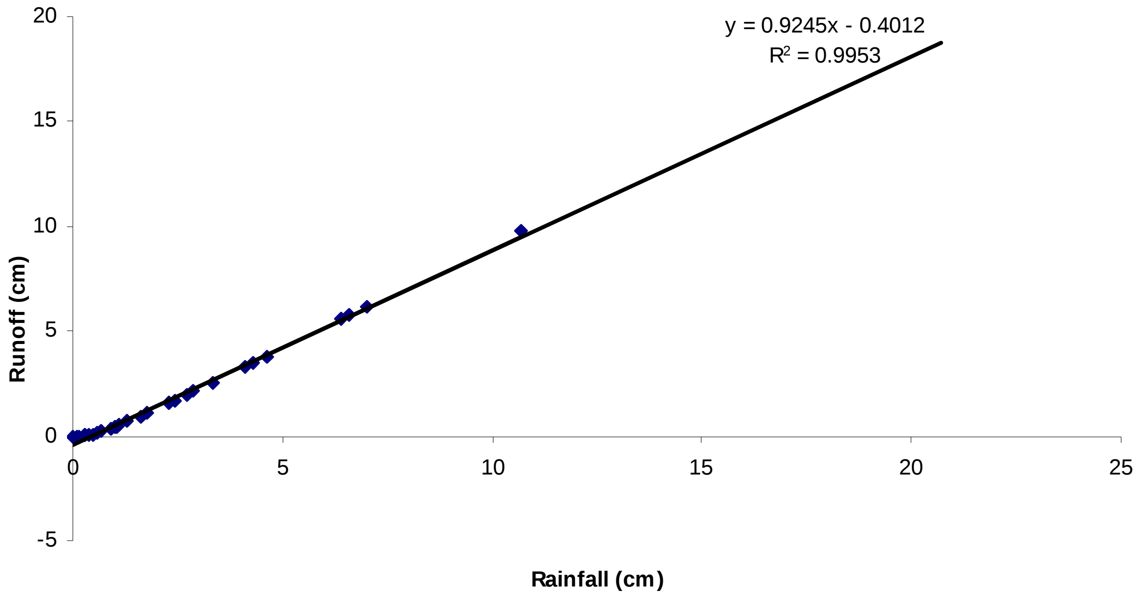


Fig 9. Runoff- Rainfall correlation for July 2005

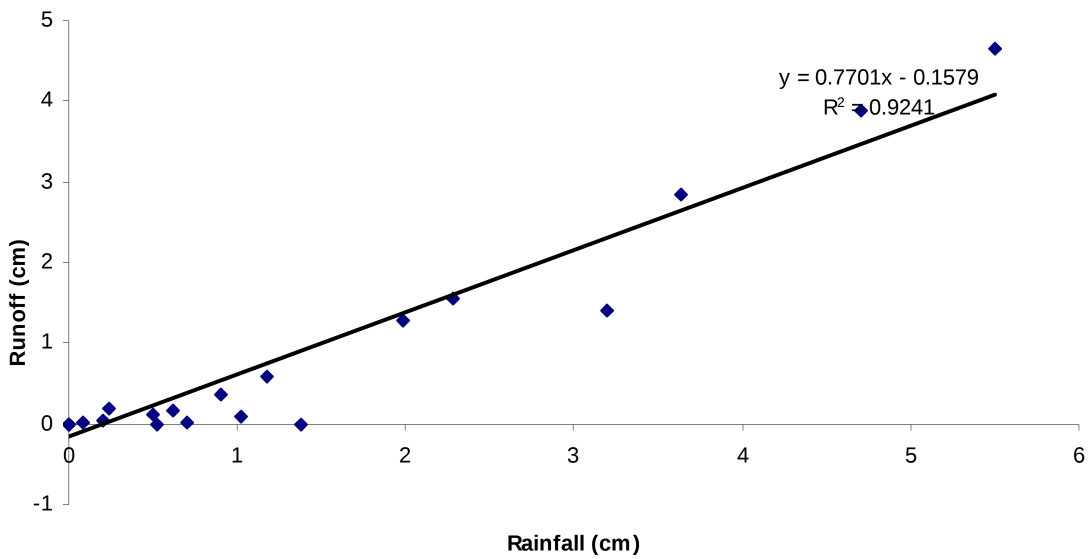


Fig 10. Runoff – Rainfall correlation for August 2005

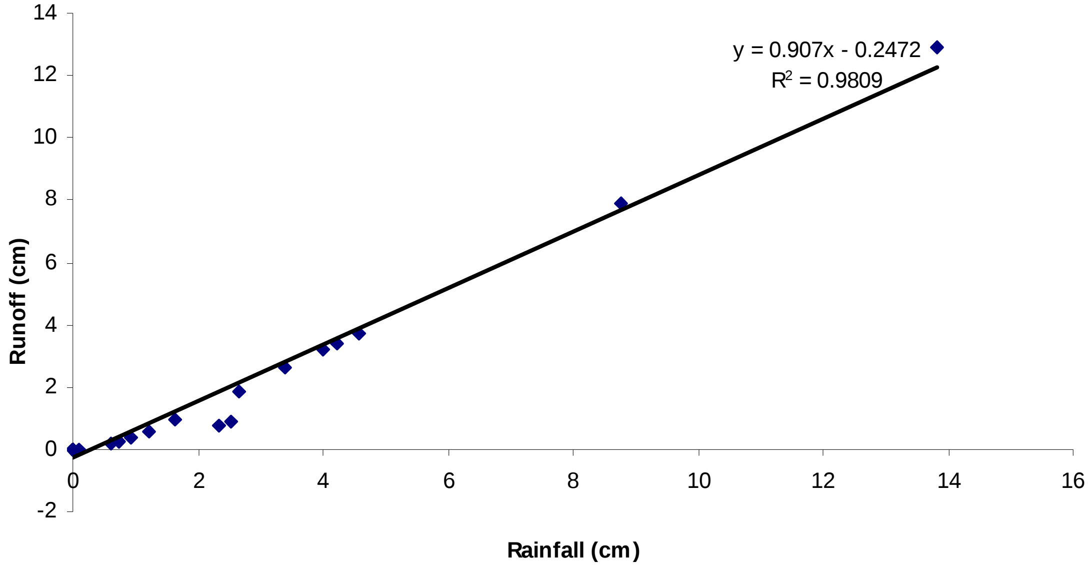


Fig 11. Runoff – Rainfall correlation for September 2005

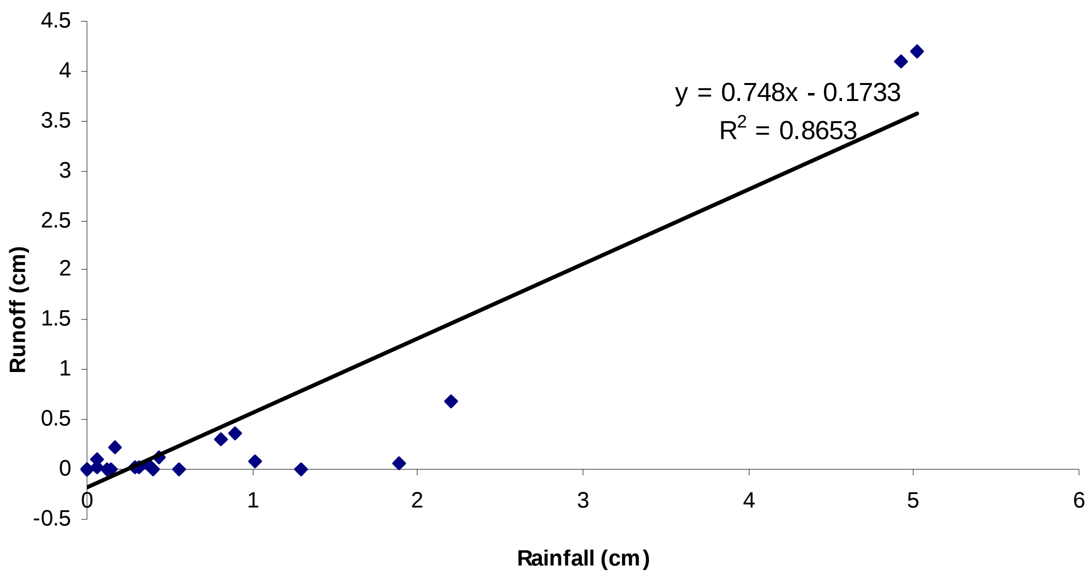


Fig 12. Runoff – Rainfall correlation for October 2005

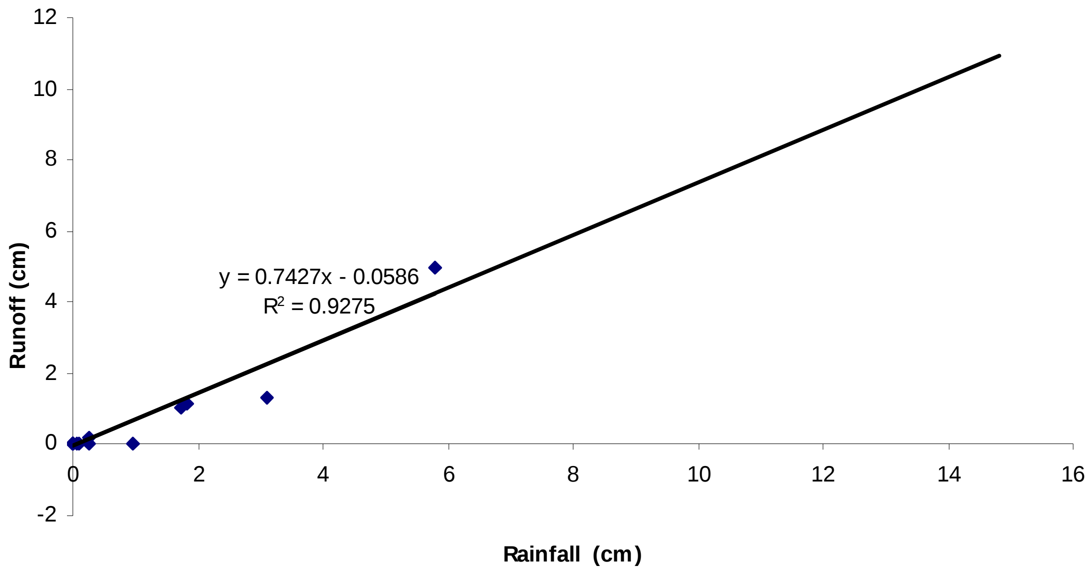


Fig 8. Runoff – Rainfall correlation for November 2005

4.8.3 Runoff volume

The runoff depth of 11.2 cm occurs from an area of 46900 m^2. Hence the total volume of runoff corresponding to a rainfall with five year recurrence interval is obtained as 5252.8 m^3.

4.8.4 Pit dimensions and spacing

Pit dimensions of 3m x 0.4m x 0.3m was chosen in the design of staggered trenches, the width and depth being 0.4m and 0.3m respectively. This permits the easy operation of a laterite quarrying machine in excavating the soil to make the pit. The pit to pit spacing was selected as 3m.

4.8.5 Design of Bund

The length of the bund was selected as equal to the length of the trench, ie., 3m. Then the cross sectional area of the bund is $0.12m^2$. The height of bund was selected as 0.3 m so as to provide sufficient root zone depth for the grass species growing on it. Then a top width of 0.3m and bottom width of 0.5m was provided.

4.8.6 Number of pits and spacing of rows

The number of pits and spacing of rows depends on the design runoff. Design runoff is a fixed percentage of the runoff corresponding to the rainfall with a recurrence interval of five years. The number of pits and row spacing required to harvest different percentages of the peak volume are shown in table 23

Table 23.Number of pits and spacing to harvest different percentages of peak runoff volume

P(%)	D(cm)	V (m^3)	N	A (m^2)	L(m)	R(m)
100	11.25	5252.8	14592	3.2	1	0.5
90	10	4728	13132	3.6	1.2	0.6
80	9	4203	11673	4	1.3	0.65
70	7.8	3677	10214	4.6	1.5	0.75
60	6.6	3152	8755	5.4	1.8	0.9
50	5.6	2627	7296	6.4	2.2	1.1
40	4.5	2102	5837	8	2.7	1.35

30	3.2	1756	4378	11	3.6	1.8
20	2.25	1051	2919	16	5.4	2.7
10	1.125	526	1460	32	11	5.5

It was observed that by providing a pit volume of 0.36 m^3 and spacing between alternate rows as 11m runoff less than or equal to 1.125 cm in magnitude will be fully harvested.

4.9 Water conservation efficiency

From the analysis of runoff data for the year 2005 it was observed that 38 values of daily runoff depths were above 1.125 cm yielding a total depth of 144.28 cm. Out of this 42.75 (38 x 1.125) would be harvested in the pits. The remaining 101.53 cm will be lost as overflow from the pits. All other daily runoff depths will be harvested in the pits. Thus

Total depth of runoff harvested = 196.3 – 101.53

= 94.77

Thus Water conservation efficiency $\eta_w = \frac{94.77}{196.3} = 48.2\ \%$

This value of water conservation efficiency is obtained without considering the infiltration from the pit. Thus it is the minimum water conservation efficiency obtained with the design. Also the efficiency varies with the pattern of rainfall.

4.10 Positioning of the trenches

The geographic co-ordinates of known points obtained using GPS e-Trex are shown in table 23. The map of the area with contours and grid points imported in to ILWIS 3.3 is shown in figure 13. The geographic co-ordinates of different points of each contour line obtained after geo-referencing the map is given in table 24.

Table 24. Latitudes and Longitudes to locate each contour line

Contour Elevation	Points	Latitude (degree)	Longitude(degree)
102			
	1	10.86	76.031
	2	10.857	76.031
	3	10.85	76.031
101			
	1	10.861	76.03
	2	10.857	76.031
	3	10.855	76.031
100			
	1	10.861	76.03
	2	10.858	76.03
	3	10.855	76.031
	4	10.855	76.031
	5	10.856	76.03
99			
	1	10.86	76.03
	2	10.858	76.03
	3	10.857	76.03
	4	10.854	76.03
	5	10.854	76.031
	6	10.855	76.031
	7	10.854	76.031
98			
	1	10.86	76.03
	2	10.858	76.03
	3	10.857	76.03
	4	10.853	76.03
97			
	1	10.86	76.03
	2	10.858	76.03
	3	10.858	76.03
	4	10.857	76.03
	5	10.854	76.03
96			
	1	10.86	76.03
	2	10.859	76.03
	3	10.859	76.03
	4	10.861	76.03
	5	10.862	76.029
	6	10.857	76.03
	7	10.856	76.029
	8	10.852	76.03
95			
	1	10.863	76.029
	2	10.862	76.029
	3	10.861	76.029
	4	10.855	76.029
	5	10.864	76.029
	6	10.863	76.029
	7	10.861	76.028
	8	10.855	76.029
94.5			
	1	10.864	76.029

	2	10.863	76.029
	3	10.864	76.028
	4	10.861	76.028
	5	10.859	76.029
	6	10.856	76.029
	7	10.855	76.028
	8	10.852	76.028
	9	10.849	76.029
	10	10.849	76.029
	11	10.85	76.029
	12	10.851	76.029
	13	10.852	76.029
94			
	1	10.865	76.029
	2	10.865	76.028
	3	10.861	76.028
	4	10.856	76.029
	5	10.855	76.028
	6	10.852	76.028
	7	10.85	76.028
	8	10.85	76.028
	9	10.848	76.028
93			
	1	10.865	76.029
	2	10.866	76.028
	3	10.862	76.028
	4	10.858	76.028
	5	10.857	76.028
	6	10.853	76.028
	7	10.85	76.028
	8	10.848	76.028
	9	10.847	76.028
92.5			
	1	10.865	76.029
	2	10.866	76.028
	3	10.863	76.028
	4	10.858	76.028
	5	10.855	76.028
	6	10.852	76.027
	7	10.85	76.027
	8	10.847	76.028
	9	10.846	76.028
92			
	1	10.865	76.029
	2	10.866	76.028
	3	10.86	76.028
	4	10.859	76.028
	5	10.856	76.027
	6	10.854	76.027
	7	10.85	76.027
	8	10.847	76.027
	9	10.846	76.028
	10	10.867	76.028
	11	10.865	76.028
91.5			
	1	10.867	76.028

	2	10.866	76.028
	3	10.861	76.028
	4	10.856	76.027
	5	10.855	76.027
	6	10.85	76.027
	7	10.846	76.027
91			
	1	10.868	76.028
	2	10.866	76.028
	3	10.863	76.028
	4	10.857	76.027
	5	10.849	76.027
	6	10.847	76.027

4.11 Suggestions

4.11.1 Machinery for excavation

Tiller with a rotary blade that are usually used in the laterite quarries for cutting the stones may be successfully used to make the trenches. The blade used for the purpose is having a radius of 25 cm and hence may be used to cut depths up to 20 cm. For the quarrying purpose a 12 hp tiller can work a volume of 9 m^3 in a day. More volume can be handled for the purpose of excavating trenches as the former involves cutting very small stones and shaping it. Two labourers are required for operating the tiller. Assuming that 15 m^3 of earth work can be done in a day the cost of operation can be worked out as follows;

Rent for the tiller	=			Rs 300 /day
Wages for the driver and cleaner	=	300 +200	=	Rs 500/day
Additional labour requirement for sizing the pit			=	Rs 150
Total cost per day			=	Rs 950
Volume of earthwork			=	525.5 m^3
No: of days of operation		= 525.5/15	=	35 days

Total cost = 35 x 950 = Rs 33250

4.11.2 Suitable vegetation

For rejuvenating the land, suitable vegetation is necessary to establish vegetation. For this suitable species are to be planted in between the trenches, along the sides and on the bunds. Since the area is of hard laterite with rocky nature, plants like pineapple, cacti ,cashew, mango etc may be planted in between the trenches. Planting on the bunds may be done with *Themeda cymbaria*(Potha grasss) , Brachiaria ruziziensis(congosignal grass) etc.

SUMMARY AND CONCLUSION

Chelloor, a hilly area in Kuttippuram gramapanchayat, is characterised by the presence of laterite soil which is in a stage of transformation to hard laterite rock. This has caused the formation of an impermeable layer on the surface of the soil and hence resulted in a very low infiltration rate of the soil . This affects the contribution of rainwater to the ground water. It was observed that the ground water potential of the area was very meagre and is insufficient to meet the demands of water in the locality. Hence the study was oriented to design proper water conservation measures so as to tap the runoff water and recharge it to the ground so as to enhance the ground water potential.

The relevant features of the study are as follows;

- The hill top of Chelloor has 4.69 ha of uncoverd ground catchment with an annual average rainfall depth of 2.82 m. The contour map of the area was prepared.
- The infiltration rate of the undisturbed soil surface is very low of the order 0.3 cm/hr. This makes the runoff coefficient as high as 0.9.But the infiltration rate of soil in the subsurface layers were found to be higher(4.8 cm/hr).
- Hence it was understood that, by making provisions for the runoff to contact the lower layers of soil and providing ample time to effect infiltration, the recharge could be enhanced. Contour trenches could serve the purpose and enable maximum water harvesting. Since it is a

high rainfall area staggered trenches were adopted as the runoff harvesting technique.

- Design procedure was done based on the rainfall with a recurrence interval of five years and runoff corresponding to it.
- Runoff for the year 2005 was calculated on a daily basis and rainfall – runoff correlation was made for each month. The maximum runoff for a rainfall with return period of five years was obtained in the month of July and design was done corresponding to it.
- Standard values of 3m x 0.4m x 0.3m were selected for the trench and spacing of the trenches required to harvest different percentages of peak runoff volume were found out. An optimum spacing which gives enough water conservation efficiency and at the same time does not affect the hydrologic cycle seriously was selected.
- Positioning of the trench sites is made easier by transferring the contours to the ground using GPS and GIS

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APPENDIX I

Antecedent moisture condition	**5 days total antecedent rainfall**	
	Dormant season	**Growing season**
I	Less than1.25	Less than 3.5
II	1.25 to 2.75	3.5 to 5.25
III	over 2.75	over 5.25

APPENDIX II

CURVE NUMBER FOR AMC II	**Conversion factor** **AMC I**	**AMC II**
10	0.4	2.22
20	0.45	1.85
30	0.5	1.67
40	0.55	1.5
50	0.62	1.4
60	0.67	1.3
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1	1

APPENDIX III

Land use cover	**treatment practices**	**Hydrologic condition**	**Hydrological soil group**			
			A	**B**	**C**	**D**
Fallow row crops	straight row	-	77	86	91	94
	straight row	poor	72	81	88	91
	straight row	good	67	78	85	89
	contoured	poor	70	79	84	88
	contoured	good	65	75	82	86
	contoured	poor	66	74	80	82
	and terraced	good	62	71	78	81
small grain	contoured	poor	65	76	84	88
	and terraced	good	63	75	83	87
	straight row	poor	63	74	82	85
	straight row	good	61	73	81	84
	contoured	poor	61	72	79	82
	contoured	good	59	70	78	81
closed seeded legumes or rotation meadow	contoured and terraced	poor	66	77	85	89
	contoured	good	58	72	81	85
	and terraced	poor	64	75	83	85
	straight row	good	55	69	79	83
		poor	63	73	80	83
	straight row	good	51	67	76	80

Land use cover	treatment practices	Hydrologic condition	Hydrological soil group			
			A	B	C	D
	contoured	poor	68	79	86	89
pastured or	contoured	fair	49	69	79	84
range	contoured	good	39	61	74	80
	and	poor	47	67	81	88
	terraced	fair	25	59	75	83
	contoured	good	6	35	70	79
	and terraced					
Meadow		good	30	58	71	78
(permanent)		poor	45	66	77	83
woodlands(f	contoured	fair	36	60	73	79
arm wood	contoured					
lots)	contoured	good	25	55	70	77

APPENDIX IV

Condition of region	I_a
Black soil AMC II & III	0.15
Black soil region AMC I	0.35
All other region	0.3

APPENDIX V

WELL No.	Name of the owner
W1	Pulikkaparambil Saidalikkuty
W2	Pulikkaparambil Abdulla
W3	Pulikkapparambil Saidalavi
W4	Shahid Kuttipuram
W5	Shahid Kuttippuram
W6	Balakrishnan Nair
W7	P V Ainudeen
W8	P V Ainudeen
W9	A Khader
W10	A Kunjan

DESIGN OF STAGGERED TRENCHES FOR A HARD LATERITE TERRAIN AND ITS POSITIONING USING GEOGRAPHIC COORDINAT

By

NIMITHA. B

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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

in

Agricultural Engineering

Faculty of Agricultural Engineering

Kerala Agricultural University

Department of

Land and Water Resources Conservation Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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ABSTRACT

Rain water harvesting is the technology used for collecting and storing of rainwater from land surface, rock catchment and roof using simple or complex technique. Contour and staggered trenches are cheapest methods of runoff harvesting and ground water recharge. They also help in retaining moisture on and near the ground surface thereby enabling establishment of vegetation . Thus it helps in improving the wastelands into productive ones.

The present study was conducted in Chelloor region of Kuttippuram gramapanchayat during the period of January 2005 to January 2006. the main objectives of the study were to conduct field topographic survey, calculation of runoff, design of staggered trenches and its positioning using geographic co-ordinates.

The procedure followed, involved the calculation of the runoff potential of the area for the year 2005, measurement of infiltration capacity of the soil on the surface and after a little excavation, design of staggered trenches so as to harvest a fixed percentage of the runoff, and positioning of thr trenches using geographic co-ordinates.

The results of the study revealed that the hill top of Chelloor is having a catchment area of 4.69 ha with high runoff potential. The infiltration capacity of lower layers of soil was found to be higher than the undisturbed soil surface. Staggered trenches 3m x 40cmx 30 cm spaced 3m between trenches and 5.5m between rows can harvest almost 50 % of the runoff

occurring from the area (water conservation efficiency of 48.2 % is obtained based on runoff data for the year 2005).

The positioning of the trenches can be much easily done than other conventional methods using GIS and GPS.

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