TEMPORAL GROUNDWATER FLUCTUATION ANALYSIS OF K.C.A.E.T CAMPUS

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KERALA, INDIA

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PROJECT REPORT

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Department of Irrigation and drainage engineering
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2009

DECLARATION

We hereby declare that this project report entitled "**Temporal Groundwater Fluctuation Analysis of K.C.A.E.T Campus"** is a *bonafide* record of project work done by us during the course of academic programme in the Kerala Agricultural University and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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(2005-02-07)

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(2005-02-09)

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(2005-02-37)

Dated: 21-12-2009

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CERTIFICATE

Certified that this project report entitled **"Temporal Groundwater Fluctuation Analysis of K.C.A.E.T Campus"** is a bonafide record of project work jointly done by Lakshmi, P. D, *(Admn. No. 2005-02-07)*, Nishna Sathyan, K.M. ***(Admn. No 2005-02-29),*** Rajeesh, M. *(Admn. No 2005-02-09),* Sabnaram.K.S. *(Admn. No 2005-02-37)* and Vineeth, V.R. *(Admn. No 2005-02-13),* under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, associateship, or other similar title of any other University or Society to them.

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Lakshmi.P.D **Nishna Sathyan.K.M** **Rajeesh .M**

Sabnaram.K.S. **Vineeth.V.R**

Dedicated

To

The Wellbeing Of

Our

Mother Earth

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Chapter 1
INTRODUCTION

1.1 Background

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions.

Groundwater crisis is not the result of natural factors; it has been caused by human actions. During the past two decades, the water level in several parts of the country has been falling rapidly due to an increase in extraction. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately increased. India's rapidly rising population and changing lifestyles has also increased the domestic need for water. The water requirement for the industry also shows an overall increase.

When groundwater gets depleted day by day it becomes imperative to take proper action for its protection. For identifying those protective measures studies should have to be conducted on groundwater. Warnings of a groundwater crisis (with falling groundwater tables and polluted aquifers) have led to calls for urgent management responses. There is a need to evaluate the hard evidence of there being such a crisis and to identify the types of management responses that actually work.

Quantification of components of water resources of an area will enable the development of appropriate guidelines for holistic decisions on efficient utilization of the water resources in that area. It will pinpoint the water resources potential both spatially and temporarily in the area as a whole. The quantum of water which contributes to the groundwater storage through gravity flow and the amount of water available for consumption could be estimated. Such quantification and temporal delineation will enable rational utilization of water resources for different purposes, for example irrigation and campus water supply.

1.2 The Study Area - K.C.A.E.T

The simulation models facilitate the replication of any physical system. A simulation model in its simplest form is to be developed to study the interaction of components of water resources in a representative area of about 100 acre in K.C.A.E.T. Campus. The area is quite unique in the sense that there is significant elevation difference within short distance which may give the scope for the exploration of the existence of a three-tiered system of groundwater tables. The first one of these three tiered groundwater system may be a perched water table. The second one may be a groundwater table which is either replenished or depleted by the river Bharathapuza lying at a lower elevation than representative area. There is a good chance for the existence of a third groundwater table with considerable depth which may run parallel to the river flow and expected to get even influenced by the tidal water fluctuations of the Ponnani coast.

1.3 Questions to be answered

KCAET the study area and it’s near by locality found to be a place which receive good rainfall, located near by Bharathapuza river is facing an acute water shortage within few days after the offset of monsoon. It’s an area where depletion of groundwater became a major concern of the public. Where does the water received during the period of monsoon gone? Why can’t river Bharathapuza stand as a solution for water crisis? Did the soil of the area lost its water retention capacity? Whether the undulating topography of the area made a negative impact on groundwater? These questions are tried to be answered throughout the study.

The study on groundwater table fluctuation revealed the behaviour of groundwater during and after monsoon. The cause of the alarming deterioration of groundwater became the major concern of the study. The groundwater of the area gets influenced by different factors such as rainfall, aquifers, river Bharathapuza, paddy cultivation, pumping etc. All these factors found to have a major role on groundwater fluctuation. But the studies revealed an unnoticed factor which later found to be the real cause behind the groundwater crisis of the area and it was sand mining.

1.4 Objectives of the study

- Analysis of temporal change in the Groundwater level in and around K.C.A.E.T.
- Preparation of depth to water table contour map of K.C.A.E.T. campus

Chapter II

REVIEW OF LITERATURE

The groundwater reservoirs gets water as a result of recharge from rainfall, rivers, streams, irrigation etc. and loses water due to regeneration in streams, movement towards other aquifers and man-made withdrawals. A study of groundwater balance is essential in order to evaluate the total groundwater resources of a basin.

2.1 What is Groundwater?

Groundwater is water held within the interconnected openings of saturated rock beneath the land's surface. The constant movement of this water is often called "the hydrologic cycle".

The cycle consists of three basic types of activity: inflows, outflows, and storage. An inflow is an increase in water to a part of the hydrologic cycle, while an outflow is a removal of water. The term "storage" refers to retention of water by a particular part of the system. If inflows to an aquifer exceed outflows, then the amount of water stored in the aquifer will increase, while if outflows exceed inflows the amount of water held by the aquifer will decrease.

There are six major components to this cycle: Evapo-transpiration, condensation, precipitation, infiltration, percolation, and runoff. Evapo-transpiration refers to the combined effect of evaporation and transpiration. Evaporation is the process by which water is returned to the atmosphere; water on various surfaces (such as ponds, rivers, and oceans) is heated by the sun until it vaporizes and rises into the atmosphere.

Transpiration refers to the return of moisture to the air by plant life; plants draw in water through their roots and then shed some of this water through the pores in their leaves. Water on the surface of plant leaves then goes through the process of evaporation. As this moisture collects in the atmosphere, clouds form. Eventually, the moisture falls as some form of precipitation (rain, snow, sleet, or hail). The form, amount, and intensity of this precipitation vary by season and geographic location, and these variables determine whether or not water will flow into streams or infiltrate into the ground.

Water that infiltrates into the ground seeps into soil and is the sole source of water to sustain vegetation growth. Infiltration also plays a role in maintaining the groundwater supply to wells, springs and streams. Physical characteristics of the soil, soil cover, water content of the soil, soil temperature and rainfall intensity all influence the rate of infiltration. The movement of water through soil and rock is referred to as "percolation"; the terms "infiltration" and "percolation" are frequently used interchangeably. The term "runoff" refers to the movement of water (typically from precipitation) across the earth's surface to streams, lakes, oceans, and depressions in the surface; rainfall duration and intensity, slope of the ground, soil type, and ground cover may all influence the rate of such runoff.

The cycle demonstrates that when rain falls, some water flows along the land surface to streams or lakes (runoff), some evaporates into the atmosphere, some is used by plants (evapotranspiration), and some seeps into the ground (infiltration). As water begins to seep into the ground, it enters what is referred to as the unsaturated zone. This zone contains both water and air.

The upper part of the zone, called the root or soil zone, supports plant growth and contains living roots, holes left by decayed roots, as well as animal and worm burrows. Beneath the root zone lays the intermediate zone, followed by the saturated capillary fringe. The saturated capillary fringe results from the attraction between water and rocks. This attraction causes water to cling as a film on the surface of rock particles. Water passes through the unsaturated zone to the saturated zone, where all the interconnected openings between rock particles are filled with water. It is within this saturated zone that we find "groundwater".

Availability of groundwater in hard rock areas is limited unlike in alluvial terrain. Therefore, estimation and development of groundwater resource of a river basin has to be planned scientifically for a better management. Though groundwater is a replenishable resource, if the exploitation exceeds the limit of dynamic recharge, it may cause many irreversible damages. Hence, the primary task of any groundwater investigation project is a proper assessment of the dynamic recharge of groundwater resources of the river basin.

2.2 Estimation of Groundwater Resource

Many methods were suggested for the assessment of groundwater resources. The basic concept behind these procedures is the estimation of the input and the output components of a river basin.

Input into the groundwater system of the basin is mostly through rainfall and to a lesser extent by seepage and recycling of surface water applied for irrigation.

Output components are the losses through evapo-transpiration, extraction of groundwater through wells for various purposes and water which flows out of the basin through the main stream as surface run off.

2.2.1 Computation of Recharge

After making a review of the various aspects of groundwater systems and considering the data collected by the Central Groundwater Board, various State Government Agencies, Research Organizations, Universities and the report of the Groundwater over Exploitation Committee, the NABARD - Groundwater Estimation Committee (1984) has recommended the following two methods —

(A) Water table fluctuation approach.

(B) Ad hoc norms of rainfall-recharge method for the estimation of groundwater resources.

It has also suggested to categories an area based on the percentage utilization of groundwater as white (up to 65 per cent); grey (65-85 per cent) and dark (more than 85 per cent) for a better management of this resource. The committee insists that the estimate has to be based on water level fluctuation method. However, in areas where monitoring of groundwater level has not been done regularly or where adequate data about groundwater level fluctuation is not available, ad hoc norms of rainfall-recharge could be utilized. It has stressed that in cases where the estimated recharge variation is more than 20 per cent between methods A and B, then ad hoc norms have to be preferred for the recharge estimation.

2.2.2 Water table Fluctuation Approach

The different steps involved in the computation of groundwater resource are as follows:

(I) Monsoon recharge (ha m) = [(Aquifer area x specific yield x water table fluctuation)

+ Gross Khariff draft from well irrigation.

- (monsoon canal seepage - monsoon recharge from surface

Water irrigation + monsoon recharge from groundwater Irrigation)]

X (normal monsoon rainfall/average monsoon rainfall) $_t$

+ Monsoon canal seepage + Monsoon recharge from surface water irrigation.

Where aquifer area corresponds to areal extent of the aquifer (ha) in the basin Specific yield may be taken from the pumping or recovery test data of the wells (Committee has recommended a value of 2-4 per cent for granites and gneisses).Water table fluctuation is the difference of water levels between the pre monsoons and postmen soon water levels recorded in the observation wells of the area. The water table fluctuation corresponds to the rainfall of the year of observation. Therefore, it is corrected to the long term normal rainfall of the area.

(II) Non-monsoon rainfall recharge: This is computed as a product of aquifer area, normal non-monsoon rainfall of the area and the infiltration factor. Infiltration factor has to be determined from field measurements. However, the committee recommends 5-15 per cent of normal rainfall as the infiltration factor for hard rock areas with granitic/gneissic terrain. Depending upon the field conditions the factor has to be selected.

(III) Recharge from surface sources: (a) Recharge from Canals: This is calculated by considering total length of the canal, average wetted perimeter, average number of water flow days and seepage factor. For unlined canals in normal type or soils with some clay content along with sand, seepage factor of 15-20 ha m/day/106sq.m. Of wetted area of canal may be assumed. For lined canals, the seepage losses are taken as 20 per cent of the unlined canals.(b) Return seepage from irrigated fields : (i) irrigation by surface water sources : This is computed by taking the area under different crops by surface water sources, average water depth required for different crops and seepage factor. Seepage factor of 40 per cent of water delivered at the outlet for application In the field for paddy and 35 per cent of water delivered at the outlet for other crops has to be taken, (ii) irrigation by groundwater sources : 30 per cent of the water applied for- crops from wells during monsoon period has to be considered as seepage to groundwater body during the monsoon period.

In the above two cases return seepage figures include losses in field channels also and need not be considered separately.

(IV) Seepage from tanks: Studies in other parts of the country has indicated that tank seepage varies from 9-20 per cent of its live storage capacity. However, as data on live storage capacity on large number of tanks may not be available, a seepage factor of AO - 60 cm/year over the total water spread has been recommended. Seepage from percolation tanks is 50 per cent of its gross storage and this component should be distributed for utilization purposes under its command area only.

An average seepage factor of 52 cm/year has been taken for computations in the present study area.

Total gross annual recharge is calculated by taking all the above factors. However, net annual recharge available for development is taken as 85 per cent of the gross recharge. The remaining 15 per cent is accounted for domestic supply and non-recoverable recharge.

2.2.3 Recharge from ad hoc norms:

In this method rainfall recharge is calculated by taking aquifer area, annual normal rainfall and rainfall-infiltration factor. Recharge from canals, surface water irrigation and seepage from tanks are to be separately computed and added. Net annual recharge is considered as 85 per cent of the gross annual recharge.

2.2.4 Annual Draft from Wells

Annual draft from wells is computed by taking total number of wells in on area which are in use and unit draft per year. Unit draft is calculated based on the amount of water pumped from each well and the total number of pumping days in a year.

In the study area, the unit draft is found to be 1 ha m per energized dug well; 1.5 ha m per bore well and 0.50 ha m per dug well with traditional type of lifting devices. Net draft is taken as 70 per cent of the annual gross draft. Groundwater is held in aquifers.

An aquifer is a rock unit that will yield water in usable quantities to wells or springs; it is typically unconsolidated deposits, sandstone, limestone, or granite. An aquifer can be visualized as a large underground sponge that contains water and, under certain conditions, will allow water to pass through it. An aquifer may contain both the saturated and unsaturated zones, and only the saturated zone. The process by which aquifers are replenished with surface water is known as "recharge".

Recharge can occur either naturally or artificially. Infiltration of rainfall into the ground, and percolation of this rainfall to underlying aquifers is a natural form of recharge, occurring as part of the hydrologic cycle that was discussed earlier. The rate of recharge is determined by several factors, including the soil's physical characteristics, plant cover, and slope of the ground and the water content of ground surface materials.

Surface waters can also recharge aquifers; this type of recharge typically occurs in dry areas, as lakes and creeks fill up with water during periods of heavy rainfall. Water may seep up from the sides of these surface water bodies and percolate. Finally, recharge may be artificially induced by pumping or injecting water into wells; the water then recharges the aquifer directly. Artificial recharge is also accomplished by spreading water onto the earth's surface, where the water can then percolate into the groundwater.

2.3 Soil properties affecting groundwater recharge:

2.3.1 Laterite soil

Laterite is an iron-rich product of long, intense tropical weathering. It forms in certain subsurface horizons where all but most resistant materials are weathered away. Quartz, sand and kaolinite clay remain and iron accumulates as dark red mottles. Lateral and lateritic soils occur in tropical climates. They are the best known soils of the tropics, though extensive areas of red-yellow pedzolics and even some black soils also occur there.

Some of the lateritic soils contain as much as 80 percent oxide clays in their mineral matter. These soils generally have very deep profiles. The climate is humid or warm all or much of the year. The native vegetation is tropical forest. These soils are poor in NPK and organic matter. The value of pH ranges from 4.5 to 6.0.

In Kerala Angadipuram, ferruginous, vesicular, soft material occur within the soil, which hardens irreversibly on exposure and used as a building material, was first recognized as ‘laterite’ by Francis Buchanan, a medical officer in the service of the East India Company. He (1807)suggested the name laterite, from ‘laterl, the Latin word for brick.

Harrassowitz(1930) presented a morphological definition for laterite, as one with a characteristic profile developing under tropical savannah and forming the following for levels or horizons in ascending order from subsurface to surface: (a) a fresh zone (b) a zone of primery alternation to kaolinite (c) a laterite bed (d) a surface zone with ferruginous incrustations and concretions.

2.4 Aquifer property

Two properties of an aquifer related to its storage function are its porosity and specific yield. Porosity is the ratio of the volume of voids or pores in a soil mass to its total volume. The volume of water, expressed as a percentage of the total volume of the saturated aquifer, that can be drained by gravity is called the specific yield and the volume of water retained by molecular and surface tention forces against the force of gravity, expressed as a percentage of the total volume of the saturated aquifer, is called specific retention and corresponds to field capacity.

Porosity = Specific yield + specific retention

Specific yield depends on grain size, shape and distribution of pores and compaction of the formation. The value of specific yield for alluvial aquifer are in the range of 10 to 20 percentage and for uniform sands about 30 percent.

To evaluate the subsurface hydrologoic consequences of any groundwater recharge technique, response of the subsurface flow system to induce recharge must be quantified. Quantification requires both tools and parameters which represent the aquifer’s hydrolic properties. Knowledge of the hydrolic properties enables the hydrogeologist to calculate the subsurface storage.

Neuman presented a comparative discussion of several methods for the determination of specific yield. The specific yield values are consistent with water balance considerations when all the components of the water budget are properly taken into account. The rate at which the groundwater level fluctuates in response to pump age is controlled by the smaller specific yield that obtained from the time-drawdown analysis.

Nautiyal (1991) carried out systematic studies for the determination of specific yield and hydrolic conductivity and monitoring of water table fluctuations for the assessment of groundwater resources of shallow aquifers of upper Ganga basin, Uttar Pradesh. Specific yield was determined by three methods namely, column drainage method, method based on grain sizes of aquifer material and pump testing method. Pump testing method is the most common field method for the determination of specific yield and transmissivity. Pump testing method requires pumping at a constant discharge from the well and recording its effect (drawdown) at different time intervals in an observation well situated at a distance. In the column drainage method for the determination of specific yield, the volume of water drained at different time interval from the aquifer sample was noted until the free drainage was negligible. The ratio of volume of water drained to the volume of saturated aquifer column in percentage gave the specific yield. The hydrolic conductivity was measured with a variable head parameter. The hydrolic conductivity values show a larger variation and most of the values are in the range of 1 to 6 m per day.

2.5 Infiltration

Infiltration is defined as the entry of water from the air side of the air soil interface into the soil profile. The rate of movement water into the soil will depend on the magnitude of the forces and gradient and also on the factors determining the hydraulic conductivity of the soil. The aspects of infiltration which which are being considered important in hydrology are cumulative and infiltration capacity. Cumulative infiltration is the total quantity of water that enters the in a given time and infiltration capacity is the maximum rate at which water can be if absorbed by the soil in a given condition.

The physical properties and depth of the soil have probably the most important controls on subsurface flow production at a site. If the texture is coarse vertical flow usually dominates; and when this soil deep, surface flow response may be delayed. If the texture is fine resistance to vertical flow results and lateral or shallow surface flow sometimes occurs quickly.

Marino (1974) studied the water table fluctuation in response to recharge. Solutions have been derived which describe the rise and fall of the water table in an extensive unconfined aquifer receiving uniform localized recharge and discharging into a surface reservoir in which water level remains equal to that of the main flow before the incidence of recharge. The solutions are expressed in terms of the head averaged over the depth of saturation and are applicable when the rise of water table is smaller than 50% of the initial depth of saturation. When prediction of future water level is desired the equation should be used in conjunction with the method of successive approximations.

Rai *et al.* (1988) derived an approximate solution of the non linear Boussinesq equation which describes the water table variations in a dith-drainage system with a random initial condition and transient recharge. The numerical results reveal that the water table variation is significantly influenced by the random initial condition and the transient rate of recharge. The amplitude of variation is maximum at the ground water divide.

Lai *et al*. (1991) compared the water table fluctuation predicted by different models. The model described in this work have been used to simulate the water table behaviour in response to subsurface drainage for climatological and soil prevailing at sample in Haryana. A field experiment on subsurface drainage was conducted to control the water table and salinity in the water logged saline soils at sample. The experiment consists of three tile drain spacing of 25m, 50m and 75m. The average depth of tile line below ground surface was 1.75m. Two models for predicting water table namely, de Zeeuw- Hellinga and Van Schilfgaarde were selected to their field applicability by comparing the observed water table heights with the predicted water table for the period July to Septemper 1985 for 75m drain spacing Van schilfgaarde model was found to be more satisfactory for its application in the field condition.

Zomorodi (1991) derived a new method for the elevation of the response of a simple numerical model. The model has several advantages over the traditional methods of mounting prediction. The effect of the unsaturated zone which modifies the recharge rate as compared with the infiltration rate is considered. Mounting is calculated for variable recharge rate induced by a variable infiltration rate. Also, the effect of in-transit water in reducing the tillable pore space above a rising water table is considered

The validity of the model results is illustrated using several sets of field data collected from the Ghazvin Plain, Iran. Sample calculations proved that the model predicts mounting more accurately than the traditional methods and therefore, more realistic recommendations for the design and operation of artifitial schemes are possible using this model.

2.6 Groundwater recharge

Groundwater recharge is that amount of surface which reaches the permanent water table either by direct contact in the riparian zone or by downward percolation through the overlying zone of aeration. The methods for the estimation of recharge are generally based on the following parameters: intensity and duration of rainfall, evaporation, soil moisture, runoff, infiltration capacities of soils, and storage characteristics of aquifers, water level fluctuations and movement of groundwater. The various recharge components to be estimated and the methods employed are discussed below.

2.6.1 Soil moisture balance

Infiltration occurring at the land surface can be estimated by the soil moisture balance approach. The soil moisture balance for any time interval can be expressed as

$P = AE + I + R + \Delta Sm$

Where

P= rainfall

AE= actual evapotranspiration

ΔSm= charge in soil moisture storage

I=infiltration, and

R= surface runoff

Soil moisture budgeting taking into account evaporation abstraction from precipitation, provides a measure of moisture available for runoff and infiltration. This can be done by Thomthwaite’s book keeping determine the available moisture down to the root zone. Monthly PET and rainfall are tabulated and compared. If rainfall P in a month is less than PET, then AE=P, the period being one of water deficit. If P is more than PET, then ae=pet, the balance of rainfall raising the moisture level of the soil to field capacity. After meeting the soil moisture deficit, the excess of rainfall over PET becomes the moisture surplus, also called water surplus. The runoff can be determined by gauging at the basin outlet, or estimated from the rainfall-runoff curves. The difference between the moisture surplus and runoff is the groundwater recharge.

The application of this method for the estimation of groundwater recharge requires information on runoff. However, in respect of arid and some semi-arid regions with no marked drainage courses, runoff can be ignored and entire water surplus can be treated as groundwater recharge.

Following as evaporation loss is negligible.

P=R+Wp

Where

P=rainfall

R= surface runoff,

Wp= recharge by infiltration from rainfall

For periods recording rainfall in excess of infiltration capacity, recharge can be estimated by superimposition of the rainfall-intensity curve over the infiltration-capacity curve. For this purpose, the rainfall should be recorded by self recording rain gauges. Rainfall in excess of infiltration capacity represents surface runoff while the rest contributes to recharge provided the moisture changes in the soil can be ignored.

The infiltration method can used to estimate recharge from ephemeral streams canals and flooded areas if the extent of wetted area and duration of wetting are known. However, recharge is limited to the available pressure level . the method is very approximate as soil moisture changes are not takern into account. Besides, rainfall of varying intensity results in a distortion of the capacity curve and recharge values.

2.6.2 Estimation from base flow

Base flow from a basin is an indirect measure of recharge as it represents the drainage of groundwater from aquifer storage after groundwater recharge has occurred.

A major advantage of using base flow separation of stream hydrographs for recharge calculation is that the method does not require broad assumptions. A major disadvantage of this technique is that each worker uses his own arbitrary method of separating base flow from total stream discharge and hence comparisons cannot always be made between works of different authors. Moreover , stream gauges are seldom located at the positions desired.

2.6.3 Flow net analysis

A flow net has to be prepared using data from the wells. The data included peizometry of these locations, as well as all available transmissivity data from aquifer system. The annual average groundwater discharge can be calculated which will be approximately aquivalent to annual recharge and the storage changes becomes insignificant with time. This method requires knowledge of the geometry of the system and aquifer properties, which may vary spatially. Caution is needed in translating water table rises into recharge, since factors such as air entrapment, changes in atmospheric pressure and hydrological influence from surrounding areas may give rise to misleading conclusions.

2.6.4 Groundwater level fluctuation method

The groundwater table and its fluctuations are functions of groundwater recharge, water yielding properties, transmissivity and geometry of aquifer. The groundwater recharge, during the time period at , can be written as

$GWR=h\times Sy\times A+Q\times At$

Where

GWR=groundwater recharge

Sy= change in groundwater level

A= area, and

Q = net groundwater flow

Here, the recessions derived from observations of decreasing groundwater levels when no recharge is supposed to occur is used. The shape of the recession curve depends on water yielding properties, transmissivity and geometry. If the groundwater table is shallow, the recessions may de influenced by evapotranspiration and frost penetration. To get the unaffected recession curve, caused only by groundwater flow, periods must be found when these processes are insignificant. The distance between the actual groundwater level and the groundwater level calculated from the recession curve, for every time interval can be summed up and multiplied by the specific yield to get the recharge. The method is attracted since groundwater level observations often are available. The method could also give information of temporal and aerial variations.

2.7 Estimation of ground water recharge

Khan (1980) estimated the groundwater recharge in a basin from the water balance study. Rainfall, stream flow evaporation, subsurface water soil moisture and groundwater storage are calculated on monthly basis to be used in the balance equation. The computation was performed by providing monthly hydrological input for the desired period. The average groundwater recharge to the basin was found as output by averaging the former values.

Sharma (1986) made a study on the measurement and prediction of natural groundwater recharge and gave a brief overview of recharge process, merits and the limitations of estimation methods. Recharge rates are spatially variable on a relatively small scale and approximate methods are required to assess the response of aquifers at varying scales. For many systems, existence of preferred pathways of water flow has been identified.

Khan et al (1989) developed an information system for implementing groundwater recharge models were developed to estimate groundwater recharge by using weather data, soil properties and other land characteristics as inputs this data, at best, are scattered and difficult to obtain a real inputs required by even the simplest groundwater recharge model.

Thorpe (1989) determined a method in which tritium as a tool is used for assessing total and net groundwater recharge to the Gnangara groundwater mound, Perth, Western Australia. Total recharge r5ates were to be estimated by using the seasonal variation in tritium concentrations as indicators of rates of soil moisture movements through the unsaturated zone. However, at all sites tritium concentrations at shallow depths were significantly higher than those measured in the previous season’s rainfall, consequently total recharge rates could not be estimated. Net recharge rates were determined by measurement of tritium-depth profile in the saturated zone from piezometer clusters and a multilevel piezometer.

Reddy (1991) utilized the water balance model for the estimation of the groundwater recharge in a basin. The study was conducted at Dulapally basin which covers 34sq.km area in the granitic terrain near Hyderabad city. Recharge to the groundwater regime mostly takes place through vertical infiltration from the ground surface. In the water balance model, various components of water balance viz., surface runoff, actual soil evaporation, actual transpiration from vegetation; soil moisture status and ground water recharge have been computed, following a daily moisture procedure. Groundwater recharge was estimated using the balance among various components.

Yong and Chun (1993) did a comparative study of calculation method of rainfall seepage to groundwater in plain area. Ground water in the plain area of China is recharged with rainfall and to a lesser extends with surface water and nearby groundwater. There are several methods for the calculation of recharge of rainfall seepage to groundwater. The calculated values using different methods vary due to the accuracy of parameters and calculation methods chosen.

The comparive study is made using the water balabce method and groundwater regime analysis method applied to the plain area of China. The accuracy of groundwater regime analysis method is superior to that of the water balance method.

2.8 Water balance – Basic considerations

Quantification of groundwater and surface water resources of any basin(or area) involves the application of the principal pf conservation of mass, sometimes reffered to as the continuity equation, to account for the quantitative changes occurring in the various components of the hydrologic cycle as applicable to the basin. The quantitative changes may be expressed as a water balance equation, in which the inflow, outflow and changes in storage in a period represented by individual components.

Obviously, this is grounded in the premise that a balance excists between the amounts of water which enters an area, changes in the amount of water in storage in the area and the water which leaves the area. Clearly the items in the equation can included a number of factors of which the most significant may be listed

$I=O+\Delta S$

Where

I = inflow

O = outflow

ΔS = charge in storage

The factor subsurface outflow can be eliminated in cases where outflow is measured at a point where impermeable strata direct all outflow to the surface. Storage can be neglected if the balance is determined for any time period during which no significant change in this is belived to occur. In view of this, it is possible to utilize a simplified version of the equation of hydrogic equilibrium in appropriate situation and this may be given water balance for a given should be worked out for a long period so that various items approach a steady state due to averaging out of climatic effects.

2.9 Groundwater balance studies

A groundwater inventory of an area quantities the various means of recharge to or discharge from the groundwater reservoir as well as changes in storage therein. It may be stated as follows:

$\Delta Sg = (Rp+Rn+Ra+Gi)-(Et+De+Da+Go+Ge)$

where

ΔSg = change in ground water storage during the period in question

Rp = recharge due to precipitation

Rn = natural recharge from stream and lakes i.e. influent seepage

Ra = artificial recharge from canals, reservoirs, irrigation return flow, treading and injection wells

Gi = groundwater inflow from area outside the basin

Et = evapo-transpiration from capillary fringe in shallow water table areas and from vegetation

De = natural discharge by seepage and streem flow

Da = artificial discharge due to pumping and consuptive use

Go = leakage from a bottom semi confined layer, and

Ge = ground water outflow to areas outside the basin

General groundwater equation as given by Tolman (1937) is

$R = E+S+I$

Where

R = Rainfall

E =Evaporation and transpiration loss

S =water discharge from the area,and

I =ground water increment

Dhir (1980) studied the hydrological balance and the influence of utilization of groundwater upon it. He related the role of groundwater in the hydrological cycle with independent variables representing the precipitation, PET, soil and plant characteristics and water table elevation. Uncertainty was introduced into the equation through the probability function of climatic variables and the probability distribution of water yields and the water balance elements. The mean values of runoff, ET and groundwater recharge have a long term average water balance which to the first order defines annual water yield and water loss in terms of the annual precipitation, PET and physical parameters of the soil, vegetation, climatic and water table.

Pinol *et al.* (1991) did the hydrological balance of two Mediterranean forested catchments located in Prades in Northern Spain. Precipitation and discharge have been measured for several years in these catchments. Actual evapotranspiration has been calculated as the difference between annual precipitation and discharge.

Langholt (1992) has steadied the water balance of a 600sq.m field site on a laetritic hill slope in Kerala in India, during two south west monsoon seasons. Surface runoff was of minor importance while infiltration and evapotranspiration were the major components amounting to approximately 2/3 and 1/3 of the rainfall, respectively. Groundwater response was rapid, involving fluctuations of several meters. Groundwater found normally to takes place during the southwest monsoon season only. The field study demonstrated that seasonal shallow groundwater recharge representing a major portion of the rainfall may be observed in this lateritic terrain.

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Chapter 3

MATERIALS AND METHODS

To achieve the objectives, various geographical and climatological features of the study area were analysed. The study consist of following steps enlisted below and it was carried out either by using specially designed and developed techniques or with the help of most suitable exisisting techniques.

Various steps involved in the study:

1. Measurement of depth to Water Table
2. Land Survey
3. Measurement of rainfall
4. Estimation of evapotranspiration
5. Measurement of infiltration

3.1 Study Area

K.C.A.E.T and its nearby locality selected for the study. K.C.A.E.T in Malappuram district of Kerala situated at 10° 55' 30 " North Latitude and 76° east Longitude. The total tropical area in the region is about 40ha. Bharathapuzha River forms the northern boundary of the study area .The total campus area is 40.99 ha. In this, total cropped area is 29.65 ha.

3.2 Climate

Study area has humid, tropical climate with temperature averaging 20-32˚c throughout the year. It receives both south-west monsoon and North –east monsoon. The mean annual precipitation varies between 300- 400cm. Humidity of the area ranges from 70-85%.

3.3 Topography

Study area had an undulating topography. Topographical map of the study site is shown in fig 3.1. The contours have been drawn between at 2m interval with reduced level of bench mark arbitrarily chosen as 31m. The locations of selected wells are shown in the map.

3.4 Water Resources

At different parts of study area there were number groundwater recourses such as ponds, open wells, filter point well and shallow tube wells. Because of the undulating topography the wells were located at different slopes, thus giving a wide scope for exploring the behaviour of groundwater and its flow pattern at these varying slopes. 23 wells (refer Table.3.1) were selected for collecting the water table data. The water table contour along the northern side of the study site is assumed to be parallel to the river.

Table. 3. 1 Description of wells observed in and around K.C.A.E.T.

Well description	Well No.	Remarks	Pumping Status
Kelappaji's Well	W 1	Clear water, not in use (E.coli)	NP
Well near Farm Shed	W2	Turbid water, not in use	NP
Well near Coconut Storage	W3	Turbid water, less storage, not in use	NP
Well in Areca nut plot near boundary	W4	Turbid water, not in use	NP
Well in Areca nut plot close to boundary	W5	Turbid water, not in use	NP
Well in Areca nut plot near boundary	W6	Clear water , not in use	NP
Newly Constructed Farm Well	W7	Clear water, more storage	Pumping
Well near Windmill	W8	Turbid water, high storage	NP
Pump House Well	W9	Clear water; high storage	Pumping
Peizometric Well 1	W10	Clear water; high storage	NP
Peizometric Well 2	W11	Clear water; high storage	NP

Peizometric Well 3	W12	Clear water; high storage	NP
Well near Papaya Field	W13	Turbid water; not in use	NP
Well between Temple and Papaya Field	W14	Turbid water; not in use	NP
Old Farm Well	W15	Clear water; high storage	NP
Private Well	W16	Clear water; high storage	Pumping
Panchayath Well 1 near School Ground	W17	Clear water; high storage	NP
School Well	W18	Clear water; high storage	Pumping
Well near Doctor’s Quarters	W19	Clear water; high storage	Pumping
Well back of Main Hospital Quarters	W20	Clear water; high storage	Pumping
Well behind Tea Shop	W21	Clear water; high storage	NP
Panchayath Well 2 near KSEB Substation	W22	Clear water; high storage	Pumping
Panchayath Well 3 near areca nut plot	W23	Clear water; high storage	Pumping

3.5 Methodology & Estimation of parameter

Various parameters such as depth to water table, rainfall, evapotranspiration, infiltration, elevation of the study area should be estimated for the study. The materials and method adopted for the study are discussed below.

3.5.1 Measurement of rainfall

Rainfall data recorded daily for analyzing the water input through precipitation. Rainfall contributed a major portion of groundwater. Study area received distinct south-west monsoon and North –east monsoon. Rainfall data recorded from the campus observatory.

3.5.2 Estimation of evapotranspiration

Estimation of evapotranspiration is an essential step of any groundwater study. While the evaporation takes place, the land area in which plant stand also loose moisture by the evaporation of water from the soil and water bodies. For a given set of atmosphere condition, evapotranspiration depends on availability of water. Measurement of evapotranspiration carried out either by using lysimeter or by the use of field plots. Large numbers of equations are available for calculation of evapotranspiration. Penman’s equation is one of the most important equations used in estimation of evapotranspiration.

3.5.3 Measurement of infiltration

The infiltration characteristics of the study site were analyses using the double ring infiltrometer. The cylinders are made of 2mm rolled steel. The inner cylinder from which the infiltration measurements are taken is 30cm in diameter. The outer cylinder which is used to form the buffer pond to minimize the lateral spreading of water is 60cm in diameter. These are 25cm deep is driven into the soil up to about 10 cm for measurement. This is done by using a drop weight hammer after keeping a wooden plank on the top of the cylinder, to prevent damages to the edges of the cylinder.

The water level in the inner cylinder was read with a field type point gauge. Infiltration data is obtained from a cylinder infiltrometer by measuring the depth of the ponded water in the cylinder at frequent intervals in the beginning and this data provided the initial infiltration rate. The readings were taken until a constant value was obtained. This data correspond to the basic infiltration rate of the soil of the site. The buffer pond is filled with water immediately after filling the inner cylinder. Water level in the inner cylinder and the buffer pond are kept approximately same.

Table 3. 2. Accumulated infiltration rate (cm) in Location 1

Elapsed time(t)min	Depth of water infiltration(cm)	Infiltration rate (cm/hr)	Accumulated infiltration(cm)
5	6	72	6.0
10	5	60	11.0
15	4.8	57.6	15.8
20	4.7	56.4	20.5
25	4.3	51.4	24.8
30	3.9	46.8	28.7
35	3.8	45.6	32.5
40	3.6	43.2	36.1
45	3.5	42.0	39.6
50	3.4	40.8	43.0
55	3.1	37.2	46.1
60	2.9	34.8	49.0
65	2.7	32.4	51.7
70	2.6	31.2	54.3
75	2.5	30.0	56.8
80	2.3	27.6	59.1
85	2.1	25.2	61.2
90	1.9	22.8	63.1

Table. 3.3 Accumulated infiltration rate (cm) in Location 2

Elapsed time(t)min	Depth of water infiltration(cm)	Infiltration rate (cm/hr)	Accumulated infiltration(cm)
5	7.1	85.2	7.1
10	5.8	69.6	12.9
15	5.4	64.8	18.3
20	4.9	58.8	23.2
25	4.6	55.4	27.8
30	4.2	50.4	32
35	4	48	36
40	3.7	44.4	39.7
45	3.5	42	43.2
50	3.2	38.4	46.4
55	2.9	34.8	49.3
60	2.8	33.6	52.1
65	2.6	31.2	54.7
70	2.4	28.8	57.1
75	2.2	26.4	59.3
80	1.9	22.8	61.2
85	1.7	20.4	62.9
90	1.6	19.2	64.5

Table.3.4 Average accumulated infiltration rate(cm) from location1and location2

Average Infiltration rate (cm/hr)	Average accumulated infiltration(cm)
78.6	6.55
64.8	11.95
61.1	17.05
57.6	21.85
53.4	26.3
48.6	30.35
46.8	34.25
43.8	37.9
42	41
37.6	44.7
36	47.7
34.2	50.55
31.8	53.2
30	55.7
29.4	58.05
25.2	60.15
22.8	62.05
21.0	63.80

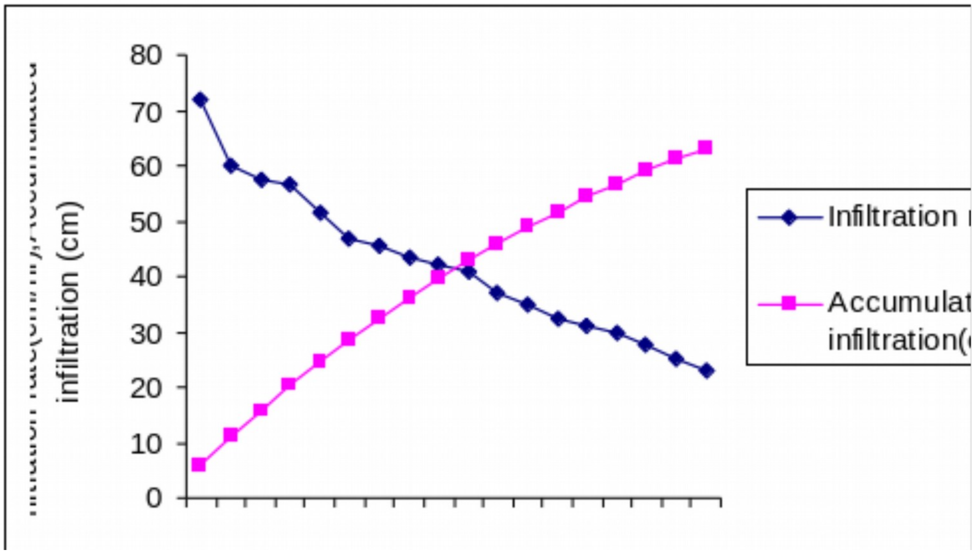

Fig 3.1 Accumulated infiltration characteristics of location I

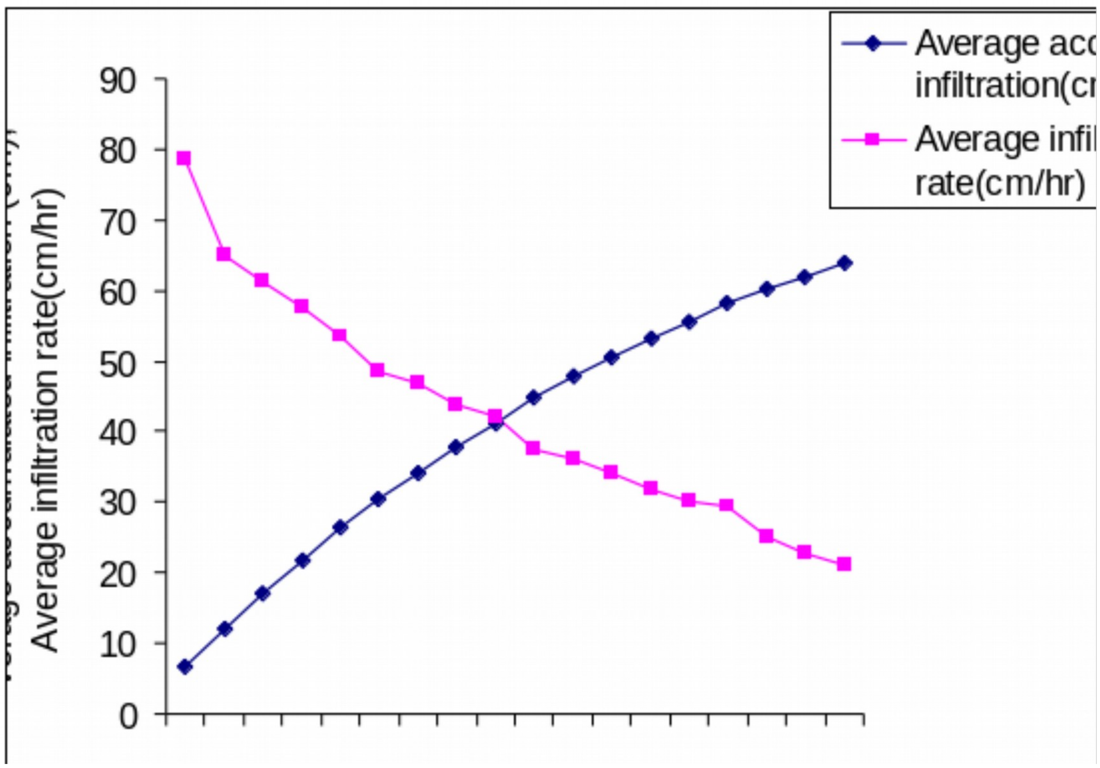

Fig .3.3 Average Accumulated Infiltration Characteristics of Study site

3.6 Measurement of depth to Water Table

For water table fluctuations recording 23 wells selected which were located at various parts of the study area. Distance of water table from ground level was recorded once in a week with the help of rope and popper arrangement.

3.6.1 Rope and popper arrangement

Rope and popper arrangement was specially designed and developed for recording groundwater fluctuation. It's an arrangement consist of 30m long rope with a conical shaped popper weighing 250gm. Popper was attached at the tip of the rope. Rope measured and marked up to 30m.

3.7 Land Survey

Survey is the art of making such measurements as will determine the relative positions of points on the surface of the earth in order that the shape and extend of any portion of earth's surface may be ascertained and delineated on a map. It is essentially a process of determining positions of points in a horizontal plane. For the study survey was conducted to identify various topographical features of the study area and to draw the contour map.

3.7.1 Traversing

Study area had an undulating topography. Surveying thus became a step in field estimation of various topographic parameters. To determine elevation of the points two instruments are required, viz. (1) a level, and (2) a levelling staff. The level furnishes horizontal line of sight, and a levelling staff is used to determine the vertical distances of the points below the horizontal line of sight. Dumpy level was used during the study. It's a simple, compact and stable level. Readings are taken and contour map is plotted.

3.7.2 Offsetting

In order to find out the distance between the wells offsetting was carried out. Lateral measurements can be taken either by perpendicular offsetting or by oblique offsetting. Perpendicular offsetting was carried out for the study. The offsets were measured with a metallic tape. Offsetting was carried out with the help of Open cross staff. Open cross staff is a simplest form of cross staff. It consists of two parts, the head and the leg. Short offsets were taken as possible to reduce the errors.

Chapter IV

RESULTS AND DISSCUSSION

When the groundwater gets depleted, the effects on the landscape and the people are drastic. The study area K.C.A.E.T and its nearby locality were found to be under the threat of an acute groundwater crisis. The study was mainly intended to identify the characteristics of groundwater and how its balance gets affected by the changes in environment. Rainfall is found to contribute a major share of the groundwater. The undulating topography of the study area had a tremendous influence on the groundwater resources. Environmental issues such as sand mining in Bharathapuza River altered the water balance of the entire area. Global issues such as climate change also found to have a major role to play in this local issue. Throughout the study period behaviour of the groundwater was precisely studied and the following results were obtained.

4.1 Rainfall Data

Rainfall is one of the major contributors of groundwater. Throughout the study period rainfall data was taken daily from a non-recording rain gauge. The average rainfall varied within the study period from May to November. Comparing the rainfall data of the study period with previous year's revealed a noticeable hike in rainfall during the study period. Details are shown in Appendix II

4.2 Evapotranspiration

The reference evapotranspiration is calculated using a computer package known as 'CROPWAT' developed by FAO. In this package, Penman Monteith method is used for calculation. The input data required are the monthly maximum and minimum temperature, air humidity, sunshine hours and wind velocity. By inputting these data, the evapotranspiration was obtained. The evapotranspiration is calculated as the product of ET and crop coefficient.

Table. 3.4 Climatological data

Month	Min.Temp (◦C)	Max.Temp (◦C)	Humidity %	Wind Km/hr	Sun hours	ETo Mm/day	Kc	ETc
June	21	30.7	85	50	2.6	2.89	.95	2.74
July	21.4	28.6	86	56	1.6	2.56	.94	2.4
August	21.9	29.4	89	55	1	2.34	.95	2.22
September	27.8	30.6	84	42	3.2	3.09	.89	2.75
October	26.5	33.3	74	47	3.8	3.30	.89	2.94
November	26.8	33.5	71	42	4	3.12	.94	3.0

4.3 Preparation of Surface Contour Map

For the preparation of Surface Contour Map, the study area was traversed by fly level method using dumpy level. Readings were taken and with the help of those readings surface contour map was plotted. The contour interval taken was 2m. The elevation and depressions of the surface of the ground are shown on the map by means of contour lines. All the groundwater resources incorporated in the study were marked on the contour map.

4.4 Preparation of Water Table Contour Map

For the preparation of water table contour map the total study area was traversed and surface contour map was plotted. Water Table Contour map in Maximum depth to water table fluctuation and Minimum depth to water table fluctuation were plotted using the software SURFER.

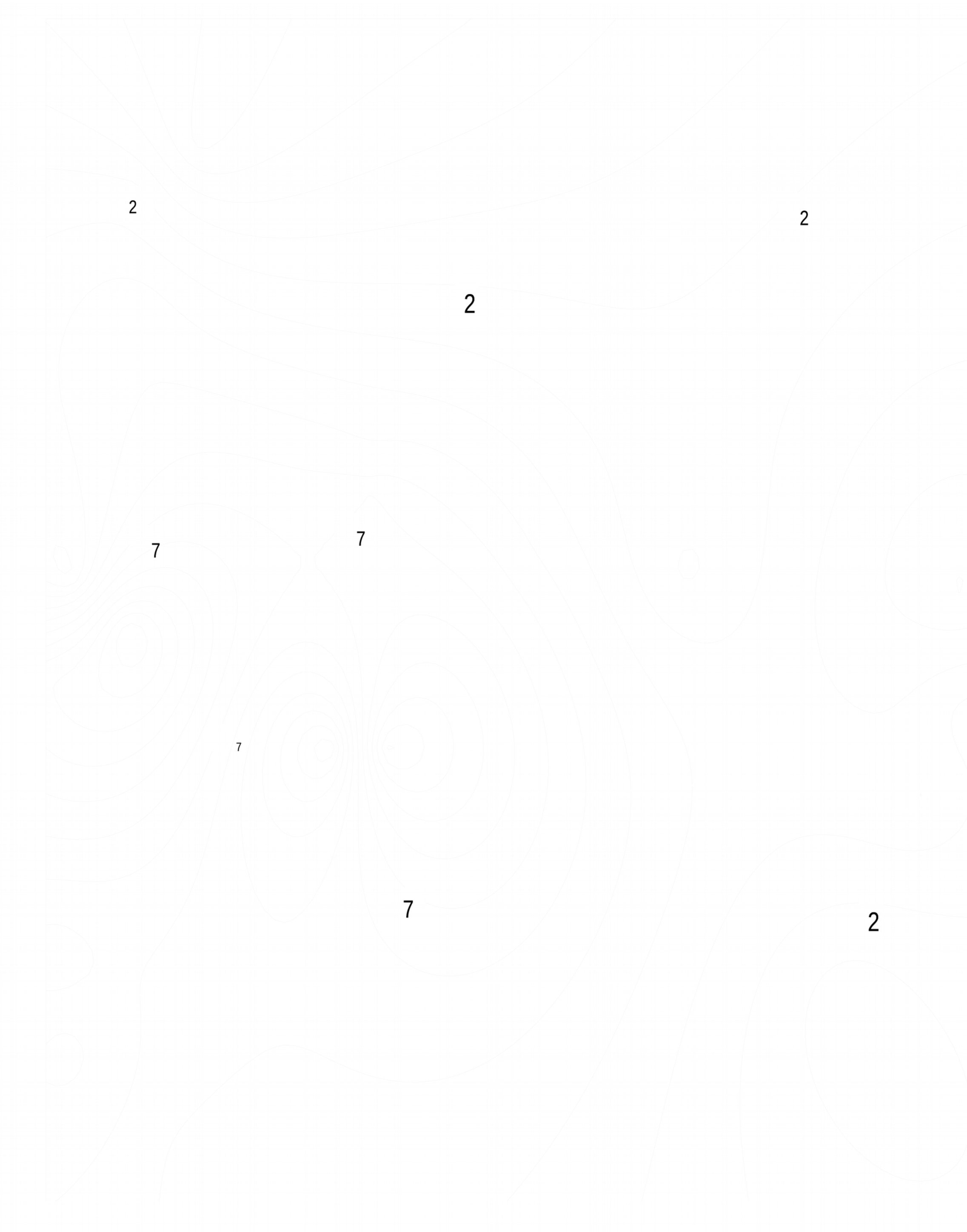

Fig. 4.1 Water table contour map in maximum depth to water table fluctuation

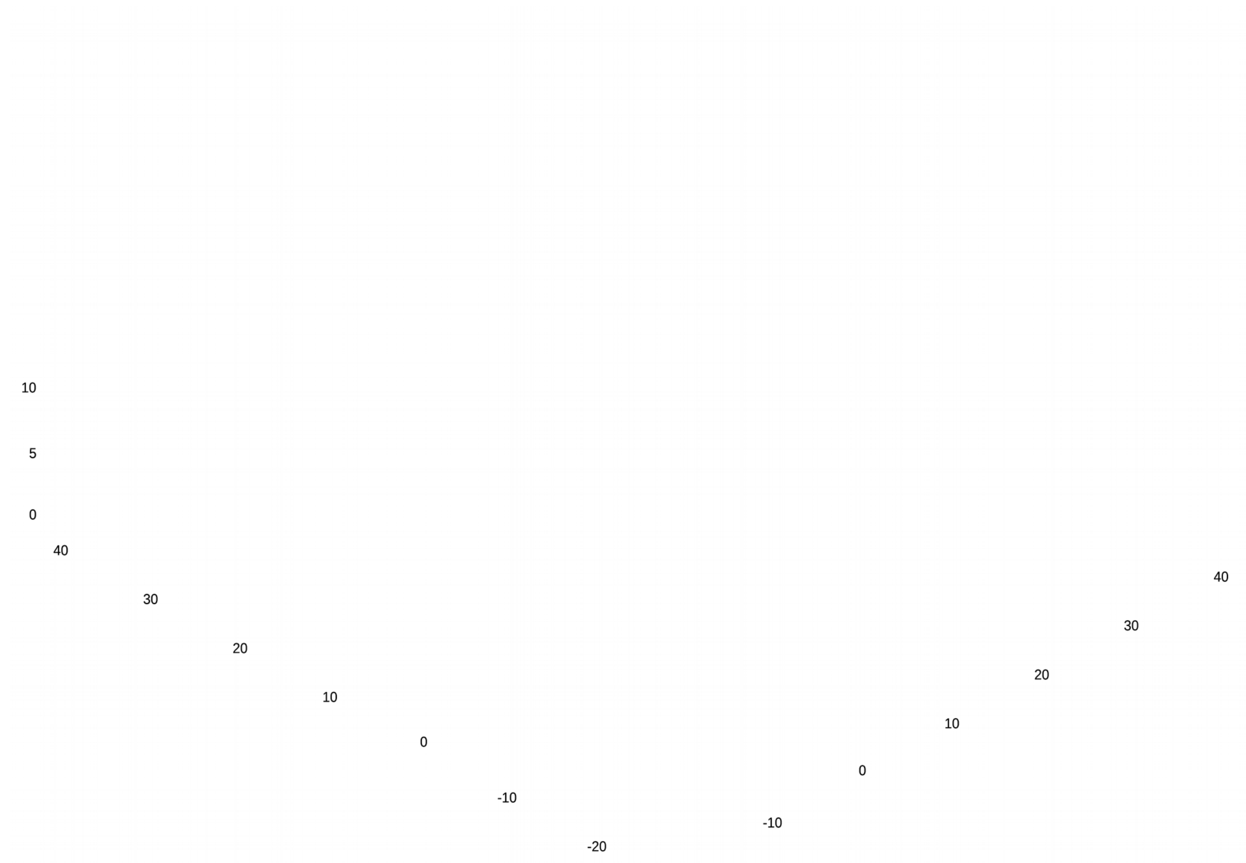

Fig. 4.2 3 D View of maximum water table fluctuation

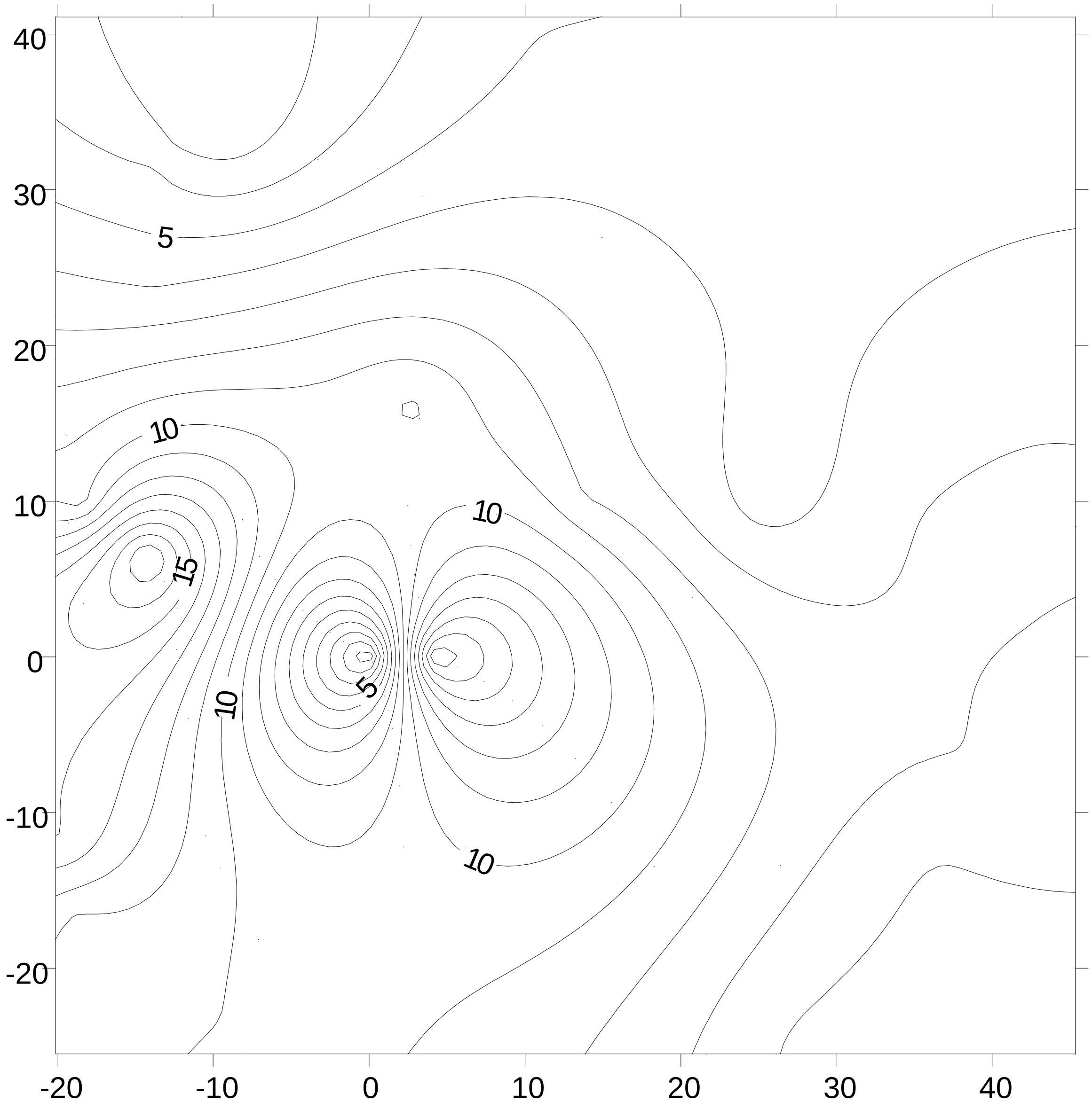

Fig. 4.3 Water table contour map of minimum depth to water table fluctuation

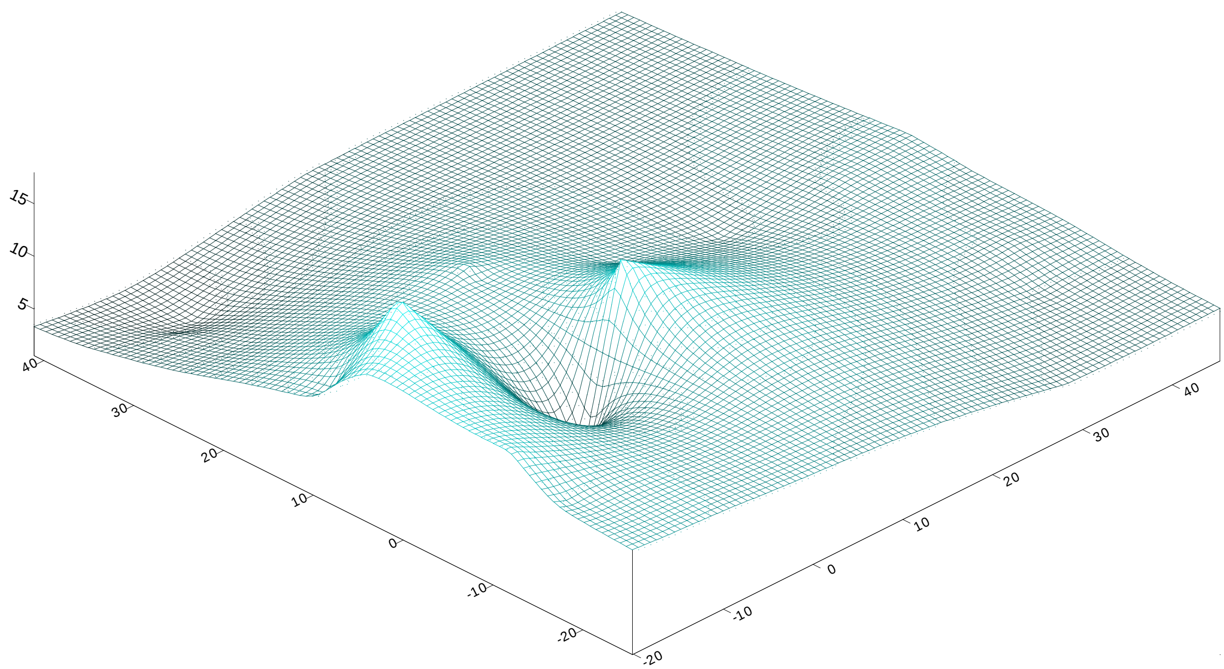

Fig. 4.4. 3 D View of minimum water table fluctuation

4.5 Climatic features

The details of the climatic features of the study area recorded from the observatory located inside the K.C.A.E.T campus. The readings were taken on daily basis. The study area had a humid tropical climate with temperature averaging 20-32° throughout the year. The mean annual precipitation varies between 300-400cm. Humidity of the area ranges from 70-85%. During the study period study area received distinct south west monsoon and north east monsoon.

4.6 Water table fluctuation

Water table fluctuation recorded weekly using rope and popper arrangement from 23 selected well. A vivid picture of groundwater behaviour was obtained from the water table fluctuation data. There was a noticeable increase in water table during rainy season and decrease during summer. The thing to be noticed was within a short period after the offset of monsoon the wells shown an alarming rate of decrease in water level.

The observed water table data from the wells in the site were analyzed and found that depth to water table showed a higher value during summer. In the period of monsoon depth to water table get reduced in such a manner that few days after monsoon water table attained a constant value. During the first week of the rainy season the lowest groundwater level for the season was established. Later in the, intensive rainfall caused rapid responses. As rain ceased the profile dried out and the water table approached the pre-monsoon level. Due to the sloppy terrine of study area at lower elevation shown lower value, and wells at higher elevation recorded a higher readings clearly indicated the behaviour of water in different terrain. The pumping wells shown entirely different characteristics compared to none pumping well. Few days after the offset of the monsoon the water in the wells declined drastically.

During study period the south west monsoon was distinct and heavy through out the study area. Still it was observed that few days after the offset of monsoon the study are faced acute ground water shortage. Water shortage didn’t prevail for a long period because of the immediate onset of north east monsoon. It revealed that groundwater's tendency to act as a base flow for near by stream.

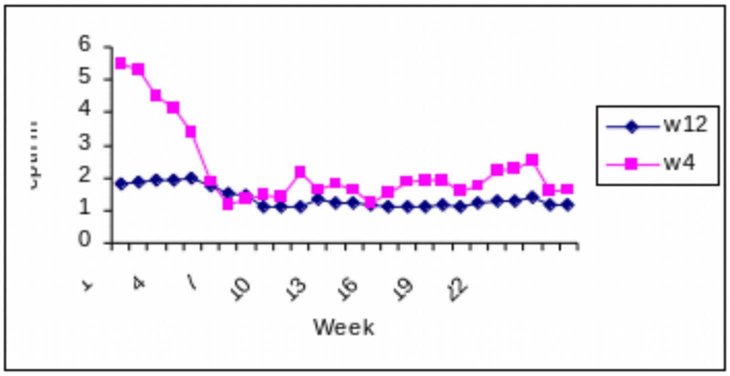

Fig .4.5 Depth to water table fluctuations in wells on 8 m contour line

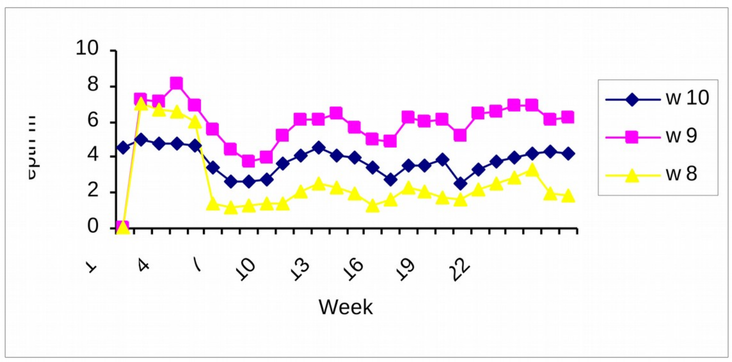

Fig. 4.6 Depth to water table fluctuations in wells on 5 m contour line

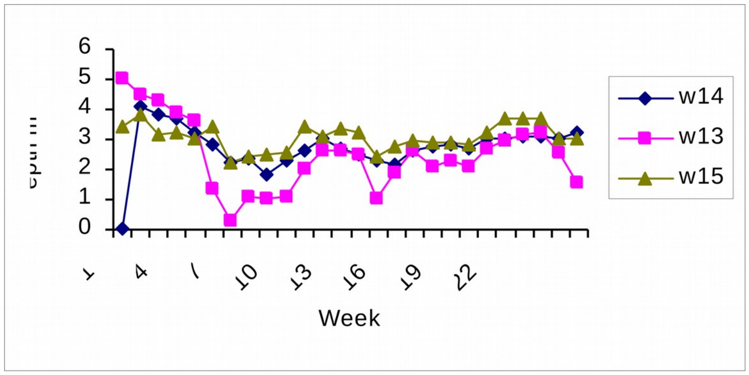

Fig.4.7 Depth to water table fluctuations in wells on 11m contour line

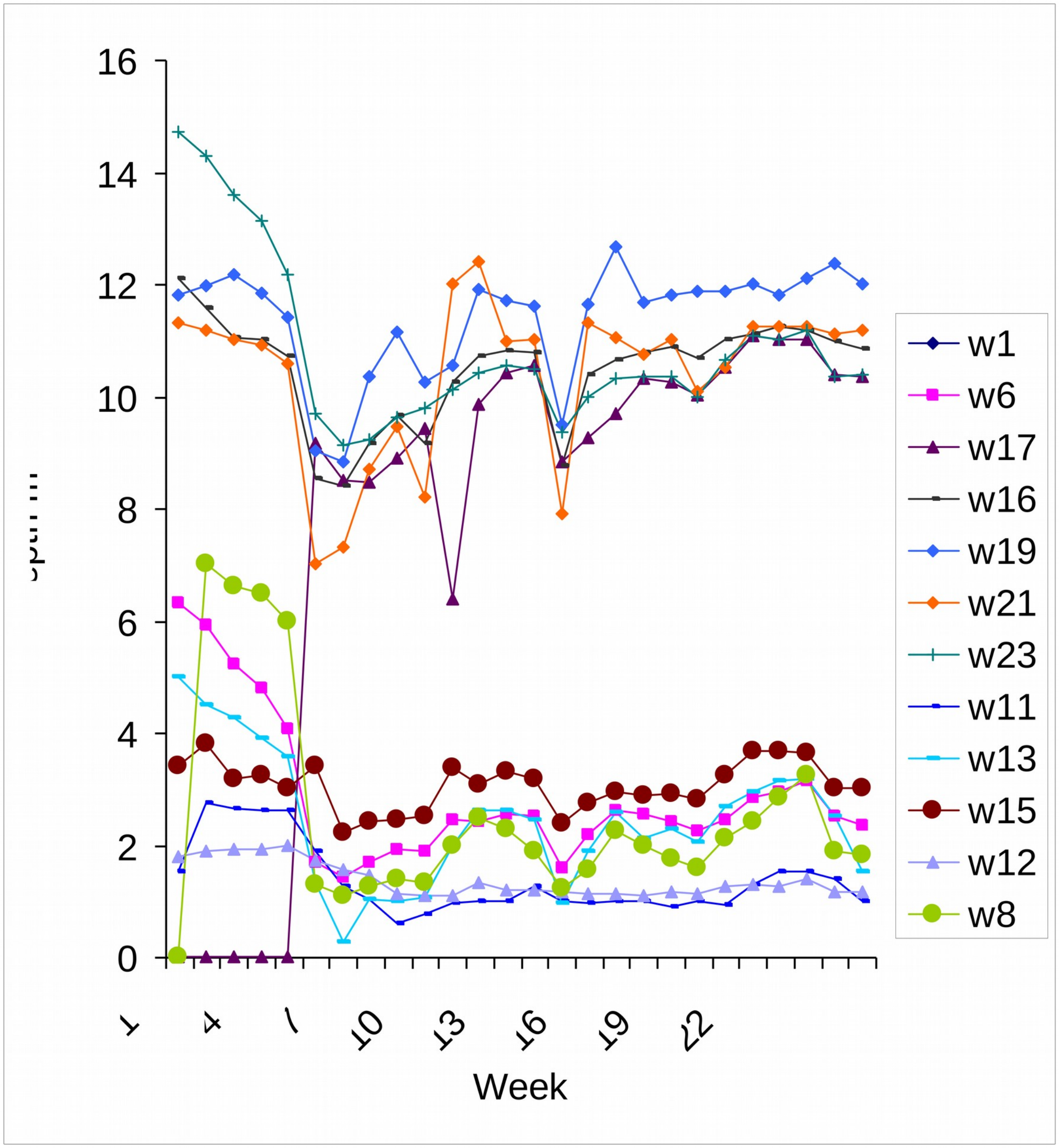

Fig. 4.8 Depth to water table fluctuations in all the observed wells

4.7 Reasons for ground water depletion

Studies revealed the noticeable hike in rainfall doesn't contribute much to groundwater. The sloppy terrine lead ground water to flow from higher elevation to lower elevation. Thus wells at higher elevation shown a drastic decline in water level.

Comparing the groundwater level observed during 1996 with that of 2009 revealed that within 13 years groundwater level declined to almost 3m. During these periods the study area received a heavy and almost well distributed rainfall. Groundwater level at 1996 and 2009 was given in appendix 1.

Studying the various factors influencing groundwater such as rainfall, topography, various climatic features and evapotranspiration concluded that the declining groundwater level was a result of sand mining carried out at river Bharathapuza. During the period of 1996 to 2009 the thing which changed drastically was the amount of sand present in Bharathapuza River. Within these 13 years approximately 46, 94,520 m^3 of sand was mined from the river Bharathapuza. It was found to be the sole reason behind the declining groundwater status.

Sand mining carried out at Bharathapuza River played a major role in the ground water level. Sand mining transforms the riverbeds into large and deep pits; as a result, the groundwater table drops leaving the drinking water wells on the embankments of these rivers dry. Bed degradation from in stream mining lowers the elevation of stream flow and the floodplain water table which in turn can eliminate water table-dependent woody vegetation in riparian areas, and decrease wetted periods in riparian wetlands. Prevention of sand mining and suggesting alternatives for sand was found to be the only solution to protect the study area from the groundwater crisis.

Chapter 5

SUMMARY AND CONCLUSION

Groundwater makes up to about twenty percent of the world's fresh water supply, which is about 0.61% of the entire world's water, including oceans and permanent ice. Global groundwater storage is roughly equal to the total amount of freshwater stored in the snow and ice pack, including the north and south poles. This makes it an important resource which can act as a natural storage that can buffer against shortages of surface, as in during times of drought.

The study area faces an acute groundwater shortage. It's a place which receives heavy rainfall and near to river Bharathapuza. The study carried out to identify the behaviour of groundwater of the concerned area. Water table fluctuations of 23 wells were recorded for 25 week. The studies showed an increase in groundwater during the monsoon and its decline during summer. Both south west and north east monsoon received during the study period. The study was carried out with following objective.

- Analysis of temporal change in the Groundwater level in and around K.C.A.E.T.
- Preparation of depth to water table contour map of K.C.A.E.T. campus

The observed water table data from the wells in the site were analyzed and found that the depth to water table showed a higher value during summer. During study period the south west monsoon was distinct and heavy through out the study area. Still it was observed that few days after the offset of monsoon the study are faced an acute groundwater shortage. Water shortage didn't prevail for a long period because of the immediate onset of north east monsoon. It revealed the groundwater's tendency act as a base flow for near by stream.

To identify topography of the area survey was carried out. With the help of readings obtained during survey the surface contour map was drawn. With the help of the software SURFER water table contour map of minimum and maximumwater table fluctuation was prepared. The surface contour map clearly depicted the undulating topography of area.

The water table fluctuation data taken during the study period of 2009 was compared with that of 1996. Comparison revealed that within a period of 13 years water table of the study area depleted to an average of 3m. During these periods area received heavy rainfall and also a normal temperature.

Analyzing various factors which affect the ground water table revealed the influence of river Bharathapuzha and the sand mining carried out. Sand layers holding considerable quantity of water in the spaces between them are disturbed; the water flow through the river gets reduced considerably. Also, the percolation of water through the river bed and its subsequent recharge into the groundwater supply declines. The riverbeds drown due to unscrupulous removal of sand. Ground water tables plummet in nearby areas, resulting in scarcity of drinking water.

The study concluded that within a few years the study area is going to face an acute groundwater crisis. Sand mining carried out at river Bharathapuza caused a fall in the groundwater levels of the study area. The absence of sand on the riverbed affects the velocity of the water flow, making it violent during monsoons.

Heavy rainfall received by the study area no longer act as a solution for water shortage. During summer groundwater contributes base flow to the River Bharathapuza. Groundwater losses its stability due to excessive sand mining carried out at Bharathapuzha.

5.1 Suggestions to meet water crisis of the study area.

- Implementation of Rain water harvesting structures throughout the campus.
- Development of alternatives for sand.
- Take necessary actions for the protection of river Bharathapuza.

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APPENDIX I

Table 6.1 Weekly water table fluctuation data 2009

WEEK	Depth to water table (meter)							
	W1	W2	W3	W4	W5	W6	W7	W8
1	19.25	4.27	Nil	5.5	nil	6.3	6	nil
2	19.18	4.34	Nil	5.28	nil	5.91	5.73	7
3	19	3.61	Nil	4.5	nil	5.22	4.59	6.62
4	19.2	3.84	Nil	4.13	4.02	4.8	4.6	6.49
5	19.17	3.37	Nil	3.37	3.3	4.08	3.65	6
6	17.68	1.87	0.7	1.89	1.37	1.67	3.18	1.3
7	15	1.72	0.64	1.15	1.24	1.43	2.8	1.1
8	14.73	2.02	0.92	1.34	1.38	1.67	3.06	1.27
9	14.61	2.32	1.08	1.44	1.43	1.92	3.37	1.39
10	15.32	2.21	1	1.4	1.43	1.9	3.12	1.33
11	15.36	3.31	1.88	2.15	2.13	2.43	4.23	2
12	15.61	3.51	1.91	1.61	1.52	2.42	4.89	2.49
13	15.5	4	1.9	1.78	1.64	2.55	6.5	2.28
14	15.78	3.62	1.67	1.65	1.6	2.5	5.18	1.9
15	15	1.81	0.72	1.24	1.28	1.58	2.87	1.23
16	15.27	2.74	1.37	1.5	1.4	2.17	3.67	1.57
17	15.55	3.3	1.9	1.85	1.68	2.6	4.2	2.25
18	15.45	3.16	1.4	1.93	2.01	2.55	3.97	1.98
19	15.74	3.21	1.89	1.92	1.88	2.4	3.96	1.74
20	15.64	2.96	1.42	1.57	1.48	2.25	4.42	1.6
21	15.72	3.66	1.86	1.77	1.82	2.45	4.62	2.12
22	15.72	4.2	2.25	2.2	2.17	2.83	7.46	2.42
23	15.94	4.4	2.3	2.29	2.21	2.95	7.17	2.84
24	15.92	4.5	2.5	2.51	2.53	3.14	7.59	3.24
25	15.72	3.45	1.71	1.59	1.55	2.5	4.28	1.9
26	15.87	3.26	1.63	1.66	1.65	2.36	4.11	1.83

Week	Depth to water table (meter)							
	W9	W10	W11	W12	W13	W14	W15	W16
1	nil	4.5	1.51	1.8	5	nil	3.4	12.1
2	7.14	4.98	2.73	1.89	4.5	4.1	3.79	11.56
3	7.05	4.72	2.65	1.93	4.25	3.81	3.16	11.05
4	8.1	4.69	2.62	1.91	3.9	3.7	3.23	11
5	6.83	4.62	2.62	2	3.58	3.18	3.02	10.71
6	5.56	3.4	1.9	1.73	1.33	2.78	3.39	8.53
7	4.33	2.58	1.24	1.54	0.25	2.22	2.2	8.41
8	3.72	2.57	1.04	1.46	1.04	2.36	2.41	9.17
9	3.9	2.65	0.58	1.13	1	1.81	2.45	9.65
10	5.13	3.6	0.76	1.1	1.05	2.25	2.51	9.15
11	6.07	4	0.97	1.1	2	2.59	3.38	10.26
12	6.11	4.46	1	1.33	2.62	3.03	3.08	10.71
13	6.37	4.09	1	1.2	2.61	2.68	3.31	10.82
14	5.6	3.91	1.24	1.2	2.45	2.49	3.19	10.78
15	5	3.33	0.98	1.17	0.97	2.3	2.38	8.75
16	4.79	2.7	0.96	1.13	1.87	2.11	2.75	10.39
17	6.16	3.5	0.98	1.13	2.58	2.6	2.93	10.63
18	6	3.44	1	1.1	2.1	2.74	2.88	10.78
19	6.1	3.8	0.9	1.15	2.27	2.8	2.9	10.88
20	5.15	2.48	1	1.12	2.05	2.7	2.8	10.69
21	6.37	3.3	0.92	1.25	2.67	3	3.23	11
22	6.5	3.72	1.28	1.29	2.93	3	3.68	11.11
23	6.89	3.96	1.52	1.27	3.13	3.05	3.66	11.24
24	6.9	4.15	1.51	1.38	3.18	3.08	3.64	11.18
25	6.06	4.24	1.4	1.15	2.52	3	3	10.97
26	6.21	4.2	1	1.16	1.53	3.22	3	10.85

Week	Depth to water table (meter)						
	W17	W18	w19	w20	w21	w22	w23
1	nil	16	11.8	15	11.3	nil	14.7
2	nil	16.8	11.98	14.33	11.17	8.7	14.27
3	nil	15.82	12.16	11.5	11	7.08	13.59
4	nil	17.93	11.82	11.48	10.92	6.84	13.13
5	nil	17.73	11.4	10.74	10.57	6.47	12.17
6	9.15	13.7	9.04	8.15	7	5.3	9.67
7	8.49	10.78	8.83	7.52	7.29	5.26	9.14
8	8.47	11.26	10.36	7.81	8.69	5.58	9.23
9	8.9	11.51	11.13	7.72	9.45	5.9	9.62
10	9.41	13.09	10.24	8.55	8.21	5.84	9.77
11	6.38	13.29	10.56	6.25	12.01	6.29	10.12
12	9.86	13.5	11.89	9.95	12.4	6.61	10.4
13	10.42	13.85	11.71	10.56	10.96	6.5	10.53
14	10.55	11.72	11.61	10.15	11.02	6.36	10.48
15	8.83	11.1	9.5	8.16	7.9	5.55	9.35
16	9.25	13.65	11.64	8.8	11.3	6.11	10
17	9.68	14.17	12.67	10.05	11.04	6.35	10.32
18	10.3	14.95	11.68	10.28	10.76	6.32	10.34
19	10.26	14.44	11.8	10.93	11	6.26	10.35
20	10.02	13.7	11.87	10	10.08	6.05	10
21	10.5	15.78	11.88	10.82	10.52	6.43	10.63
22	11.07	17.43	12	12.5	11.24	6.98	11.06
23	11	16.06	11.8	13.06	11.25	6.7	11
24	11	15.15	12.1	14.09	11.23	6.78	11.16
25	10.38	14.64	12.35	10.37	11.1	6.4	10.35
26	10.36	14.79	12	10.51	11.16	6.39	10.38

Week	Depth to water table (meter)				
	W1	W7	W6	W15	W3
1	15.3	4.89	2.43	2.15	4.29
2	14.34	3.55	1.96	1.09	3.01
3	13.92	3.05	1.40	0.65	2.91
4	13.7	2.51	1.9	0.53	3.08
5	13.54	2.1	1.68	0.45	2.57
6	13.15	1.85	1.34	0.32	2.39
7	12.42	1.42	1.03	0.27	2.09
8	12.29	0.74	0.92	0.20	1.51
9	12.21	0.92	0.8	00	1.32
10	11.99	0.7	0.7	0	0.95
11	12.75	0.41	0.55	00	1.46
12	12.93	0.65	0.9	0.08	1.89
13	12.75	0.4	1.00	0.14	2.11
14	12.48	0	1.09	0.27	2.01
15	13.21	0.43	1.20	0.36	2.05
16	13.43	0.88	13.34	0.48	2.19
17	13.54	1.29	1.51	0.61	2.23
18	13.69	1.4	1.69	0.74	2.38
19	13.74	1.59	1.78	0.81	2.47
20	13.81	1.74	1.75	0.97	2.51
21	13.9	1.88	1.93	1.06	2.56
22	14	2.03	1.79	1.17	2.68
23	2.08	2.11	1.55	1.24	2.78
24	14.11	2.24	1.73	1.31	2.87
25	14.16	2.46	1.78	1.48	2.86

Table 6.2 Weekly water table fluctuation data 1996 (Source, BeenaThomas)

APPENDIX II

Table 6.3 Daily Observed Rainfall Data

Date	**Rainfall**	Date	Rainfall
30.05.09	0	27.06.09	4.15
31.05.09	51.2	28.06.09	18.4
01.06.09	0	29.06.09	35.1
02.06.09	0.8	30.06.09	15
03.06.09	1.4	1.07.09	91.8
04.06.09	0	2.07.09	40
05.06.09	8.8	3.07.09	78
06.06.09	49.6	4.07.09	47
07.06.09	33.6	5.07.09	45
08.06.09	39.8	6.07.09	47
09.06.09	8.4	7.07.09	19.2
10.06.09	0	8.06.09	7.4
11.06.09	0	9.07.09	6.8
12.06.09	1.2	10.07.09	14.4
13.06.09	2.1	11.07.09	24.6
14.06.09	12.6	12.07.09	7.8
15.06.09	0.7	13.07.09	28.8
16.06.09	8.2	14.07.09	75.2
17.06.09	20.6	15.07.09	13
18.006.09	25	16.07.09	18.8
19.06.09	4.8	17.07.09	22.5
20.06.09	22.2	18.07.09	84.1
21.06.09	1.89	19.07.09	25.2
22.06.09	20.6	20.07.09	5.4
23.06.09	4.7	21.07.09	13
24.06.09	11.8	22.07.09	22.8
25.06.09	17	23.07.09	10.6

26.06.09	77	24.07.09	2
Date	Rinfall	Date	Rainfall
25.07.09	0.6	09.09.09	34
26.07.09	0	10.09.09	0
27.07.09	7	11.09.09	0
28.07.09	26	12.09.09	0
29.07.09	24.6	13.09.09	0
30.07.09	45.2	14.09.09	0
31.07.09	9.6	15.09.09	0
1.08.09	47.4	16.09.09	0
2.08.09	5.2	17.09.09	19.6
3.08.09	1.2	18.09.09	9
4.08.09	2	19.09.09	36.6
5.08.09	4.5	20.09.09	4.4
6.08.09	2.6	21.09.09	1
7.08.09	1.2	22.09.09	9
8.08.09	0	23.09.09	0.4
9.08.09	4.2	24.09.09	23
10.08.09	12.4	25.09.09	14.2
11.08.09	4.5	26.09.09	4.4
12.08.09	2.8	01.10.09	0
14.08.09	0	03.10.09	64.8
15.08.09	13.4	04.10.09	26.4
16.08.09	0	05.10.09	8.2
17.08.09	16.2	06.10.09	1
19.08.09	1.2	08.10.09	0
20.08.09	0	09.10.09	0
21.08.09	9.5	10.10.09	0
22.08.09	4.8	11.10.09	0
23.08.09	16.4	12.10.09	0
24.08.09	31.2	13.10.09	0
25.08.09	9	14.10.09	0.1
26.08.09	13.2	15.10.09	0

27.08.09	12	16.10.09	0.4
Date	Rainfall	Date	Rainfall
17.10.09	0	15.11.09	57.6
18.10.09	0	16.11.09	28.8
19.10.09	0	17.11.09	1.4
20.10.09	0	18.11.09	0
21.10.09	0	19.11.09	13.6
22.10.09	0	20.11.09	0.8
5.11.09	58	23.11.09	28.2
8.11.09	96	24.11.09	0
9.11.09	61	25.11.09	3.2
10.11.09	9		

TEMPORAL GROUNDWATER FLUCTUATION ANALYSIS OF K.C.A.E.T CAMPUS

By

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In
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Kerala Agricultural University

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ABSTRACT

Quantification of components of water resources of an area will enable the development of appropriate guidelines for holistic decisions on efficient utilization of the water resources in that area. It will pinpoint the water resources potential both spatially and temporarily in the area as a whole. Temporal groundwater fluctuation analysis of K.C.A.E.T campus revealed the behaviour of groundwater at varying conditions. Study thoroughly analysed the variation in depth to water table of different wells located at different elevations of the study area. The variation caused by the monsoon found to be distinct and prominent. During the monsoon wells attained minimum fluctuations in depth to water table. Few days after the offset of monsoon wells showed a drastic decline in water level. At summer the area experienced acute groundwater shortage. The study revealed characteristics and behaviour of groundwater at different period of time.