

TECHNICAL REPORT

**EFFECTIVENESS OF STORAGE TANKS FOR GROUNDWATER RECHARGING
IN NORTH KARNATAKA REGION**



NATIONAL INSTITUTE OF HYDROLOGY

HARTD ROCK REGIONAL CENTRE

BELGAUM, KARNATAKA

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**EFFECTIVENESS OF STORAGE TANKS FOR GROUNDWATER RECHARGING
IN NORTH KARNATAKA REGION**

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**NATIONAL INSTITUTE OF HYDROLOGY
REGIONAL CENTRE
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PREFACE

In India, groundwater is used as a major source of water for domestic as well as irrigation purposes. Rural areas of our country are solely dependent on groundwater for all water needs. In recent times, increasing exploitation of this vital resource has reached its tolerance limits in various parts of the country. In many situations, the extraction exceeds the limit of natural replenishment through rainfall. Concerted efforts are being made to replenish the depleting aquifers, especially in hard rock areas, through various artificial recharging efforts like check dams and weirs across drains, storage tanks, rain water harvesting, etc. However, the efficacy of these interventions are not evaluated scientifically. For instance, storage tanks/ irrigation tanks are vastly employed in the northern parts of Karnataka for irrigation. But, poor maintenance of these tanks and lack of understanding on the recharging aspects limit the aquifer recharging capabilities of these tanks. Therefore, systematic studies in this direction have to be taken up by duly considering hydrogeological and agro-climatic aspects of the locality with a view to emulate the outcomes from such studies to similar situations elsewhere.

As such, HRRC NIH has taken up a demand-driven study, upon the request of JalaSamvardhaneYojanaSangha (JSYS) to investigate recharging aspects of these storage tanks and their interaction with the aquifer. The World Bank funded JalaSamvardhaneYojanaSangha (JSYS) project of the State of Karnataka had been implementing Tank rejuvenation programmes in the state by de-silting a number of irrigation tanks. Even though the project envisaged augmenting tank storage capacity and enhanced recharge to the local aquifer system, it lacked any scientific investigations to assess the effectiveness and to quantify the recharging. The study team of scientists of HRRC and officials from JSYS have identified two distinct tanks in North Karnataka with different agro-climatic and hydrogeologic characteristics to carry out the investigations. Issues like, interaction between tank water and groundwater, effectiveness of de-silting the tanks on recharging of the aquifer system etc. will be investigated in the study using various techniques.

Presented is the report of the study by HRRC NIH compiled with a technical brief on the subject matter, analyses and results. The study has been carried out by Dr. Mathew K Jose, Scientist D (Principal Investigator) along with Dr. B. Venkatesh. Field assistance like field survey and data collection has been provided by Shri. B. Alagawadi(JSYS). The study is expected to provide useful information on the assessment of effectiveness of tank recharging.

R D Singh
(DIRECTOR)

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ABSTRACT

Accessibility, common availability and low extraction costs make groundwater the most preferred source of water in most parts of our country. It is estimated that ninety two percent of the annual withdrawal of groundwater in India is utilised for irrigation purposes. Intense agriculture activities in past decades, however, had resulted in increased exploitation of this vital resources. In several states the extraction of groundwater exceeded the limit of natural replenishment. Due to vagaries of monsoon and reduced rainfall inputs, the full potential of recharging of many aquifers are not attained. Concerted efforts are being made at various levels to augment aquifer systems through various means of artificial recharging techniques like, check dams/ weirs across drains/ storage tanks/ rain water harvesting/ injection wells etc. While rigorously pursuing the structural measures of aquifer recharging, the efforts to scientifically understand the processes and their interactions have been neglected. In this context, the storage tanks/ irrigation tanks employed for irrigation in Karnataka can be considered as active sources of recharging the local aquifer system in addition to serving the primary purpose of irrigation. But, there are hardly any attempts made to scientifically investigate the role of these irrigation tanks in supplementing the aquifer recharging. It is important to understand the hydrogeology as well as flow processes including interaction of surface water and groundwater systems to ascertain the effectiveness of tanks in recharging aquifer systems. Therefore, systematic studies in this direction have to be taken up by duly considering hydrogeological and agro-climatic aspects of the locality. Outcomes such studies may be emulated for similar situations in other areas too. As such, HRRC NIH has taken up a demand-driven study along with Jala Samvardhane Yojana Sangha (JSYS) of the State of Karnataka, to investigate recharging aspects of storage tanks. The World Bank funded project JSYS had been implementing Tank rejuvenation programmes in the state by de-silting a number of irrigation tanks. The project envisages augmenting tank storage capacity and enhanced recharge to the local aquifer system. However, some scientific studies are needed to assess and quantify the effectiveness of these efforts on groundwater recharge. Consequently, the team of scientists and officials from JSYS have identified two tanks located in two different agro-climatic and hydrogeologic zones, namely, (i) K. Nandgad Tank, Khanapur taluk, and (ii) K. Chandargi Tank, Ramdurg taluk of Belagum district in Karnataka to carry out the investigations. Issues like, interaction between tank water and Groundwater, effectiveness of de-silting the tanks on recharging of the aquifer system etc. have been investigated in the study. The selected tanks have been monitored and water samples have been collected at regular intervals to facilitate environmental isotopic analysis. Groundwater flow modeling has been carried out to ascertain the groundwater flow directions and volumes. The are presented in the report.

INTRODUCTION

General

Groundwater is the predominant source of water for domestic and agriculture uses in rural India. Groundwater possesses the advantage of easy accessibility, general availability, dependability on quality and quantity as well as low investment in extraction. The increasing dependence on ground water has culminated into indiscriminate extraction in various parts of the country without bothering about the recharging capacities of aquifers.

As per the latest assessment, the annual replenishable ground water resource of country has been estimated as 433 billion cubic meter (bcm), out of which 399 bcm is considered to be available for development for various uses (CGWB, 2012). Ninety two percentage of the annual withdrawal of groundwater in our country is utilised for irrigation purposes. The stages of development of ground water in various states of India exhibits considerable variations ranging from 98% in the North Western Plain States to 43% in the Eastern Plain States as per the assessment of the Central Groundwater Board.

So, the availability of groundwater resources and its utilisation are non-uniformly distributed in time and space. Management of ground water resources in such a complex system is not an easy task, and there need to be multi-level, localised management strategies for different groundwater sectors in the country. Therefore, scientific management of ground water resources should involve a combination of supply side and demand side measures depending on the regional setting. Measures of replenishing the local aquifers, besides natural recharging, through appropriate management strategies/ artificial means need to be adopted.

Irrigation Tanks in North Karnataka

In this context, the storage tanks existing in the hard rock region, predominantly used for irrigation purposes, can also be considered to be a source for recharging the local aquifer system. In the hard rock areas, which happened to be more than 60% of the geographical area of the country, the groundwater resources are scanty due to low recharge and storage capacity. Over-exploitation is particularly sensitive in hard-rock and semi-arid regions, where the storage is limited by the aquifer geometry and recharge is highly variable. Geologically, the hard rock terrains are formed by consolidated/semi-consolidated formations (sedimentary rocks, basalts and crystalline rocks) and availability groundwater depends on secondary porosity developed due to weathering and fracturing/ fissures with varying yields. The presence of bedding planes, joints, contact zones and fractures controls the ground water occurrence, movement and yield potential.

Even though efforts are on to augment dwindling aquifers in the hard rock region through check dams/ weirs/ tanks/ rainwater harvesting etc, the efficacy of these interventions are not evaluated scientifically. Most of the cases, success of such measures are ascertained merely observing the improvement in terms of water levels in wells without considering any other parameters. However, to facilitate selection of suitable recharge sites to optimise recharging, it is important to understand the hydrogeology as well as flow processes including interaction of surface water and groundwater systems. Studies in this direction have to be either site specific or pertaining to typical hydrogeological and agro-climatic regions so that results may be emulated to similar situations to a certain extent.

JalaSamvardhanaeYojanaSangha

The JalaSamvardhanaeYojanaSangha (JSYS), a World Bank funded project in Karnataka, had been implementing an Integrated Tank Development Plan by de-silting a number of irrigation tanks in different parts of the state with water-users' cooperation. The project envisaged augmenting tank storage capacity and enhanced recharge to the local aquifer system. However, there have not been any scientific study conducted to assess the effectiveness of this exercise of de-siltation on groundwater recharge.

Back ground of the Present Study

Based on the observations of the funding agency on the lack of scientific understanding on the issue, the JSYS has approached HRRC NIH to carry out specific studies on the subject of recharging aspects of these storage tanks upon de-siltation to help ascertaining the utility of the project. Consequently, a team of scientists and officials from JSYS carried out field visits to two such tanks in Belgaum district, namely, (i) K. NandgadTank, Khanapur taluk, and (ii) K. ChandargiTank, Ramdurg taluk and made a reconnaissance survey on the feasibility of the study. These two tanks are located in different agro-climatic and hydrogeologic zones; K Channdargi being a semi-arid zone while K Nandgadin a wet zone with fairly good normal annual rainfall.

Subsequently, these tanks have been identified for detailed investigations on aspects like, interaction between tank water and Groundwater, role of the tank as a means for artificial recharging of the aquifer system in two distinct hydro-geo-climatic zones. Therefore, monitoring of these selected tanks in the North Karnataka region has been facilitated by JSYS to initiate a systematic study on the effectiveness of these storage tanks on recharging the aquifer by NIH. Depth to Groundwater level in Bore wells, and Dug wells, and Tank water filling status are being recorded regularly.

OBJECTIVES

The objectives of the present study are to review the topic of recharging of aquifer system through storage tanks, and to assess interaction patterns of these surface water bodies (tanks) with the aquifer system. The specific objectives are set at:

- i. To identify two water storage tanks from the northern Karnataka region having distinct hydro-geological and agro-climatic characteristics, and to monitor these tanks in their typical zones to assess the effectiveness of these tanks in replenishing the groundwater system.
- ii. To understand and compare the tank behaviour (storage and percolation aspects) before and after de-silting of tank bed to augment storage. (the de-siltation project of tanks are being executed by the JSYS in a participatory mode)
- iii. To employ groundwater flow modeling techniques to investigate the interaction of these surface water bodies with groundwater system.

DESCRIPTION OF STUDY AREA

General:

Most parts of northern Karnataka fall under the semi-arid category, with scanty rainfall received for a shorter duration during the monsoon season. As such, a number of storage tanks are in existence in this region. Primarily, these tanks serve the purpose of irrigation and other local water needs. The percolation of water from these tanks to the strata below may also serve as a means of recharging of the aquifers. It is obvious that over the years, the capacity of the tanks is being reduced due to siltation and also percolation rates reduce. Nevertheless, regular de-siltation and proper maintenance of these storage tanks may contribute to improve recharging.

Case Studies:

The study area is Belgaum District in North Karnataka region. The two storage tanks selected for investigations are: (i) K. Chandargi Tank catchment and command areas, Chandargi, Ramdurg (Tal), Belgaum (Scanty rainfall zone) and (ii) Nandgad Tank catchment and command areas, Nandgad, Khanapur (Tal), Belgaum (normal rainfall zone). Specifications pertaining to these tanks are given in Table 1 & 2 respectively.



Table –2: Basic information for Tank K Nandgad, Khanapur, Belgaum

| <i>Sl. No.</i> | <i>Parameter</i> | <i>Attribute</i> |
|----------------|--|------------------|
| 1 | Nearest Raingauge station | Khanapur |
| 2 | Tank catchment area | 284.34 |
| 3 | Max. distance from upstream point to tank (km) | 2.31 |
| 4 | Soil type | Red |
| 5 | Water spread area (Ha) | 9.53 |
| 6 | Command area (Ha) | 96.22 |
| 7 | Tank capacity (mcm) | 0.1199 |
| 8 | Max. Water depth (m) | 1.98 |
| 9 | Water demand for khariff (mcm) | 0.2884 |
| 10 | Water demand for Rabi (mcm) | - |
| 11 | Annual rainfall (mm) | 1761 |
| 12 | Average runoff (mm) | 599 |
| 13 | Average annual spill over (mcm) | 2.17 |
| 14 | Forest cover in the catchment (Ha) | 54.50 |
| 15 | Agricultural plantation (Ha) | 13.46 |
| 16 | Crop (khariff + rabi) | 156.0 |

| |
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|--|

Table – 1: Basic information for Tank K Chandargi, Ramdurg, Belgaum

| Sl. No. | Parameter | Attribute |
|---------|---------------------------------|-----------|
| 1 | Nearest Raingauge station | Chandargi |
| 2 | Tank catchment area | 725.86 |
| 3 | Soil type | Black |
| 4 | Water spread area (Ha) | 13.16 |
| 5 | Command area (Ha) | 725.0 |
| 6 | Tank capacity (mcm) | 0.3069 |
| 7 | Max. Water depth (m) | 2.1 |
| 8 | Water demand for khariff (mcm) | - |
| 9 | Water demand for Rabi (mcm) | - |
| 10 | Annual rainfall (mm) | 484.0 |
| 11 | Average runoff (mm) | 39.5 |
| 12 | Average annual spill over (mcm) | 0.0657 |

Desiltation Process in Tank K Chandargi



Before Desiltation



Desiltation in progress



After Desiltation

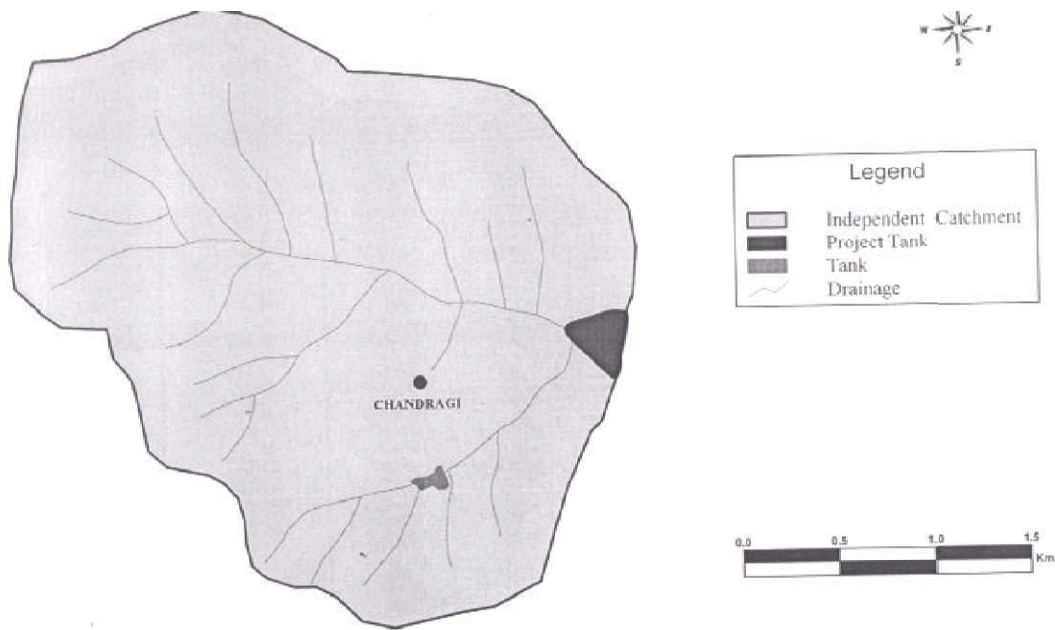


Fig- Catchment area of K Chandargi irrigation tank at Chandargi, Ramdurg, Belgaum

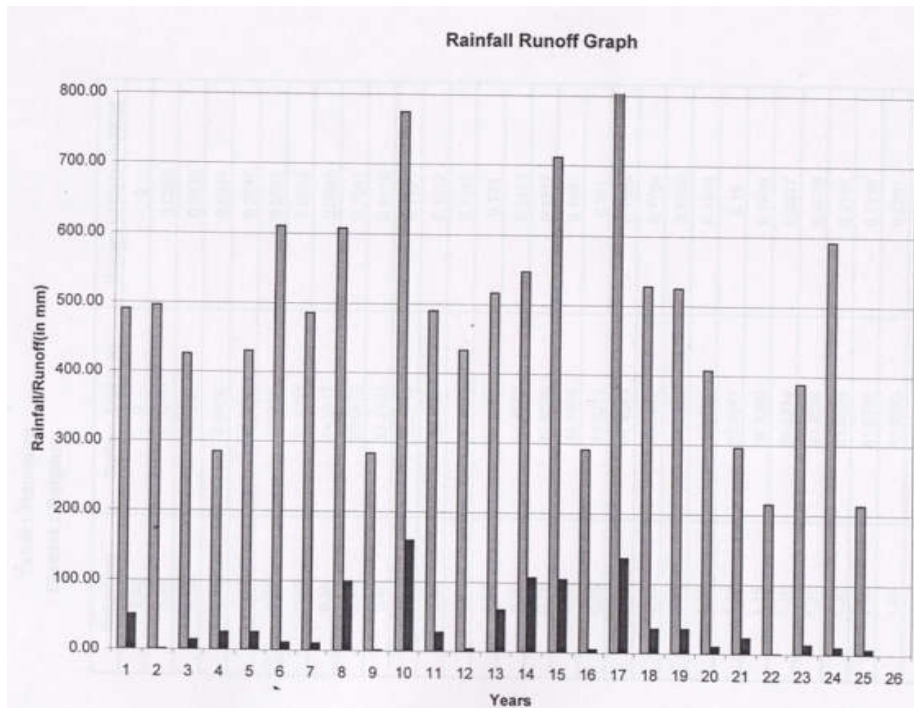


Fig- Rainfall Runoff representation in K Chandargitank catchment

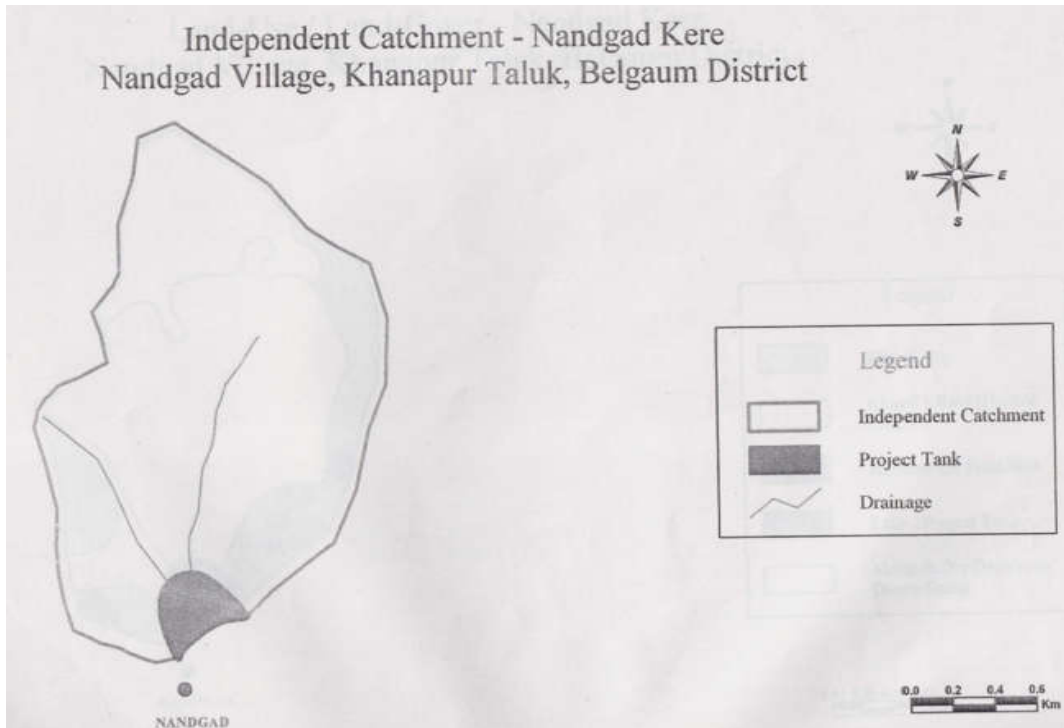


Fig- Catchment area of K Nandgad irrigation tank at Nandgad, Khanapur, Belgaum

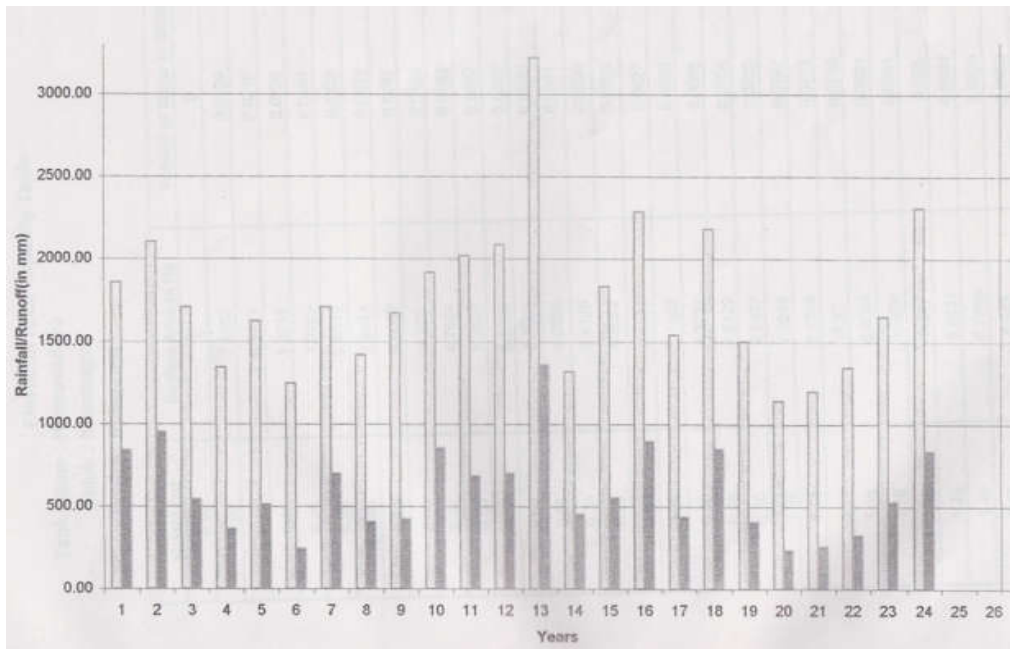


Fig- Rainfall Runoff representation K Nandgad tank catchment

ARTIFICIAL RECHARGE Vs IRRIGATION TANKS

Artificial recharge and rainwater harvesting are effective methods for supplementing dwindling water levels in ground water aquifers. It is relevant to note that, artificial recharge techniques to adopted in a site site-specific manner. Need, suitability of area in terms of availability of sub-surface storage space and availability of surplus monsoon run-off are important considerations for successful implementation of artificial recharge schemes. Hydrogeological considerations and hydraulic characteristics of the aquifer material also play crucial role.

Rainwater harvesting and artificial recharge programmes are implemented by various organizations in the country at national, state and local levels. Results are encouraging in terms of improved ground water availability, check in rate of decline of ground water levels, prolonged duration of assured supply and reduction of surplus run off. Increased sustainability of existing abstraction structures, increase in irrigation potential, revival of springs, soil conservation through increase in soil moisture and improvement in ground water quality are among other benefits of the schemes. In the coastal tracts, tidal regulators, constructed to impound the fresh water upstream and enhance the natural recharge are effective in controlling salinity ingress.

Artificial recharge schemes have been implemented by Central Ground Water Board in different hydrogeological settings in the country. In order to harness optimal benefits, recharge activities need to be implemented in the entire hydrological units such as watersheds/ sub-basins. Modification of natural movement of surface water into the aquifers through various structures like check dams, percolation ponds, recharge pits, shafts or wells are considered suitable in rural areas. On the other hand, roof-top rainwater harvesting, either for storage and direct use or for recharge into the aquifers is suited for urban habitations with its characteristic space constraints. Community level involvement is essential for the success of recharging programmes.

The ground water behavior in the hard rock terrain is complex due to the occurrence of diversified geological formations with considerable lithological and hydrogeological heterogeneity, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups in alluvial / soft rocks even transcend the surface basin boundaries. Broadly two groups of rock formations have been identified depending on characteristically different hydraulics of ground water, viz., porous formations and fissured formations.

The present study focuses on two representative tanks from distinct hydrogeological setups for assessing recharge aspects from irrigation tanks in North Karnataka.

METHODOLOGY

Recharging through irrigation tanks may address issues like sustainable yield in over-exploited aquifers, conserving excess surface water in underground storage, and improving the quality of groundwater through dilution. Hydrogeology, flow and storage aspects, aquifer parameters, water usage, land use pattern etc. play important roles in the present assessment process. Therefore, the methodology to be adopted need to facilitate providing meaning full answers to the question of effectiveness of the tank recharging under various scenarios of de-silting and augmenting tank storages.

Systematic monitoring:

Systematic monitoring data of the selected tanks are available since 2009. Some of the parameters monitored for these tanks are: rainfall, tank water levels, monitoring of water levels in groundwater wells/ bore wells, utilization pattern/ irrigation pattern in the tank commands, crop information, etc.

Application of flow modeling techniques:

Flow modelling is considered as one of the useful tools in identifying flow directions and recharge quantities. Once a conceptual model of the tank aquifer system is formulated, a three dimensional modeling of flow within the framework can be envisaged by using well known models like MODFLOW. This will enable one to quantify the contribution from the tank to the aquifer system under different hydrogeological set ups. The field and laboratory methods like the isotopic analyses can corroborate and supplement modeling outcomes.

Application of isotope hydrology:

Environmental isotopic application also has been utilized in identifying preferential flow paths as well as in assessing recharge quantities. It is proposed to use stable isotope techniques to analyse groundwater flow. It is known that (i) stable isotope characteristic of precipitation varies according to altitude of precipitation (altitude effect) and (ii) isotopic composition of surface water gets enriched during evaporation (enrichment effect). In several case studies, these isotopic effects are suitably used in deciphering recharging sources and their contribution to groundwater. Further, groundwater is usually much older in terms of its turnover time compared to turn over time of water in small surface water bodies. As a result, within the zone of influence of these tanks, groundwater appears modern. Environmental tritium content in groundwater is widely used as indicator of groundwater age.

Therefore, variation of tritium content in groundwater provides way to map the zone of influence of surface water bodies and their effectiveness in groundwater recharge.

Data requirement:

In general, the data required are: Aquifer parameters (eg: K, Sy, Ss, T, water levels, lithology/ fence diagrams, aquifer delineation/ layer etc.); River data (eg: stage/ discharge, cross sections, L-sections, river morphology, sediment/ bed material transport, etc.); well information in study area, groundwater utilization pattern in the study area, conjunctive use information, existing sand removal practices and quantities, information of structures over river, installations near river banks etc., landuse & soil maps, sediment/ bedload samplings at designated locations, rainfall and aquifer recharge data.

WORKS CARRIED OUT

Field Investigations:

- Several field visits carried out along with JSYS officials in monitoring the selected tanks and for data collection

K Chandargi Tank catchment and command areas, Chandargi

Field survey of the catchment and command areas was carried out and bore-well water samples collected. The area falls under semi-arid classification (annual rainfall less than 600mm). Interaction with farmers in the command area of the Tank revealed that for the Chandargi tank, its catchment did not receive sufficient rains for the last two years to yield any cognizable storage. As such, open wells were found to be dry. Only bore-wells of depth around 200ft. yield approximately 100- 130 gallons per hour for drinking / irrigation purposes. Major crops in the area are found to be jowar, onions, corn, plantain etc.

Nandgad Tank catchment and command areas,

Field survey has been carried out in the Nandgad of Khanapur(Tal), Belgaum. This area may be classified under wet conditions as the mean annual rainfall amounts to be about than 2000 mm. There are a number of open wells operational in the catchment area and command area of the tank. A few representative wells have been chosen for sampling water for isotopic

analysis and samples were collected. Well irrigation is practiced in the catchment as well as command. Paddy is the major crop.

- Fortnightly monitoring of water levels in the tanks and in the wells in the district by JSYS officials
- Joint field surveys by scientists from HRRC NIH Belgaum, NIH Roorkee and JSYS
- Collection of water samples at regular intervals from the designated tanks, and wells from the respective catchment and command areas of these tanks for environmental isotopic analysis
- Compilation of collected data/ information
- Isotopic analysis of collected water samples at NIH HQ progressing

Data Collection:

A number of tanks in Belgaum Dist. were identified and rejuvenation works carried out on a participatory mode with local water user communities like farmers, panchayats etc. Basic hydro-geological information of these existing tanks were collected and the information compiled. Further, water levels in the storage tanks as well as wells in the vicinity were monitored. In addition to, rainfall data, are-elevation details of tanks, land use information, agricultural pattern, soil and hydrogeological data etc. have been collected.

ANALYSIS AND DISCUSSION

The analyses carried by applying modeling tools and discussion of results are given in the following sections. Recharging through these tanks may address issues like sustainable yield in over-exploitation aquifers, conserving excess surface water in underground storage, and improving the quality of ground water through dilution. Hydrogeology, flow and storage aspects, aquifer parameters, water usage, land use pattern etc. play important roles in the present assessment process. Flow modelling has been carried out for the selected tanks. Flow directions and recharge quantities have been estimated. The tank recharge aspects have been analysed. Further, tank water samples for have been collected on a monthly basis and submitted for environmental Isotopic analyses to identify preferential flow paths as well as in assessing recharge quantities.

CHANDARGI TANK

Hydrogeological characterization

In the study area water table generally follows the topography of the area and is at greater depths in the water divides and topographic highs, but becomes shallower in the valleys and topographic lows. Hence, groundwater moves down and follows the gradient from the higher to lower elevations, that is, from recharge area to discharge area. The area is underlain by basalt. Deccan basalts act as a multilayer aquifers having low to medium permeability. In Deccan basalts that comprise different flows, fractures and interstitial pore spaces of vesicular zones, are good repositories of ground water.

Groundwater occurs under phreatic conditions in weathered zone of these basalts and under semi-confined to confined conditions in inter-trepans and also in joints and fractures at deeper levels. The aquifers occurring within the shallow depth range of 0 to 20 m below ground level are mainly weathered and fractured formations. Groundwater occurs in these formations under phreatic condition. Based on the pumping test data of the dug wells, it is inferred that there is a progressive increase in the permeability exceeding >100 m/ day in the water table phreatic zones of basaltic aquifers towards the east, even though the area falls in the northern dry and transitional zone having low to moderate rainfall.

Model conceptualization

The foundation of all hydro geological investigations is to gather sufficient reliable information to develop an understanding of how a particular groundwater system works. Such an understanding usually called Conceptual Model. It is generally pictorial representation of groundwater flow system. Conceptual model describes how water enters an aquifer system, flows through aquifer system and leaves the aquifer system. It includes information about water budget equation. Developing a conceptual model is an iterative process, as it is usual to review your ideas several times during the investigations progresses as more data is gathered from existing records or field measurements. Having develop a conceptual model, computational model are used to analysis of conceptual model to find out field parameter values.

Here we have considered aquifer viewpoint for conceptual model. In this viewpoint, groundwater is strictly assumed to be horizontal through aquifers. Though the area is basaltic, consist of interstitial pore spaces. Hence, assuming validity of Darcy's law:

Type of Aquifer : Unconfined
 Type of flow : Two dimensional
 Area : Rectangular
 Aquifer Thickness : 20m
 Strata Type : Basaltic
 Boundary Conditions : Specified head @ u/s & d/s boundary
 and

other kept as active nodes

Initial Boundary Conditions : Specified head @ u/s & d/s boundary

Hydraulic Conductivity : 100 m/day

Specific Storage : 0.25

Effective Porosity : 0.25

Source : Rainfall

Sinks : Dug wells

Elevation : Varying from 645m-660m MSL

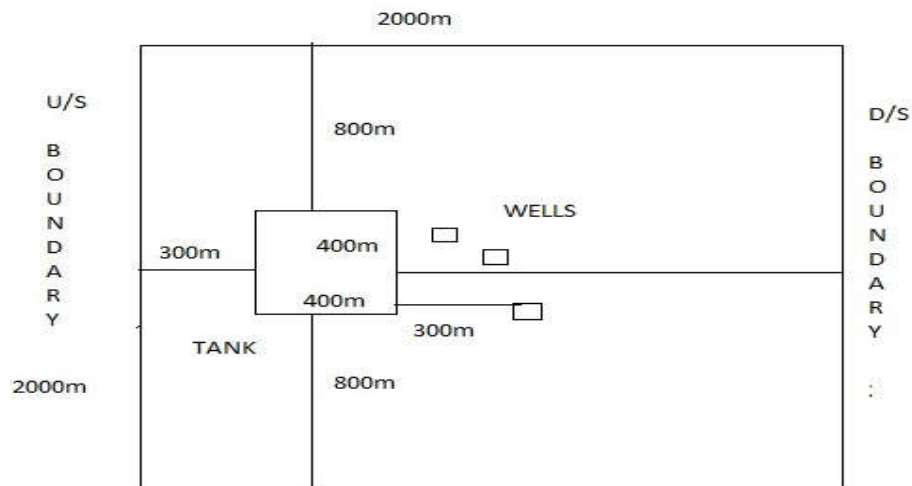
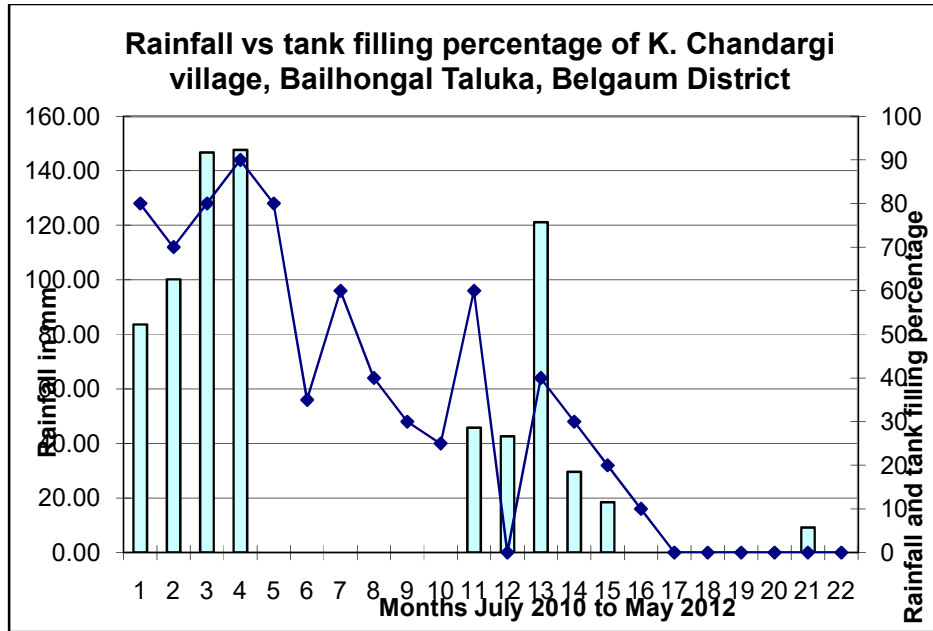


Fig. Conceptual Model of the Chandargi Tank area (Plan View)

Code selection

In this study we have used the Processing MODFLOW available in public domain. It facilitates the various options to consider the time dependent and independent data. The water budget calculation can be done for sub-regions. As we are dealing with

the interaction of Chandargi Tank with groundwater system, the software provides the Reservoir Package. To facilitate the use of Processing MODFLOW, more than 60 documented ready-to-run models are included in this software. Some of these models deal with theoretical background; some of them are of practical values.



Processing MODFLOW (PM) was originally developed to support the first official release of MODFLOW-88 (McDonald and Harbough, 1988) to simulate the inundation process of an abandoned open-cast coal mine. Since the release of MODFLOW-88, many computer codes have been developed to add functionalities to MODFLOW or to use MODFLOW as a flow-equation solver for solving specific problems. MODFLOW is a modular three-dimensional finite-difference groundwater model published by the U. S. Geological Survey. The first public version of MODFLOW was released in 1988 and is referred to as MODFLOW-88. MODFLOW-88 and the later version of MODFLOW-96 were originally designed to simulate saturated three-dimensional groundwater flow through porous media. MODFLOW-2000 attempts to incorporate the solution of multiple related equations into a single code.

Discretized domain

There are two types of finite difference grids: the block-centred grid and mesh-centred grid. The difference between them lies mainly in the way in which flux boundaries are handled. In the block-centred approach flux boundaries are located at the edge of block. In a mesh-centred boundary, the boundary coincides with a node.

In this study we have used block centred approach. In large general computer codes, the finite difference mathematics for boundaries are more easily treated with block centred approach. MODFLOW uses this kind of grids.

| | |
|---------------------------|----------------------|
| Area | 400 Ha (2000 * 2000) |
| Size of Column | 50m |
| No. of Columns | 40 |
| Size of Row | 50m |
| No. of Rows | 40 |
| Elevation of u/s Boundary | 660m above MSL |
| Elevation of d/s Boundary | 645m above MSL |
| Datum | 630m above MSL |

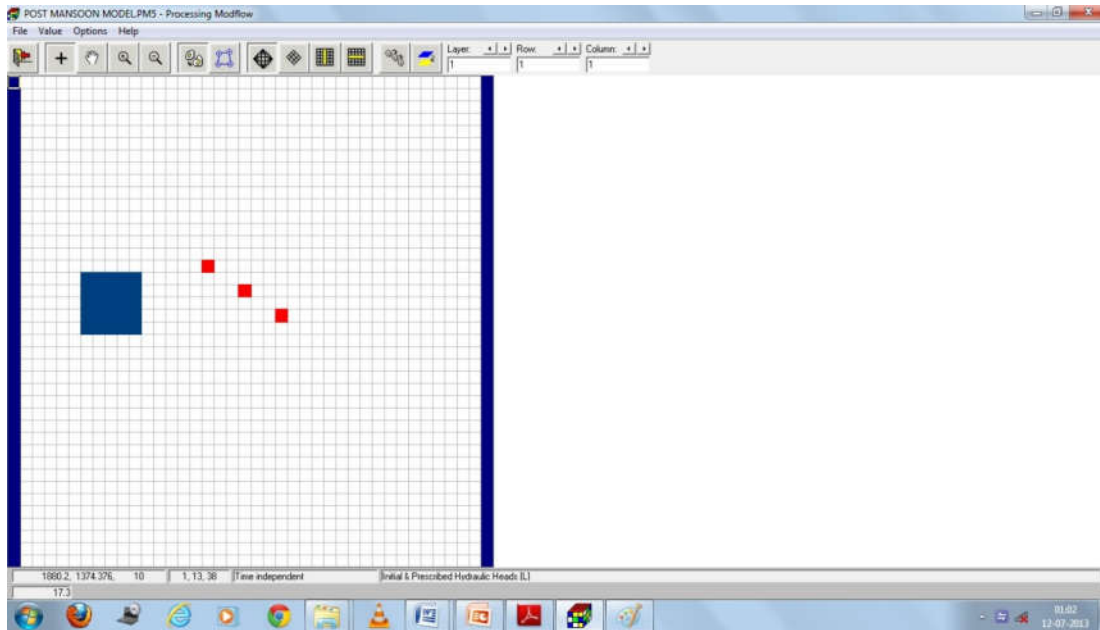


Figure: Discrete model domain

Input data preparation

To understand the work of groundwater system, we carried out three simulations namely Pre Monsoon, Monsoon and Post Monsoon over a year each of four months. We provided the 8 time steps for each simulation to get the water budget fortnightly.

Model Thickness = Elevation of top of layer (TOP) - Datum= 650-630=20m

Elevation

Top of Layer (TOP) 20m

Bottom of Layer (BOT) 0m

Time

Each Simulation 4 Months (3.05E+7 sec)

Table: Initial Boundary Conditions, Tank Area, Evapotranspiration and Recharge

| Season | Specified head @ u/s boundary | Specified head @ d/s boundary | Tank Area | Evapo-transpiration | Recharge |
|-----------------|-------------------------------|-------------------------------|-----------|---------------------|----------|
| | M | m | Ha | m/s | m/s |
| Pre Mansoon | 14.7 | 2.86 | 4 | 0 | 6.2E-9 |
| Mansoon | 17.9 | 6 | 14 | 1.24E-9 | 2.31E-8 |
| Post Mansoon | 17.3 | 5.47 | 9 | 1.24E-9 | 1.27E-8 |

Parameters

Hydraulic conductivity 0.00115
m/s
Effective porosity 0.25
Specific storage 0.25
Pumping rate 5 l/s

Reservoir Package (Tank)

Reservoir No. 1
Land Surface Elevation 17.9m
Vertical Hydraulic Conductivity 0.0001 m/s
Thickness of Reservoir Bed 2.1

Simulation and outputs (Time Step 8)

Hydraulic head

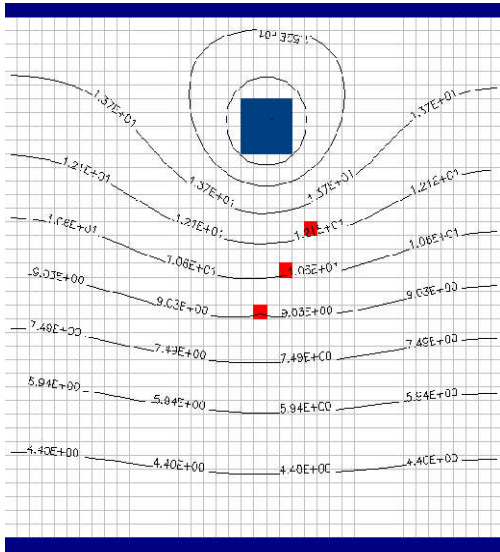


Fig. Pre monsoon hydraulic head

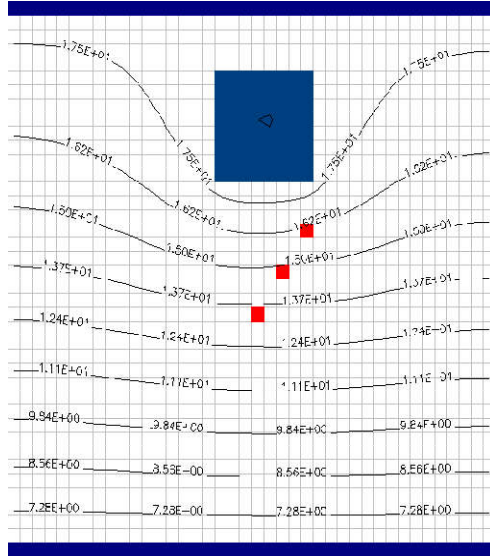


Fig. Monsoon hydraulic head

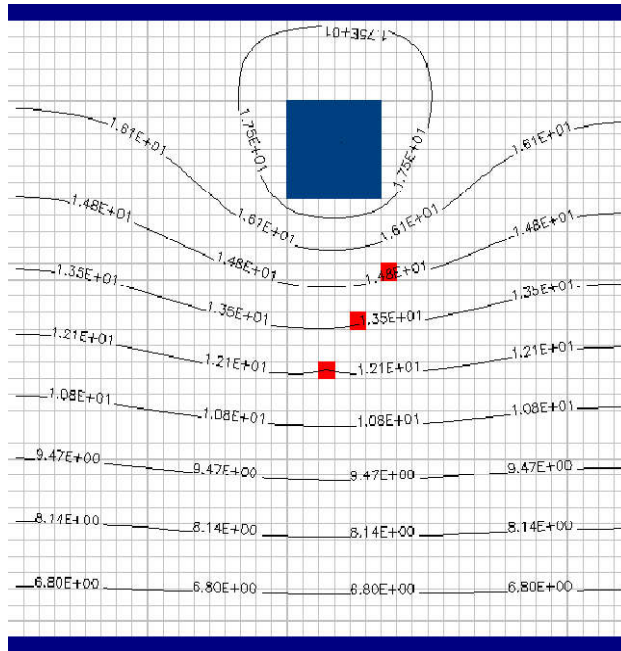


Fig. Post monsoon hydraulic head

Drawdown

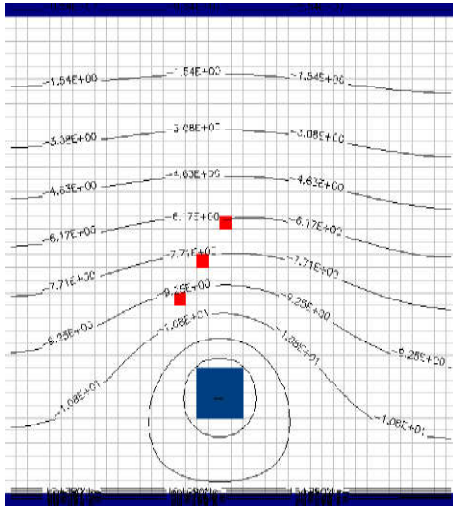


Fig. Pre monsoon drawdown

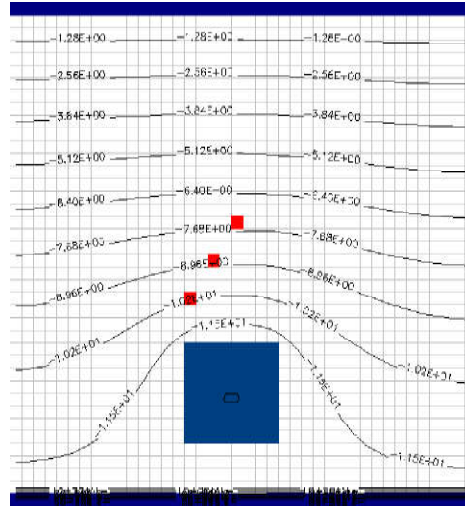


Fig. Monsoon drawdown

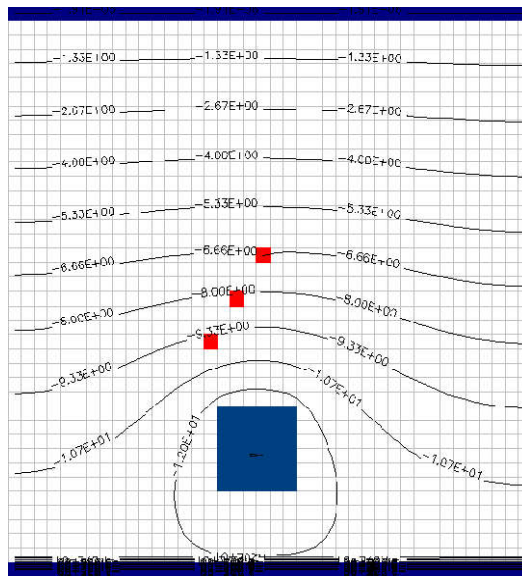


Fig. Post monsoon drawdown

Comparison of Observed and Simulated Water Levels in Wells

Table: Pre Monsoon (Feb-May)

| Well No. | Observed water level below ground level | Model elevation | Model hydraulic head (Time Step 8) | Simulated water level below ground level | Mean square error |
|----------|---|-----------------|--------------------------------------|--|-------------------|
| W1 | 5.77 | 17 | 12.38 | 4.62 | 1.07238 |

| | | | | | |
|----|------|----|-------|------|--------|
| W2 | 4.7 | 16 | 10.75 | 5.25 | 0.7416 |
| W3 | 4.92 | 16 | 9.1 | 6.9 | 1.4071 |

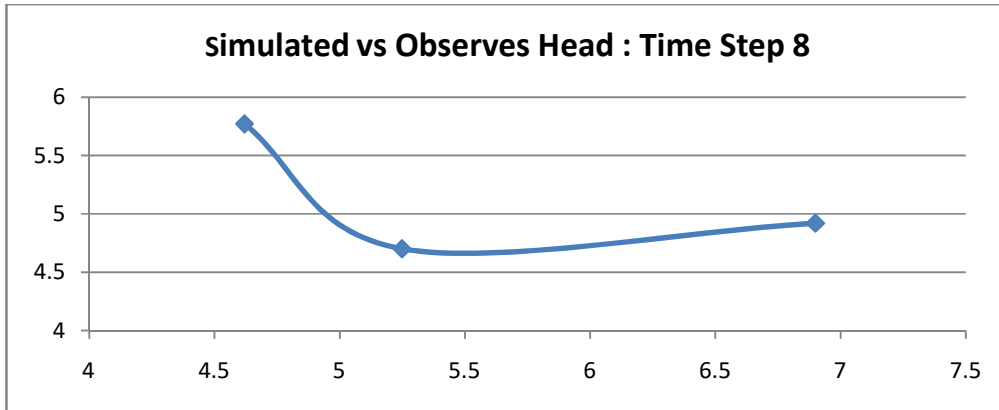


Fig. Pre Monsoon simulated Vs observed head

Table: Monsoon (June- Sept)

| Well No. | Observed water level below ground level | Model elevation | Model hydraulic head (Time Step 8) | Simulated water level below ground level | Mean square error |
|----------|---|-----------------|--------------------------------------|--|-------------------|
| W1 | 3.75 | 17 | 14.47 | 2.53 | 1.1045 |
| W2 | 3.79 | 16 | 12.98 | 3.02 | 0.8774 |
| W3 | 4.78 | 16 | 11.46 | 4.54 | 0.4898 |

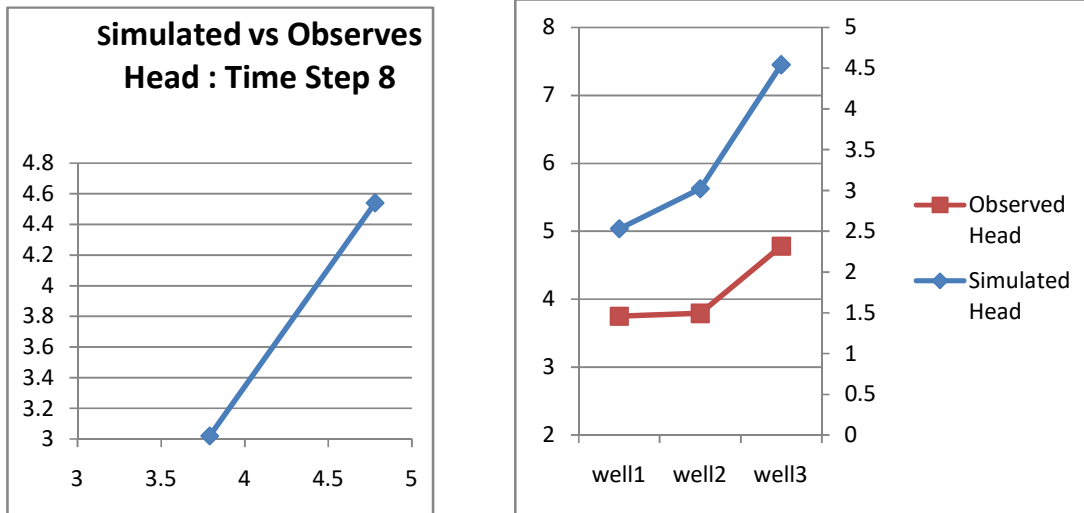


Fig. Monsoon simulated Vs observed head

Table: Post Monsoon (Oct-Jan)

| Well No. | Observed water level below ground level | Model elevation | Model hydraulic head (Time Step 8) | Simulated water level below ground level | Mean square error |
|----------|---|-----------------|--------------------------------------|--|-------------------|
| W1 | 3.76 | 17 | 14.4 | 2.6 | 1.0770 |
| W2 | 3.51 | 16 | 12.98 | 3.02 | 0.7000 |
| W3 | 4.24 | 16 | 11.6 | 4.4 | 0.4000 |

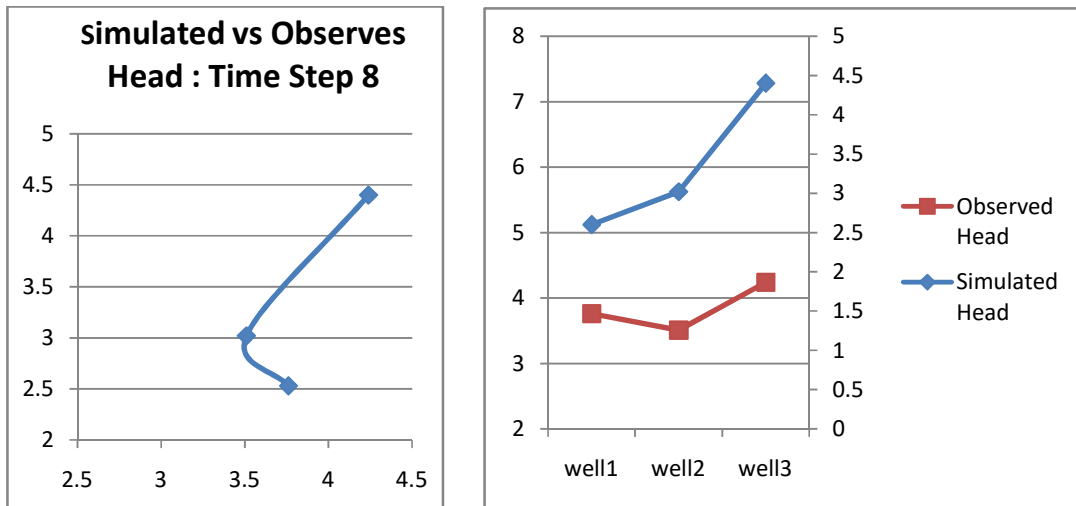


Fig. Post Monsoon simulated Vs observed head

The numerical groundwater flow model MODFLOW has been employed to calibrate a percolation tank system in a semi-arid region of north Karnataka. A percolation tank at Chandargi, meant for artificial recharging of the local aquifer has been chosen to demonstrate the usage of MODFLOW in simulating percolation characteristics of the tank-aquifer system. The study basically focuses on the interaction of Chandargi Tank and groundwater system. Geological boundaries, hydraulic boundaries, inflow/ outflow, storage capacity, porosity, hydraulic conductivity/ transmissivity, recharge sources, natural recharge, water balance, lithology, depth of the aquifer etc are the important parameters need to be considered in artificial recharging schemes.

In the present model, the finite difference scheme chosen, imposes certain restrictions regarding topographic features as well as boundary conditions. As such, a number of assumptions had to be made related to topography, hydrogeology, sources and sinks etc. Other parameters and input information have either been generated or deduced from the available tank monitoring data. Simulations have been carried out for pre monsoon, Monsoon and Post Monsoon seasons. The results have been plotted to visualise the distribution of head in the aquifer system. The simulation results are encouraging for the wet season and post-monsoon season. The hydraulic contours and zoned budget information show that contribution from the tank towards the aquifer system is considerably good. This corroborates the

existence of good infiltration capacity in the locality due to high hydraulic conductivity. The well water levels downstream of the tank monitored in regular intervals indicated improved water levels in the wells due to recharging from the tank.

However, it has been observed that there is need of detailed hydrogeological monitoring and parametric data to carry out similar modelling exercises to yield more exhaustive results.

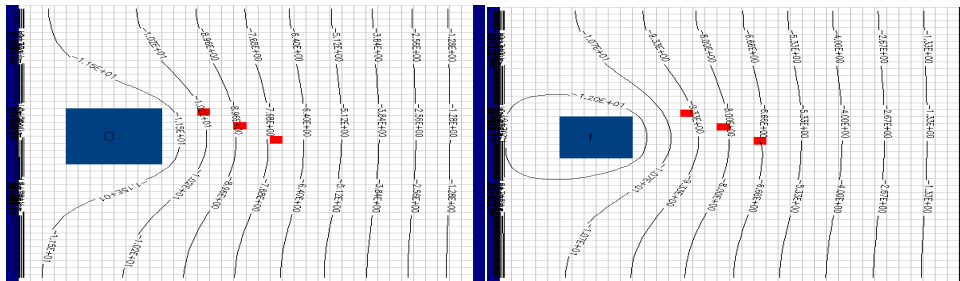


Figure: Drawdown around the Chandargi Tank during monsoon and post-monsoon respectively

Nandgad Tank:

Geomorphology and Equivalent Porosities

The Nandgad irrigation tank at Nandgad village is located in Khanapur Taluka of Belgaum District. Belgaum district is primarily located on the eastern side of the Western Ghats and its topography is predominantly undulating. A “rugged terrain” marks the western part of Khanapur and Belgaum talukas with deep cutting ravines on the foothills of the Western Ghats. The region consists of hard rock strata. In the

hard rock terrain, the groundwater flow is governed by primary as well as secondary porosities in the aquifer media.

The region receives good amount of rainfall, thus the tank is filled partially or fully throughout the year. The total catchment for the tank is around 284.34 Ha out of which 96.22 Ha is the command area. The tank, thus most of the time is use to provide water for irrigation in the command area. The ground strata is comprised of igneous type of weathered lateritic soil up to 20 - 25m depth, and granite having fractured water bearing zone from about 25 to 60m. The permeability (hydraulic conductivity) of the porous medium in the surrounding area is approximately, 45 m/day ($\sim 5.08 \times 10^{-4}$ m/s).

Water Levels for the Model Domain

The observation wells in the vicinity of the tank provided the water levels. However, there are no well observations near the boundaries. Therefore, the groundwater levels for the model domain has been computed by arithmetic interpolation of the available well data. Thus, groundwater levels has been computed for upstream and downstream of the tank.

Tank Characteristics

Using the collected tank monitoring data, tank filling levels and capacities, the water spread area for different stress periods, etc.

Selection of Area for the Model

In order to find the influence of the tank on the aquifer system, a conceptual model has been formulated with an area of 2 km x 1km (2 sq.km.) as given in Fig.1

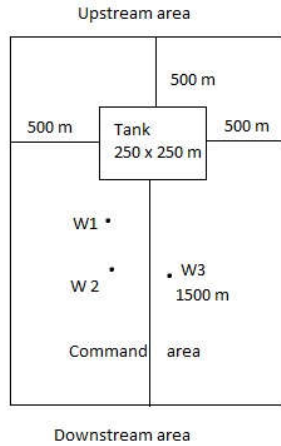
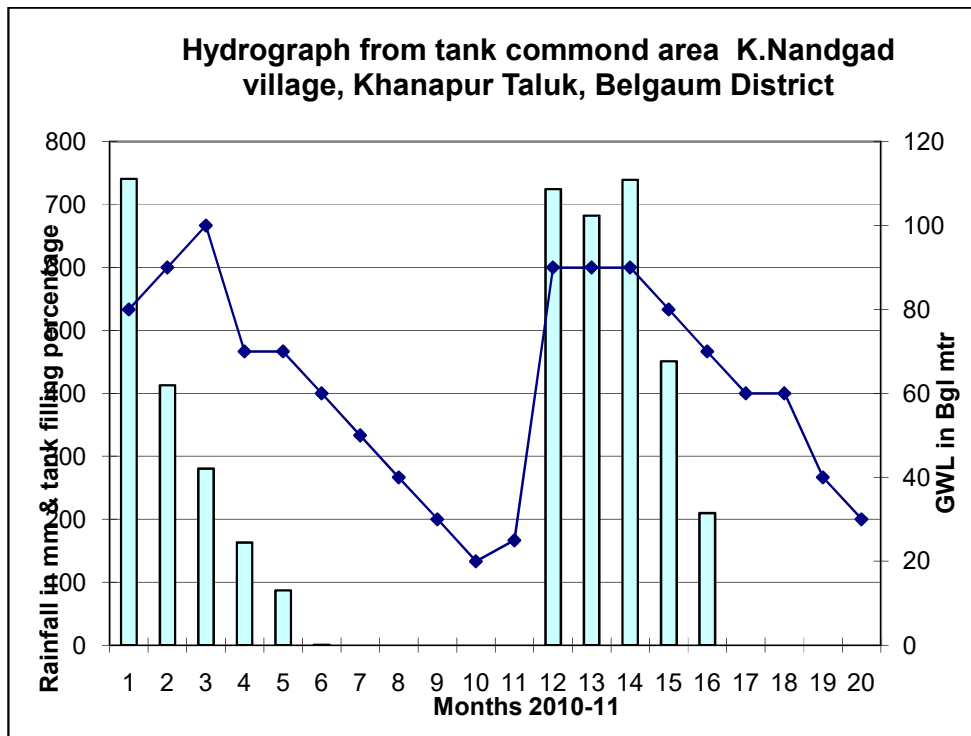


Fig. Conceptual model (plan-view) for the Nandgad tank

Water Budget for the Region

The water budget for the area has been computed using data on monthly rainfall, monthly runoff, evaporation and infiltration was computed. The monthly rainfall, monthly runoff and evaporation data recorded for 25 yrs facilitated to compute the rainfall recharge for the given region. Thus, the water budget has been prepared for annual, pre-monsoon, monsoon and post-monsoon basis.



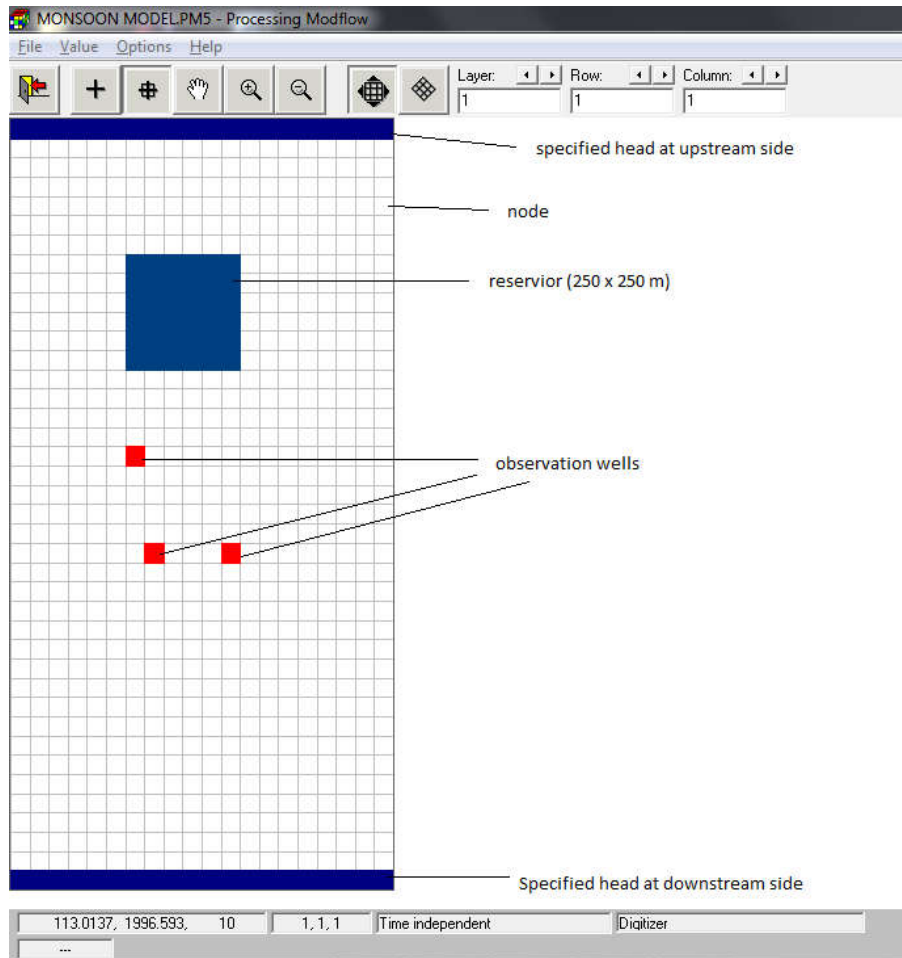


Fig. Plan view of the Modelled area with the tank and wells

PROCESSING THE CONCEPTUAL MODEL IN MODFLOW

Grid Layout

The model domain (2 km x 1 km) has been discretized into small grids of 50m x 50m size consisting of 40 rows and 20 columns. The datum for the model has been considered as 680 m (msl). Therefore, all the vertical dimensions (domain depth, water levels, elevations etc) has been converted with reference to the datum.

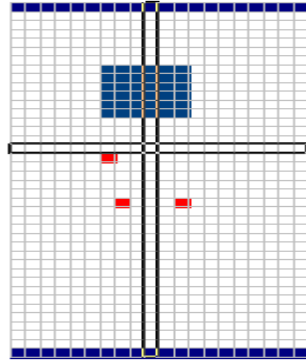


Fig. Preparation of mesh grid for the model

Number of layers and layer properties

A single unconfined groundwater stratum has been considered for the model based on the hydrogeology of the locality.

Boundary Conditions

Boundary conditions consisting of specified head boundaries have been specified with reference to the datum (680 msl) on upstream and downstream sides. These specified head values vary according to the seasonal pattern. The adjacent boundaries have been taken as active boundary.

Layer Elevations and Thickness of Aquifer

A layer elevation of 20 m at the top of layer 1 from the specified datum has been provided.

Stress Periods and Time Steps

For simulations on annual basis, a stress period of 1 year has been taken with 8 time steps. For seasonal simulations, the year has been partitioned into three seasons viz., premonsoon, monsoon and post monsoon periods with 8 time steps for each season. The outputs and simulation results are shown for monsoon season (June to September). Transient state simulation has been taken into consideration.

| Period | Active | Period Length | No. of Time Steps | Multiplier (Flow) | Transport Stepsize | Max. No. of Transport Steps | Multiplier (Transport) |
|--------|-------------------------------------|---------------|-------------------|-------------------|--------------------|-----------------------------|------------------------|
| 1 | <input checked="" type="checkbox"/> | 1.0513E+07 | 8 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |
| | <input type="checkbox"/> | 1 | 1 | 1 | 0 | 50000 | 1 |

Simulation Time Unit: seconds

Simulation Type: Steady-State Flow Simulation Transient Flow Simulation

Auto Update Period Length

Total Period Number = 1
Total Time Steps = 8
Total Simulation Time = 1.0513E+7 seconds

Load... Save As... OK Cancel Help

Fig. Stress Period and Time Steps for Steady / Transient Simulations

Spatial Aquifer Parameters

Input aquifer parameters such as initial and prescribed hydraulic head at the upstream and downstream sides, horizontal hydraulic conductivity, vertical hydraulic conductivity, effective porosity, specific storage and specific yield were given.

Flow packages

The flow simulation packages such as evapotranspiration from the top grid, amount of recharge to the top grid, tank characteristics, and well characteristics for different seasons were given and model was then run to simulate for different time steps.

MODFLOW - Monsoon Model

Input parameter Data

The values for elevation, specified water heads, stress period and stratum properties for simulating the model for monsoon season are give in Table-1.

Table: Input Parameters for Monsoon season

| GENERAL DATA | | |
|--------------|------------------------------|----------------------|
| 1 | Upstream surface elevation | 700 m |
| 2 | downstream surface elevation | 685 m |
| 3 | upstream water head | 696.89 m |
| 4 | downstream water head | 684.29 m |
| 5 | number of layers | 1 |
| 6 | Datum considered | 680 m |
| 7 | Aquifer thickness | 20 |
| 8 | duration of simulation | 1.0513E7 sec |
| 9 | number of time steps | 8 |
| 10 | permeability | 5.208 E -4 m/s |
| 11 | tank filling capacity | 86% |
| 12 | evaporation | 0.00000000092789 m/s |
| 13 | recharge | 0.00000000209017 m/s |

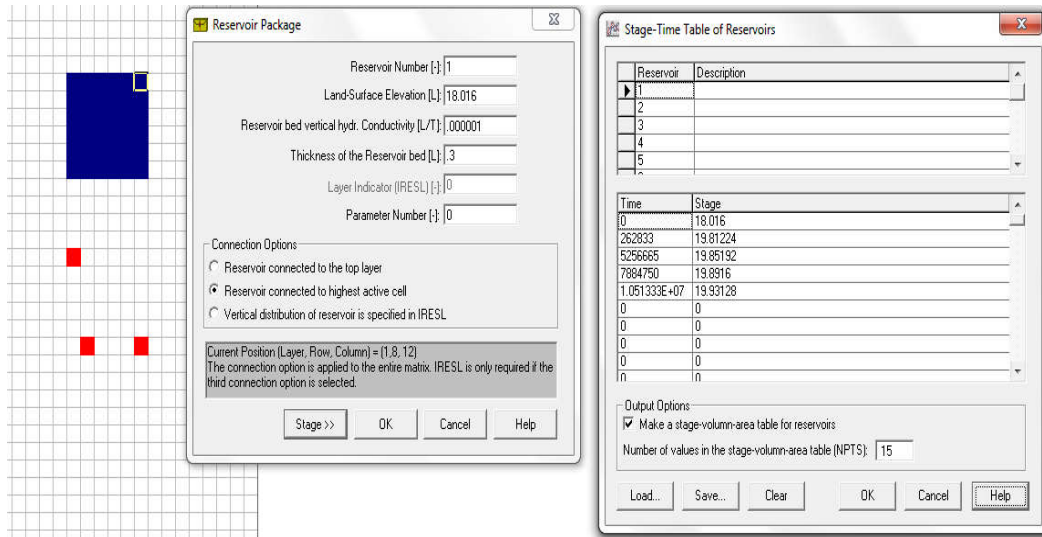
Tank Characteristics

The tank size during the monsoon period was its maximum size (250 x 250 m) with water level of 1.984 m and capacity of 0.1199 MCM

| TIME STAGE RELATION OF TANK | | |
|-----------------------------|----------|----------|
| TIME | STAGE | % filled |
| 0 | 18.016 | 0 |
| 262833 | 19.81224 | 0.86 |
| 5256665 | 19.85192 | 0.88 |
| 7884999 | 19.8916 | 0.9 |
| 105133300 | 19.93128 | 0.92 |

Fig. Reservoir Package and Time Stage data for tank on monsoon season

Well Data



All the well surrounding the tank area were pumping well, their pumping rate is as follows:

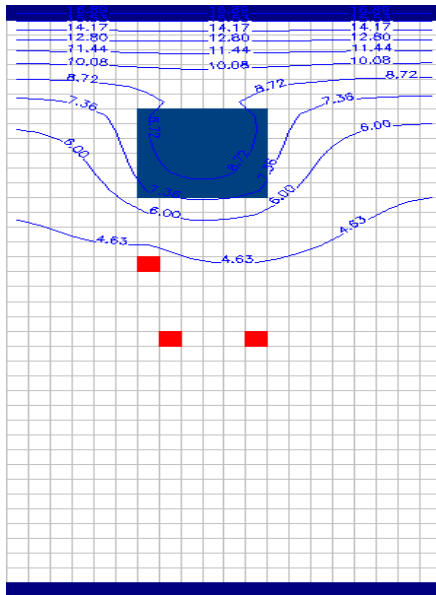
| WELL DATA | | | |
|-----------|-----------|------------|---------|
| well no | Elevation | WATER HEAD | PUMPING |
| | M | M | RATE |
| W1 | 691 | 690.39 | 6 LPS |
| W2 | 687 | 686.54 | 5LPS |
| W3 | 689 | 688.5 | 5LPS |

Fig. Well data for monsoon season

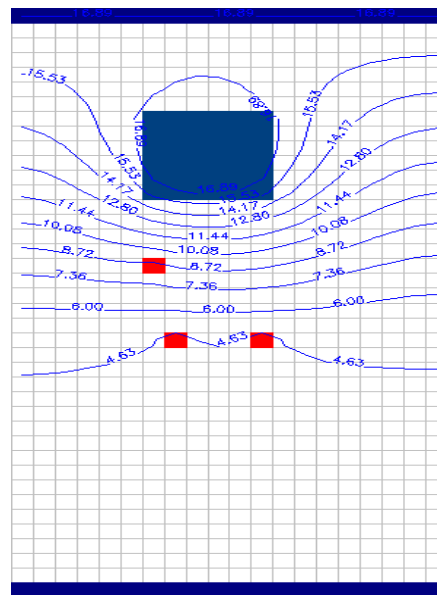
SIMULATION AND OUTPUTS

Simulations of Head at various Time Steps for Monsoon Season

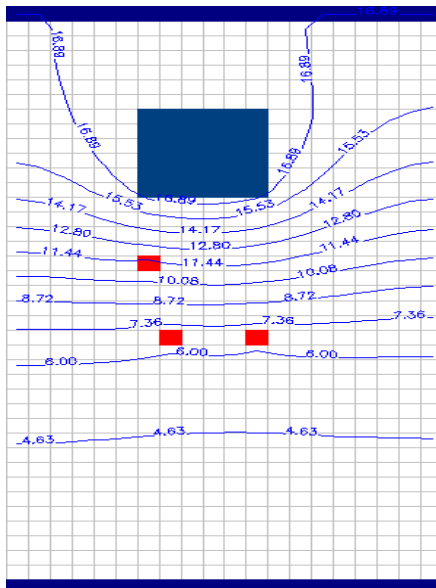
Following figures show the contours of water levels, upstream boundary to downstream. The simulations were carried out for 8 time steps



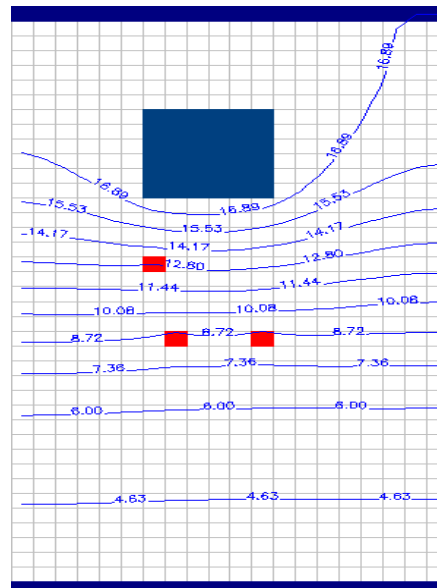
Head at time step 1



Head at time step 4



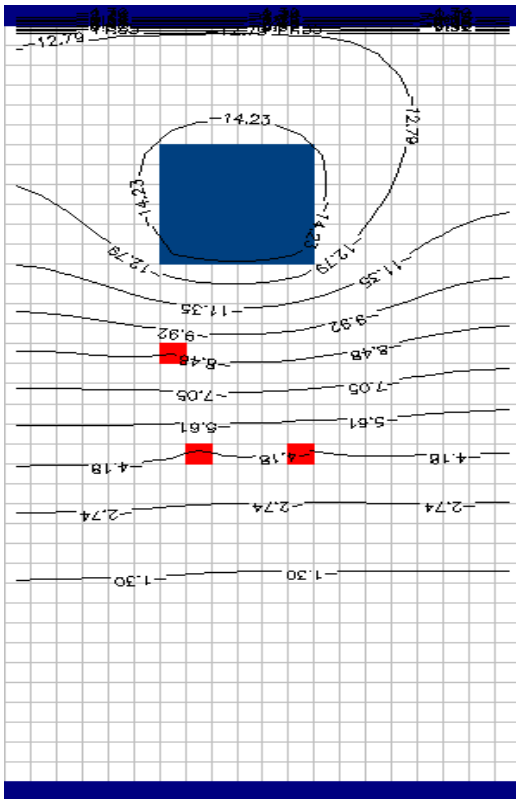
Head at time step 6



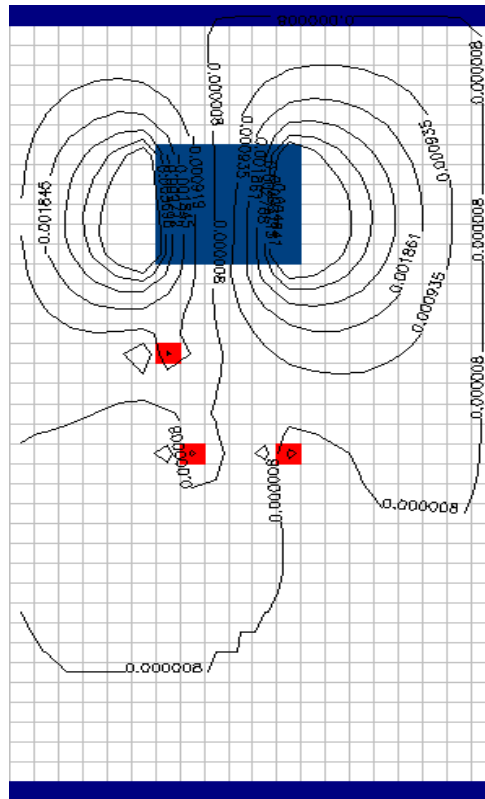
Head at time step 8

Fig. Water Levels during different Time Steps for Monsoon Season

Drawdown and Flow Faces



**Fig. Drawdown for monsoon season
Cell Flow**



**Fig. Flow Right Face Cell by
Cell Flow**

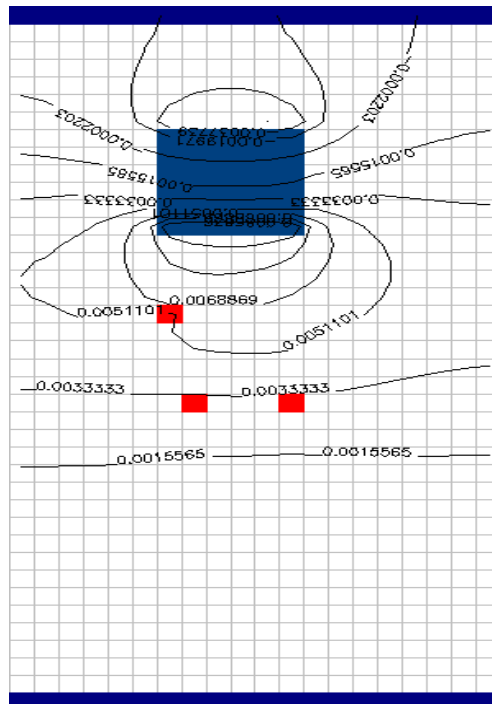


Fig. Flow Front Face Cell by Cell Flow

Water Budget, Output and Comparison

The model created for the monsoon season had a discrepancy of almost 0% which meant that the flow going in and out of the aquifer system were exactly equal. Also the model gave appreciable outputs in terms of the simulated heads at wells at different time steps.

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=====
WATER BUDGET OF THE WHOLE MODEL DOMAIN:
=====

```

| FLOW TERM | IN | OUT | IN-OUT |
|------------------|---------------|---------------|----------------|
| STORAGE | 0.0000000E+00 | 1.5998781E-01 | -1.5998781E-01 |
| CONSTANT HEAD | 3.4626055E-04 | 2.7146991E-02 | -2.6800731E-02 |
| WELLS | 0.0000000E+00 | 1.5999999E-02 | -1.5999999E-02 |
| DRAINS | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| RECHARGE | 3.9709769E-03 | 0.0000000E+00 | 3.9709769E-03 |
| ET | 0.0000000E+00 | 6.4960012E-05 | -6.4960012E-05 |
| RIVER LEAKAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| HEAD DEP BOUNDS | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| STREAM LEAKAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| INTERBED STORAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| RESERV. LEAKAGE | 1.9888049E-01 | 0.0000000E+00 | 1.9888049E-01 |
| SUM | 2.0319773E-01 | 2.0319976E-01 | -2.0265579E-06 |
| DISCREPANCY [%] | 0.00 | | |

Fig. Water Budget for Monsoon Season (Time Step 8)

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=====
WATER BUDGET OF THE WHOLE MODEL DOMAIN:
=====

```

| FLOW TERM | IN | OUT | IN-OUT |
|------------------|---------------|---------------|----------------|
| STORAGE | 0.0000000E+00 | 1.4562875E-01 | -1.4562875E-01 |
| CONSTANT HEAD | 5.9787869E-02 | 6.6380878E-04 | 5.9124060E-02 |
| WELLS | 0.0000000E+00 | 1.5999999E-02 | -1.5999999E-02 |
| DRAINS | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| RECHARGE | 5.6050145E-03 | 0.0000000E+00 | 5.6050145E-03 |
| ET | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| RIVER LEAKAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| HEAD DEP BOUNDS | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| STREAM LEAKAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| INTERBED STORAGE | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| RESERV. LEAKAGE | 9.6899837E-02 | 0.0000000E+00 | 9.6899837E-02 |
| SUM | 1.6229272E-01 | 1.6229255E-01 | 1.6391277E-07 |
| DISCREPANCY [%] | 0.00 | | |

Fig. Water Budget for Post-Monsoon Season (Time Step 8)

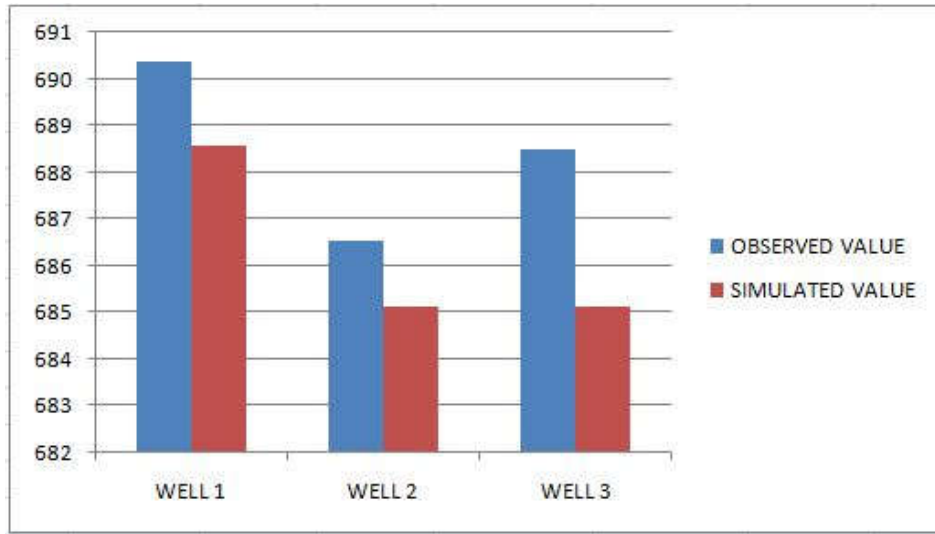


Fig. Observed and Simulated values of water levels in well

observed vs simulated values for monsoon season

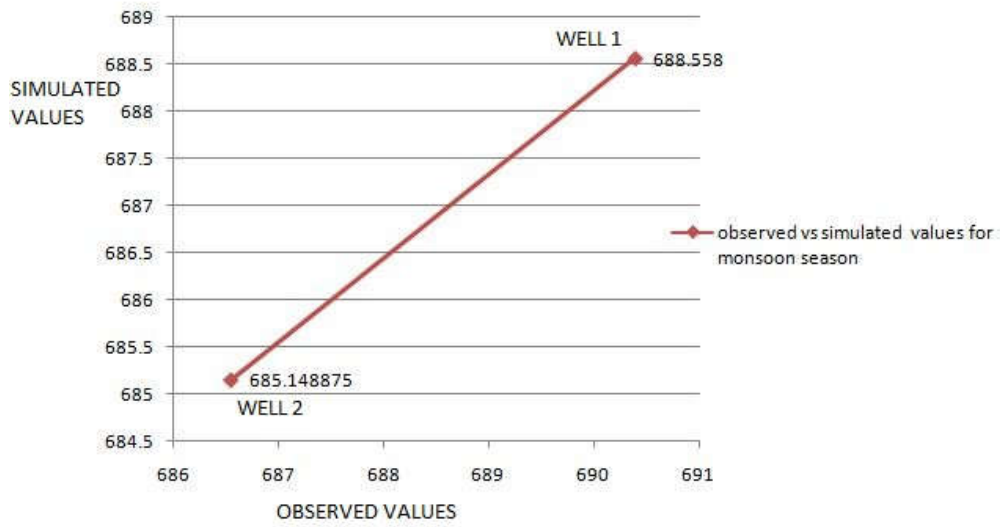


Fig. Graph for Observed VS Simulated values of water levels in well

SUMMARY

A study on the subject of effectiveness of irrigation tanks in recharging the aquifer system is prepared. Some description about the study area and methodology proposed are also discussed. Further, an outline of the future activities are also mentioned in this interim report.

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