GROUNDWATER UTILIZATION AND SUSTAINABILITY: A CASE STUDY OF PYDIBHEEMAVARAM INDUSTRIAL AREA, INDIA

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Abstract—The over extraction of groundwater from the coastal aquifers, result in reduction of groundwater resource and lowering of water level. In general, the depletion of groundwater level enhance the landward migration of saltwater wedge. Now a days the ground water extraction increases by year to year because increased population and industrialization. The ground water is the only source of irrigation, domestic and Industrial purposes at Pydibhimavaram industrial area, which is located in the coastal belt of Srikakulam district, India of Latitudes 18.145N 83.627E and Longitudes 18.099N 83.674E. The present study has been attempted to calculate amount of water getting recharged into this aquifer, status of rainfall pattern for the past two decades and the runoff is calculated by using Khosla's formula with available rain fall and temperature in the study area. A decision support model has been developed on the basis of Monthly Extractions of the water from the ground through bore wells and the Net Recharge of the aquifer. It is concluded that the amount of extractions is exceeding the amount of recharge from May to October in a given year which will in turn damage the water balance in the subsurface layers.

Keywords—Aquifer, decision support model, Groundwater extraction, Run off estimation and Rainfall.

I. INTRODUCTION

Most of the Earth's liquid freshwater is found, not in lakes and rivers, but is stored underground in aquifers. Indeed, these aquifers provide a valuable base flow supplying water to rivers during periods of no rainfall. They are therefore an essential resource that requires protection so that groundwater can continue to sustain the human race and the various ecosystems that depend on it. The contribution from groundwater is vital; perhaps as many as two billion people depend directly upon aquifers for drinking water, and 40 per cent of the world's food is produced by irrigated agriculture that relies largely on groundwater. In the future, aquifer development will continue to be fundamental to economic development and reliable water supplies will be needed for domestic, industrial and irrigation purposes. Aquifers serve the important function in the hydrological cycle of storing and subsequently releasing water. The water thus discharged from aquifer storage fulfils two major roles. First, it can benefit the environment by naturally maintaining and sustaining river flow, springs and wetlands. Secondly, it can provide a valuable water supply to meet the growing demand for water for drinking and domestic use, crop irrigation and industry [1]. Groundwater is basically a dynamic resource that may be expressed as the quantity of water measured by the difference between optimum and minimum water table within the aquifer, which is principally recharged from monsoon rainwater for the rest of the year. The groundwater extraction rate does not always correlate with groundwater level trends. Some counties with declining groundwater extraction still see declining groundwater levels. This combination of pumping and groundwater behavior is most notable in southern California, northern Nevada, southern Idaho, and some counties in northern Texas[2].Exploitation or over withdrawal of groundwater resources imposes stress on groundwater regime distorting the aquifer recharge-withdrawal equilibrium and as a result, a continuous decline in water table may occur cause much adverse surface and subsurface environmental effect [3].Groundwater recharge is influenced not only by climate variability but also human intervention including, unsustainable withdrawal and groundwater abstraction. Where excess surface water resources are available, even intermittently, it may be more economic to recharge groundwater than to forego already efficient irrigation production [4].

II. STUDY AREA

Pydibheemavaram is located in Ranasthalam mandal ,Srikakulam district of Andhra Pradesh, India. It is located in the geographical coordinate range of 18° 04′ 43.82″ N, 84° 37′ 03.34″ E and 18° 09′ 33.97″ N, 83° 40′ 56.70″ E. Srikakulam district has the longest coast line about 193 kms in the state of Andhra Pradesh. The Nagavali and Vamsadhara are the major rivers in Srikakulam district. The study area covers an area around 22 square kilometers .The area is recognized as a Industrial area by the Government of India. Many Industries viz. Andhra Organics, Dr.Reddy's Laboratories, Aurobindo, United breweries are situated in the Pydibhimavaram. The entire study area is cultivated and solely dependent on the ground water. The most appropriate way to represent recharge in a groundwater model depends upon both physical factors and study objectives. Where the water table is close to the land surface, as in humid climates or regions with low topographic relief, a constant-head

boundary condition is used. Conversely, where the water table is relatively deep, as in drier climates or regions with high relief, a specified-flux boundary condition is used [5].

III. METHODOLOGY

The monthly rainfall data is obtained from Chief Planning office, Srikakulam. The amount of evaporation in the study area is negligible and the entire study area is covered with Plantation crops. For the growing of crops the pumps are operated approximately 6 hours in a given day at different times and the average capacity of a pump in the area is $35m^3$/hr. With the help of local people and Direct observation the study area having Approximately180 open Wells in 2008-09,300 open Wells In 2009-10, 320 open Wells in 2010-11, 345open Wells in 2011-12 and 380 open Wells in 2012-13 are located at Boyapalem, Naruva, Akkayapalem, Mentada and Lova. The conceptual water balance model is developed to estimate monthly surface water balance components accounting rainfall, runoff, evapotranspiration, potable water supply, waste water discharges and surface water and groundwater extractions in the South Creek catchment [6].Net recharge into the aquifer is equal to actual recharge from precipitation minus Extractions from bore wells.

$$Rn = Rp-Eb$$

where, R_n = Net Recharge in given month, R_p = Recharge from precipitation, E_b= Gross extractions = $l \times n \times m \times C$,
l = no. of working days, m = hours of current supply, n = Number of pumps running and C = Average capacity of each pump.

A. Runoff Estimation

Many methods are used to estimate the runoff from a watershed. The curve number method, also known as the hydrological soil cover complex method, is a versatile and widely used procedure for runoff estimation [7]. This method includes several important properties of the watershed namely, soils permeability, land use and antecedent soil water conditions which are taken into consideration. In the present study Runoff is estimation by using khosla's formula. This formula is useful for the estimation of monthly rain fall by considering rainfall,, evaporation ,temperature and wind velocity.

Khosla's formula $R_m = P_m-L_m$

$L_m = 0.48T_m$ for $T_m > 4.5°C$
R_m = Monthly runoff in cm and $R_m > 4.5°C$
P_m = Monthly precipitation in cm
L_m = Monthly losses in cm
T_m = Mean monthly temperature of the catchment in °C.

The Runoff Calculations using khosla's formula from September to December is given in Table I.

B. Estimation of run off coefficient

The run off coefficient is used run off coefficient method

$$R= KP$$

wher>e R=Run off (cm)P= precipitation (cm) and K =Run off Coefficient

C. Estimation of Net Recharge

The atmospheric chloride mass balance (CMB) [8] method is used for estimation of net aquifer recharge in volcanic island environments. Net aquifer recharge means the ground water fraction that remains in the aquifer after discounting ground water up-take by direct evaporation and deep-rooted vegetation from direct rainfall and runoff infiltration through the vadosezone after some delay [8]. Two models of water balance equations were applied to estimate of the groundwater recharge on Ching-Shui watershed in Taiwan [9]

In the present study the recharge is estimated general hydrological equation of Infiltration /Recharge is equal to Precipitation in given month and Runoff of the corresponding month. The net recharge is calculated based on extraction from the aquifer and Recharge of the aquifer from precipitation.Net recharge calculations in Table III of Negative sign indicates extractions are more than recharge into the aquifer.

IV. RESULTS AND DISCUSSIONS

A. Rainfall Trend

The average annual rainfall is calculated for the particular year over the catchment. The Rain fall trend over the two decades as shown in Fig. 1. It is found that the annual rainfall does not follow a regular trend. The rainfall trend is observed for the last two decades and it shows that the peak annual rainfall of 1600mm is observed in the year 2010 over the catchment and least annual rainfall is observed in the year 2008.

B. Variation of Run off

Year wise run off estimation values (cm) from January to December in the respective years as shown in Table II. The runoff values were very poor in the first four months of every year from1996to 2013. Gradually runoff values increased as monsoon season started and again decreased in November and December. However, from the above calculated runoff values, It is inferred that the average runoff co-efficient for the catchment area is 0.318. It indicates that31.8% of the rainfall converts into runoff and remaining comprises of losses and

infiltration.

It was found there is no recharge in the summer season while extractions are common throughout the year. Especially, in the months of January, February, March, April, May have no recharge of ground water through precipitation which is causing drastic change in the water levels in summer (200feet) and monsoon seasons (50feet). Groundwater levels vary seasonally and annually. They are high at the end of the wet season and low at the end of the

dry season; likewise, they are high at the end of a wet year and low at the end of one or more dry years [10]

TABLE I

RUNOFF CALCULATIONS FROM SEPTEMBER TO DECEMBER

Year,Sept.	Rainfall (cm)	Temperature(°c)	Losses(cm)	Runoff (cm)	Year,Oct.	Rainfall (cm)	Temperature(°c)	Losses(cm)	Runoff (cm)
1996-97	13.1	29.2	14	0	1996-97	14.5	29.1	13.9	0.6
1997-98	24	29.2	14	10	1997-98	5.84	29.1	13.9	0
1998-99	22.8	29.2	14	8.8	1998-99	28.5	29.1	13.9	14.6
1999-00	16	29.2	14	2	1999-00	18.34	29.1	13.9	4.44
2000-01	9.01	29.2	14	0	2000-01	8.1	29.1	13.9	0
2001-02	12.8	29.2	14	0	2001-02	20.4	29.1	13.9	6.5
2002-03	8.3	29.2	14	0	2002-03	14.2	29.1	13.9	0.3
2003-04	11.67	29.2	14	0	2003-04	54.4	29.1	13.9	40.5
2004-05	10.6	29.2	14	0	2004-05	23.2	29.1	13.9	9.3
2005-06	41.7	29.2	14	27.7	2005-06	26.7	29.1	13.9	12.8
2006-07	18.5	29.2	14	4.5	2006-07	6.04	29.1	13.9	0
2007-08	33.2	29.2	14	20.2	2007-08	14	29.1	13.9	0.1
2008-09	23.6	29.2	14	9.6	2008-09	2.06	29.1	13.9	0
2009-10	13.5	29.2	14	0	2009-10	9.54	29.1	13.9	0
2010-11	20.5	29.2	14	6.5	2010-11	28.1	29.1	13.9	14.2
2011-12	18.7	29.2	14	4.7	2011-12	3.04	29.1	13.9	0
2012-13	25.3	29.2	14	11.3	2012-13	9.41	29.1	13.9	0
Year &November	Rainfall (cm)	Temperature(°c)	Losses(cm)	Runoff (cm)	Year &December	Rainfall(cm)	Temperature(°c)	Losses(cm)	Runoff (cm)
1996-97	2.92	25.1	12.04	0	1996-97	0.1	23	11	0
1997-98	1.74	25.1	12.04	0	1997-98	3	23	11	0
1998-99	14.1	25.1	12.04	2.06	1998-99	0	23	11	0
1999-00	6.52	25.1	12.04	0	1999-00	0	23	11	0
2000-01	0.3	25.1	12.04	0	2000-01	0	23	11	0
2001-02	12.6	25.1	12.04	0.56	2001-02	0	23	11	0
2002-03	0.1	25.1	12.04	0	2002-03	0	23	11	0
2003-04	0.26	25.1	12.04	0	2003-04	5.79	23	11	0
2004-05	1.04	25.1	12.04	0	2004-05	0	23	11	0
2005-06	6.11	25.1	12.04	0	2005-06	0	23	11	0
2006-07	1.7	25.1	12.04	0	2006-07	0	23	11	0
2007-08	0	25.1	12.04	0	2007-08	0	23	11	0
2008-09	0.9	25.1	12.04	0	2008-09	0	23	11	0
2009-10	7.8	25.1	12.04	0	2009-10	0	23	11	0
2010-11	15.6	25.1	12.04	3.56	2010-11	12.8	23	11	1.76
2011-12	0	25.1	12.04	0	2011-12	0.1	23	11	0
2012-13	26.66	25.1	12.04	14.62	2012-13	3.09	23	11	0

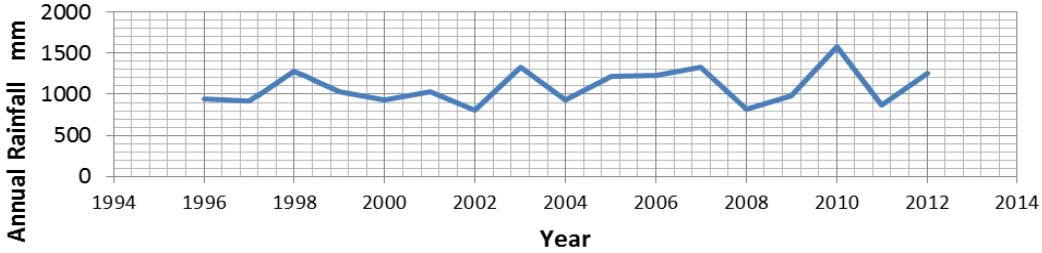


Fig. 1 Rainfall trend for last two decades

TABLE II
YEAR WISE RUN OFF ESTIMATION VALUES (CM) FROM JANUARY TO DECEMBER

Year	Jan	Feb.	Mar	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1996-97	0	0	0	0	0	0	0	2.3	0	0.6	0	0
1997-98	0	0	0	0	0	0	5.5	5.2	10	0	0	0
1998-99	0	0	0	0	0	0	9	1.3	8.8	14.6	2.06	0
1999-00	0	0	0	0	0	12.1	0	0	2	4.44	0	0
2000-01	0	0	0	0	0	6.1	0	16.4	0	0	0	0
2001-02	0	0	0	0	0	0	0	9.5	0	6.5	0.56	0
2002-03	0	0	0	0	0	2.3	0.8	2	0	0.3	0	0
2003-04	0	0	0	0	0	0	8.4	8.3	0	40.5	0	0
2004-05	0	0	0	0	0	1.8	6	0	0	9.3	0	0
2005-06	0	0	0	0	0	0	0	0	27.7	12.8	0	0
2006-07	0	0	0	0	0	0	13.6	26.7	4.5	0	0	0
2007-08	0	0	0	0	0	22.6	0	2.3	20.2	0.1	0	0
2008-09	0	0	0	0	0	0	8.4	8.3	9.6	0	0	0
2009-10	0	0	0	0	1.9	0	7.6	0.8	0	0	0	0
2010-11	0	0	0	0	0	0	10.1	12.3	6.5	14.2	3.56	1.76
2011-12	0	0	0	0	0	0	1.8	12.3	4.7	0	0	0
2012-13	0	0	0	0	0	0	13	3.5	11.3	0	14.62	0

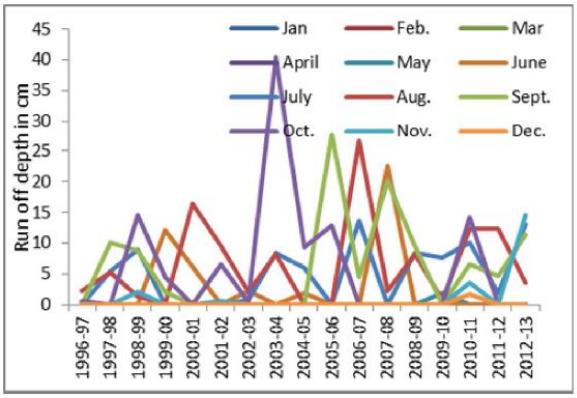


Fig. 2 Runoff variation from January to February

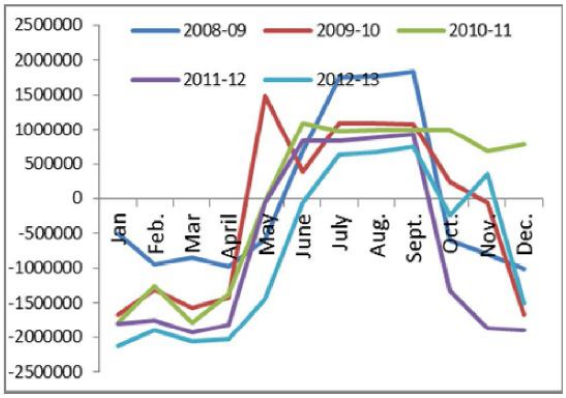
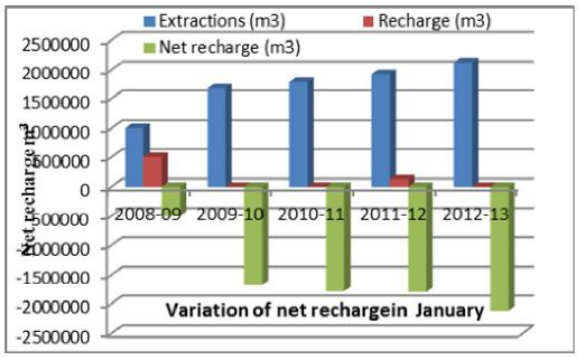
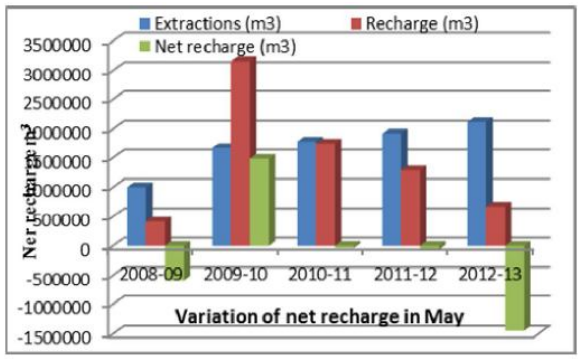


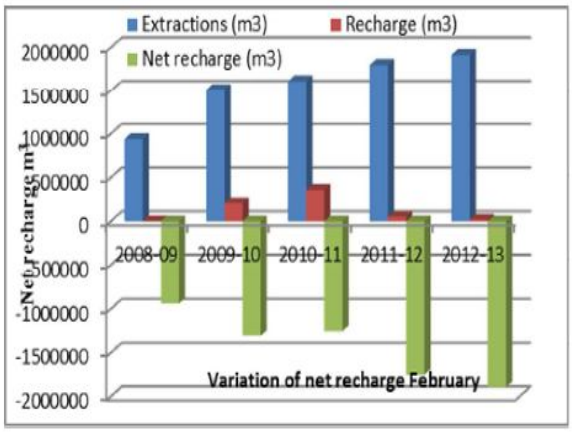
Fig. 3 variation of net recharge from Jan. to February

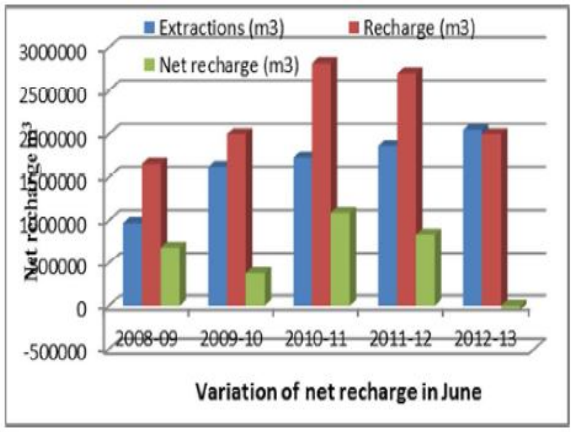
TABLE III
YEAR WISE NET RECHARGE VALUES (CM) FROM JANUARY TO DECEMBER

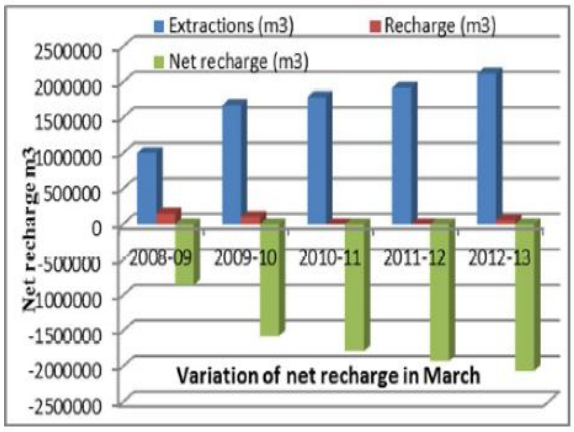
Year	Jan	Feb.	Mar	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2008-09	-500400	-939600	-852400	-972000	-586400	686000	1755600	1775600	1828000	-592900	-792000	-1004400
2009-10	-1674000	-1306000	-1574000	-1414000	1486000	380000	1086000	1086000	1080000	234000	-60000	-1674000
2010-11	-1785600	-1254800	-1785600	-1370000	-35600	1092000	974400	994400	994400	994400	680000	774400
2011-12	-1799100	-1752900	-1925100	-1815000	-63110	837000	834900	874900	937000	-1317100	-1863000	-1899100
2012-13	-2120400	-1895200	-2064400	-2032000	-1444400	-52000	639600	659600	748000	-238400	356000	-1502400

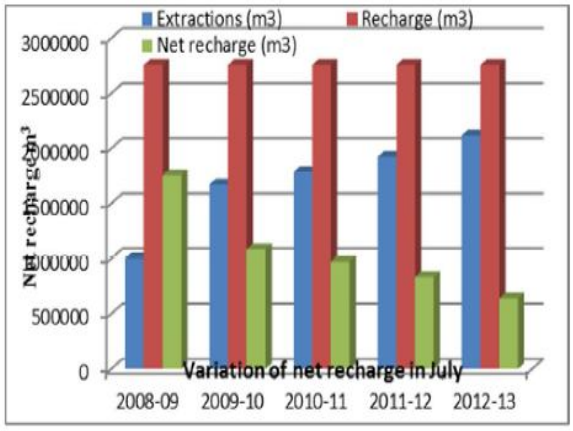


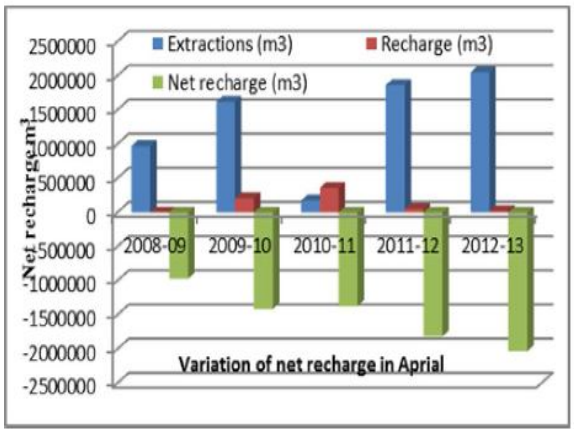












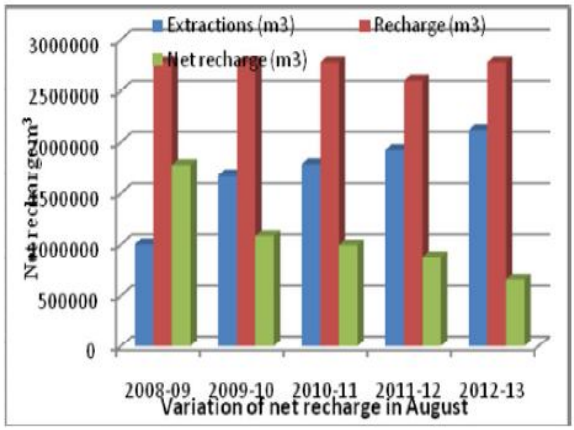
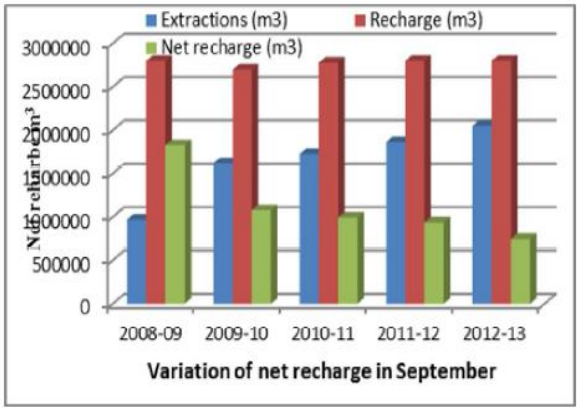
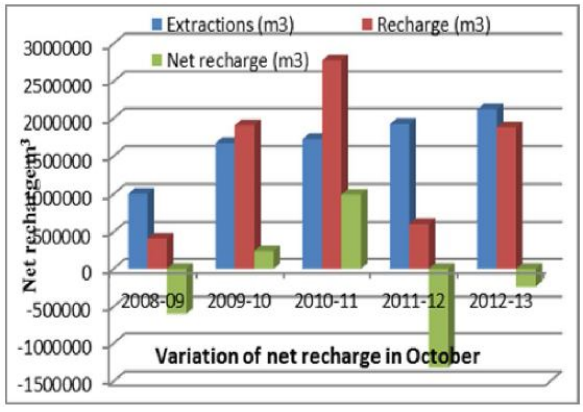
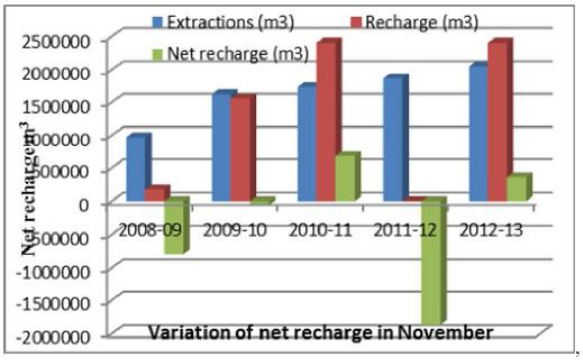


Fig. 4 Graphs of Extractions &Recharge from Jan. to Aug







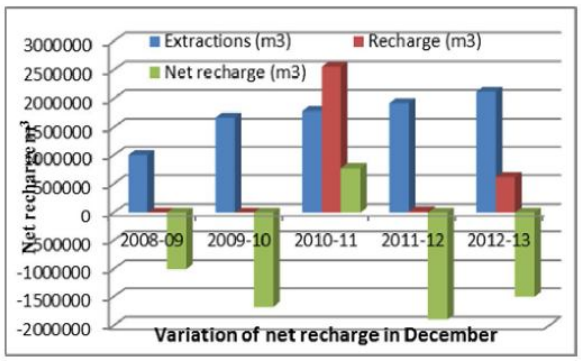


Fig. 5 Graphs of Extractions &recharge from Sep. to Dec

In the month January to May the runoff depth is almost all equal to zero, because the entire rain fall is converted in to ground water storage,. In the month of June the maximum run off depth is 22.6mm and average run off depth is 2.641cm. In the month of July the maximum run off depth is 13.6mmmm and average run off depth is 4.952. August the maximum run off depth is 26.7mm and average run off depth is 7.24. September the maximum run off depth is 27.7mm and average run off depth is6.19cm. The maximum runoff depth is occurred in the month of October is 40.5mm & average depth is 6.07. The runoff in the month of November and December is almost all zero it indicates the entire rain fall is converted in ground water. The graph of variation of discharge from January to February of respective years as shown in Fig. 2.

C. Net Recharge with Inflows and Extractions

The net recharge is estimated with the help of estimated extractions from the aquifer and inflows in to the aquifer. The details of net recharge values of the study area as shown in Table III and Graph of net recharge values with reference line as shown in Fig. 3.

It is found that the months of January, February, March and April are adversely affected by the poor Net recharge of ground water due to low precipitation. This will adversely affect the ground water levels. Due to this phenomenon, it is observe that drastic changes in the levels of water in monsoon and summer season. Proper ground water management is required in these months by providing an external source of water for irrigation especially in summer season. In this type of conduction groundwater allocation based on marginal value of water has been suggested as the panacea for falling groundwater table [11]. In the months of June, July, August and September the recharge of the aquifer is more than the extractions of the ground water and in the months of October and November net recharge is negative at 2009 and 2012.and December month net recharge values having negative values as shown in Figs. 4, 5.

CONCLUSIONS

The average Run off coefficient is calculated as 0.318. It can be estimated that 31.8% of precipitation in the area converts into runoff and the remaining includes Infiltration, Evaporation losses and other minor losses. It is observed that the months of January, February, March, April and May are critical for the ground water usage as ground water extractions are more when compared with the recharge through rainfall. A proper ground water management is required especially where the net recharge having negative values for better yield of the ground water from the aquifers. It is concluded that the rate of extractions is increasing periodically due to which high stress is being developed on the ground water cycle balance. Artificial recharge techniques should be adopted along the coastal belt to maintain the ground water balance and the rate of extractions should be controlled.

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