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# Evaluation of Recharge Basin Technique for Junagadh Region, India

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**A B S T R A C T**

Recharge basin structure having masonry spillway was evaluated in the experiment. The quantities of available runoff water under the maximum rainfall up to 5 consecutive days were estimated. Hydrograph was prepared by recording water level in the basin against time for duration of live storage period. The curve of water spreading area versus depth of water was drawn using contour map of basin for the determine evaporation loss and storage capacity of basin. Rainfall data analysis of Junagadh showed that average annual rainfall of Junagadh was 937 mm, highest 2794 mm, lowest 146 mm and rainfall of 15years return period was 1533 mm. Also annual maximum, average, minimum and 15 years return period of rainy days were 76, 40, 13 and 54 respectively recorded for Junagadh. The curve number technique was adopted for the estimation of annual and daily runoff from catchment area of basin. It was found that values for maximum, average, minimum and 15 years return period of runoff were 1830 mm, 253 mm, 0 mm and 516 mm respectively. It was also found that values for highest, average, lowest, and 15 years return period of per day runoff were 976 mm, 107 mm, 0 mm and 190 mm respectively. Recharge basin maximum storage capacity and maximum water spread area were estimated to be 3182 cu.m and 7057 sq.m respectively. During monsoon season total of 33381 cu.m of runoff volume was generated from catchment area of recharge basin, out of which 15510 cu.m was collected in the basin and collected runoff was contributed as groundwater recharge and 17870 cu.m was escaped from the basin. Evaporation loss from the basin was estimated as 657 cu.m. So, runoff collected minus evaporation loss was consider as effective recharge and it was 14853 cu.m. under recharge basin structure in Junagadh region

## Introduction

Groundwater is the part of precipitation that seeps down through the soil until it reaches rock material is saturated with water. Water in the ground is stored in the spaces between rock particles. Groundwater slowly moves underground, generally at a downward angle (because of gravity), and may eventually seep into streams, lakes, and oceans. Water movement in aquifer is highly dependent of the permeability of the aquifer material. Permeable material contain interconnected cracks or spaces that are both numerous enough and large enough to allow water to move freely. In some permeable material groundwater may move several meters in a day; in other places. It moves only a few centimeter's in a century. Groundwater moves very slowly through relatively impermeable material such as clay and shade United States Geological Survey (USGS).

Groundwater recharge can be defined as the amount of water that's joins the groundwater table vertically and horizontally either through infiltration from ground surface or any surface water body including artificial recharge structures.. Groundwater recharge may be natural or artificial, the natural groundwater recharge is the recharge through rainfall infiltration and or rivers, streams, etc. On the other hand, artificial recharge is the recharge through artificial means like tanks, wells, pits, shafts, etc. Groundwater recharge is the component of infiltration into subsurface that joins groundwater through unsaturated zone, the river bed or lake ground. Groundwater recharge is the water that has soaked into (infiltration) the ground, and moved through pores and fracture in the soil and rock to the water table (http://www.innovateus.net /earth-matters/what-groundwater-recharge). The principal source for replenishment of moisture in the soil water system and recharge of ground water is rainfall. Moisture movement in the unsaturated zone is controlled by suction pressure, moisture content and hydraulic conductivity relationships. Groundwater recharge maintain the supply of freshwater to wells, streams, springs and wetlands, which support the humans, plants and animals that are the part of the ecosystem. Present study was carried out with the objectives, to evaluate runoff potential by curve number technique for Junagadh region and to evaluate groundwater recharge potential under recharge basin structure.

## Materials and Methods

### Analysis region

The experiment on groundwater recharging by recharge basin technique in Junagadh region was carried out considering existing recharge basin structure constructed under AICRP on irrigation water management at Instructional farm, Collage of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh It is located about 1.5 km South-West of Junagadh town, bearings are 21031′ N latitude and 70036′ E longitude and elevation above mean sea level is 82.92 m. The total geographical area of CAET Instructional Farm is 19.14 ha. The soil of the study area was observed to be sandy clay loam to silt loam in texture. The climate of the study area is subtropical and semi-arid. The average annual rainfall (1957–2014) was 937 mm. The main source of ground water recharge is rainfall, through infiltration, deep percolation and seepage.

### Data collection

The daily rainfall and annual rain fall data records of 58 years (1957-2014) and the climatic data records of year 2014 were collected from the JAU Agro meteorological Observatory, JAU, Junagadh.

### Recharge basin structure

### Runoff computation (Rational Method)

This is a most common method used to predict the peak runoff rate defined as the maximum runoff, to be used as capacity for a given structure that must carry the runoff. Rational method used the following formula for computing the design runoff (Ramser, 1972).

$$Q = \frac{CIA}{360}$$

Where,

Q = Peak runoff rate, $m^3/s$

C = Runoff coefficient in rational method,

I = Rainfall intensity (mm/h) for a duration equal to time of concentration,

A= Watershed area (ha).

## Runoff coefficient in rational method

The land Use map of catchment area of recharge basin and location of structure is shown in the figure 1 weighted runoff coefficient 'C' value of rational formula estimated as table with the help of the land use map of catchment area of recharge basin The results data are presented in Table 1.

The data presented in Table 1 showed that the values of weighted runoff coefficient 'C' value of rational formula

*Weighted,* $C = \Sigma a_i \times C_i / \Sigma a_i$ (1)
= 43888.45 / 98608.15 = 0.4451

Estimation of time of concentration ($T_c$) (2)

$T_c = [(2 \times L \times n)/S_o^{1/2}]^{0.467}$

Where,

L = Maximum length of overland flow, m; $S_o$ = Slope in fraction; $T_c$ = Time of concentration, min.; n = Manning's coefficient From the recharge basin catchment geometry,

L = 584 m, H= 3.5 m, $S_o$ = 0.006, n = 0.04 taken

So $T_c$ = 19.88 min = 0.3315 hours.

## Rainfall intensity (mm/h) for a duration equal to time of concentration

The following model of rainfall intensity-duration-frequency relationship was developed for the design of water harvesting-cum groundwater recharging structures etc for scientific community/ NGOs/Government sectors working on implementations of projects on water harvesting-cum-groundwater recharge by AICRP on irrigation water management, JAU- Junagadh center in 2006-07 was adopted.

$$I = \frac{68.86\, T^{0.265}}{(t + 0.86)^{1.022}} \quad (3)$$

Where,

I= rainfall intensity (mm/hr); T= return period (years); t = duration (hours); Rainfall intensity was estimated for 15 years return period and Considering 15 year life of structure and duration equal to time of concentration.

So, I = 118.04 mm/hr

## Runoff measurement

The peak rate of runoff for 9.86 ha area was calculated by using Rational formula by taking the value of runoff coefficient as 0.445, rainfall intensity as 118.04 mm/hr. by this way the attained peak rate of runoff Q is 1.4396 $m^3/s$

## Rainfall analysis

A ground water recharge system collects rainwater from the catchments area during rainy days. Therefore, the amount and distribution of rainfall are major factors influencing the systems. Recurrence interval T is the average number of years during which a storm of given magnitude (maximum depth or intensity) may be expressed to occur once. Frequency F is the percentage of years during which a storm of given magnitude may be equaled or expressed.

Kimball's method, (Kimball, 1960)

$$T = \frac{n+1}{m} \quad (5)$$

And the frequency F (expressed as percent of time) of that storm magnitude (having recurrence interval T) is given by

$$F = \frac{1}{T} \times 100\% \quad (6)$$

This probability that a T-year storm (and frequency F=1/T×100 %) may not occur in any series of N years is

$$P_{(N,0)} = (1 - F)^N \quad (7)$$

And that it may occur is

$$P_{Ex} = 1 - (1 - F)^N \quad (8)$$

Where,

$P_{EX}$ = probability of occurrence of a T-year storm in N-years.

## Estimation of runoff

The land use map of catchment area of recharge basin as per figure 6 was prepared to estimate curve numbers and runoff. Starting from 1957 to 2014 of 58 years rainfall data were collected from the JAU observatory. The data were processed to determine year wise 1 to 5 days maximum rainfall by adding consecutive rainfall of neighboring rainfall values daily run off for all 58 years were estimated as per curve number method.

The maximum one day, average run off and yearly runoff of were obtained. The runoff values were arranged in descending order. These runoff values for 15 years return period from catchment area of recharge basin were estimated. The following expressions were used for the runoff estimation by CN Method (Hawkins, 1978).

CN = 2540 / 25.4 + S (9)
$Q = (P - 0.2S)^2 / (P + 0.8S)$ (10)

Where,

CN = Curve number, S = Surface retention, mm, P = Rainfall, mm, Q = Run off, mm

## Hydrograph

Hydrograph is a graphical representation of water level in the basin against duration of live storage, periodic live storage in recharge basin like structure may observe in monsoon season only. Starting from month of June to end of monsoon that is month of October, hydrograph was developed by recording periodic water level observation of basin against time.

## Capacity stage curve

The water storage capacity against depth of water was developed by preparing contour map of water storage area of basin and storage volume was calculated by multiplying average area of two consecutive contour areas with depth between that two contours. Finally curve of cumulative capacity versus cumulative depth up to maximum depth was prepared.

## Water spread area stage curve

The water spreading area versus depth of water curve was prepared using contour map of basin.

## Recharge

Preparing water balance, daily runoff from catchment area, minus spill over escaped water, minus evaporation loss was calculated and recharge was estimated.

## Results and Discussion

The results obtained were analyzed and presented as follows. Possibilities of water harvesting and recharge under recharge basin system were analyzed and presented below.

## Rainfall analysis and runoff potential

The rainfall of the location plays important role, which is main source of basin catchment area runoff. Annual daily rainfall data collected from JAU observatory of 58 years.

## Hydrograph

Hydrograph was drawn by recording water level in the basin against time for duration of live storage period. Water depth in the basin against time was recorded by depth gauge. For the year 2014, monsoon season rainfall data were collected and the runoff generated for each rainfall event was calculated by CN method. Based on the runoff data the hydrograph were developed and is presented in Figure 2. It was observed from hydrograph that during 16$^{th}$ June, 18$^{th}$ July, 1$^{st}$ 2$^{nd}$ & 3$^{rd}$ August and 5$^{th}$ September, 2014 runoff was higher.

## Capacity stage curve

For the preparation of capacity stage curve contour map as per shown in Figure 4 of storage area of basin was prepared. The curve of cumulative capacity versus cumulative depth (up to spill level) was prepared and presented in the Figure 3 and Table 2.

Highest elevation of the basin was observed to be 1.10 m and open area for the elevation 7907 $m^2$. Total volume of the basin was observed 5545 $m^3$

**Table.1** Weighted C value of rational method for catchment of recharge basin

| Plot No. | Area in sq.m | land use | Slope | Soil | C value | ai.ci | Remarks |
|---|---|---|---|---|---|---|---|
| $a_1$ | 16401.95 | H | < 5% | Clay and silt Loam | 0.3 | 4920.585 | H = Horticulture<br>WL = West Land<br>C = Cultivated land<br>FS = Farm shed |
| $a_2$ | 15440.02 | C | < 5% | | 0.5 | 7720.01 | |
| $a_3$ | 7227.69 | C | < 5% | | 0.5 | 3613.845 | |
| $a_4$ | 5464.94 | C | < 5% | | 0.5 | 2732.47 | |
| $a_5$ | 4304.015 | C | < 5% | | 0.5 | 2152.0075 | |
| $a_6$ | 10725.07 | C | < 5% | | 0.5 | 5362.535 | |
| $a_7$ | 6565.84 | C | < 5% | | 0.5 | 3282.92 | |
| $a_8$ | 1610.44 | FS | < 5% | | 0.95 | 1529.918 | |
| $a_9$ | 8717.69 | WL | < 5% | | 0.3 | 2615.307 | |
| $a_{10}$ | 9900.11 | C | < 5% | | 0.5 | 4950.055 | |
| $a_{11}$ | 5581.97 | H | < 5% | | 0.3 | 1674.591 | |
| $a_{12}$ | 6668.41 | C | < 5% | | 0.5 | 3334.205 | |
| $\Sigma a_i$ | 98608.15 | | | | $\Sigma a_i.c_i$ | 43888.45 | |

**Table.2** Recharge basin depth capacity observations

| Contour | Elevation (m) | Open area ($m^2$) | Volume($m^3$) | cum. Volume ($m^3$) |
|---|---|---|---|---|
| 69.90 | 0.00 | 263 | 0 | 0 |
| 70.00 | 0.10 | 1044 | 65 | 65 |
| 70.10 | 0.20 | 2473 | 176 | 241 |
| 70.20 | 0.30 | 3537 | 301 | 542 |
| 70.30 | 0.40 | 4378 | 396 | 938 |
| 70.40 | 0.50 | 5186 | 478 | 1416 |
| 70.50 | 0.60 | 5910 | 555 | 1971 |
| 70.60 | 0.70 | 6595 | 625 | 2596 |
| 70.70 | 0.80 | 7057 | 683 | 3278 |
| 70.75 | 0.85 | 7345 | 360 | 3638 |
| 70.80 | 0.90 | 7455 | 370 | 4008 |
| 71.00 | 1.10 | 7907 | 1536 | 5545 |

**Fig.1** Land use map of catchment area of recharge basin

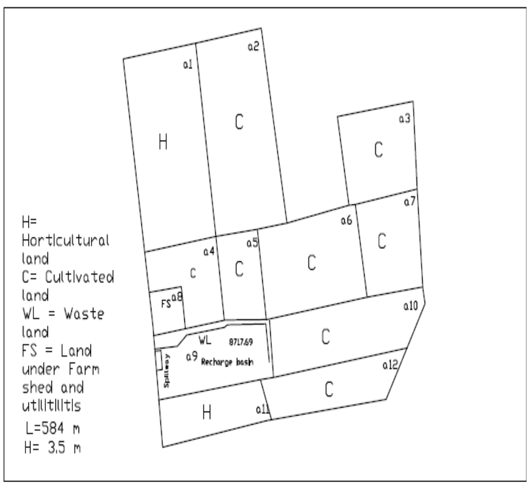



**Fig.2** Basin hydrograph

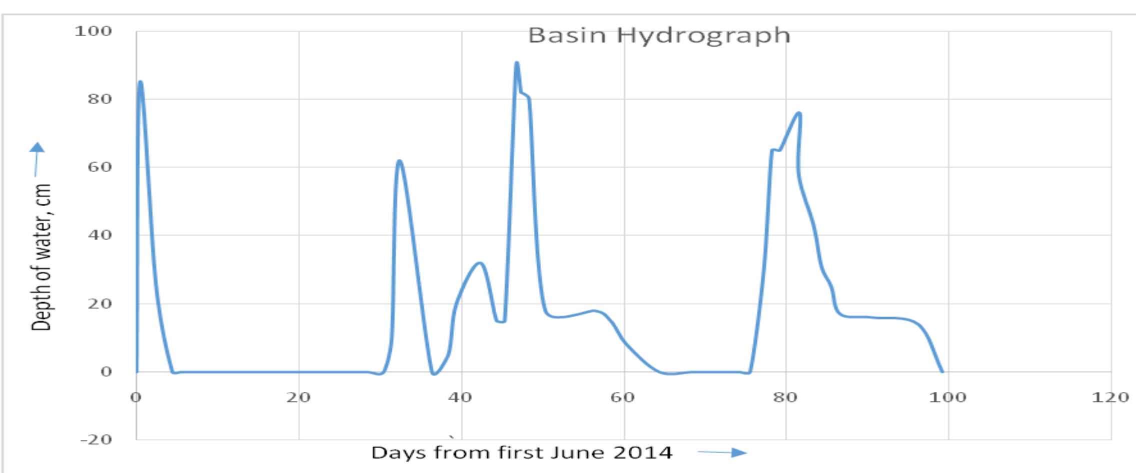


**Fig.3** Curve of cumulative capacity versus cumulative depth

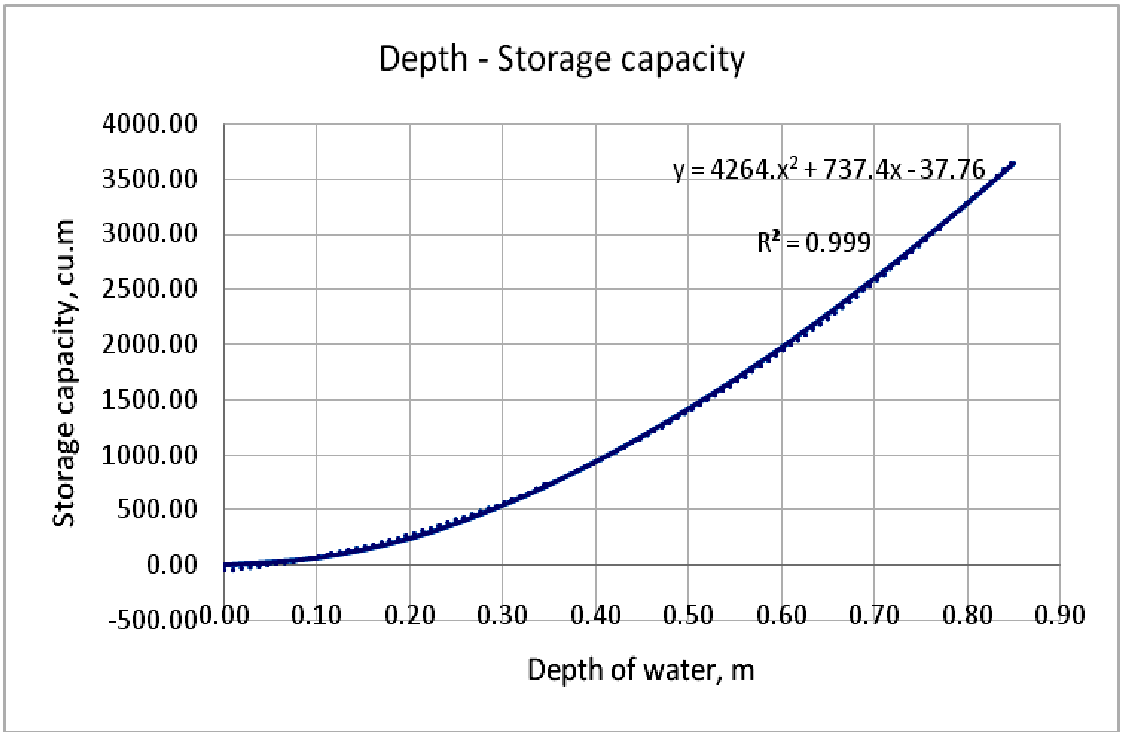



**Fig.4** Contour map of recharge basin storage area

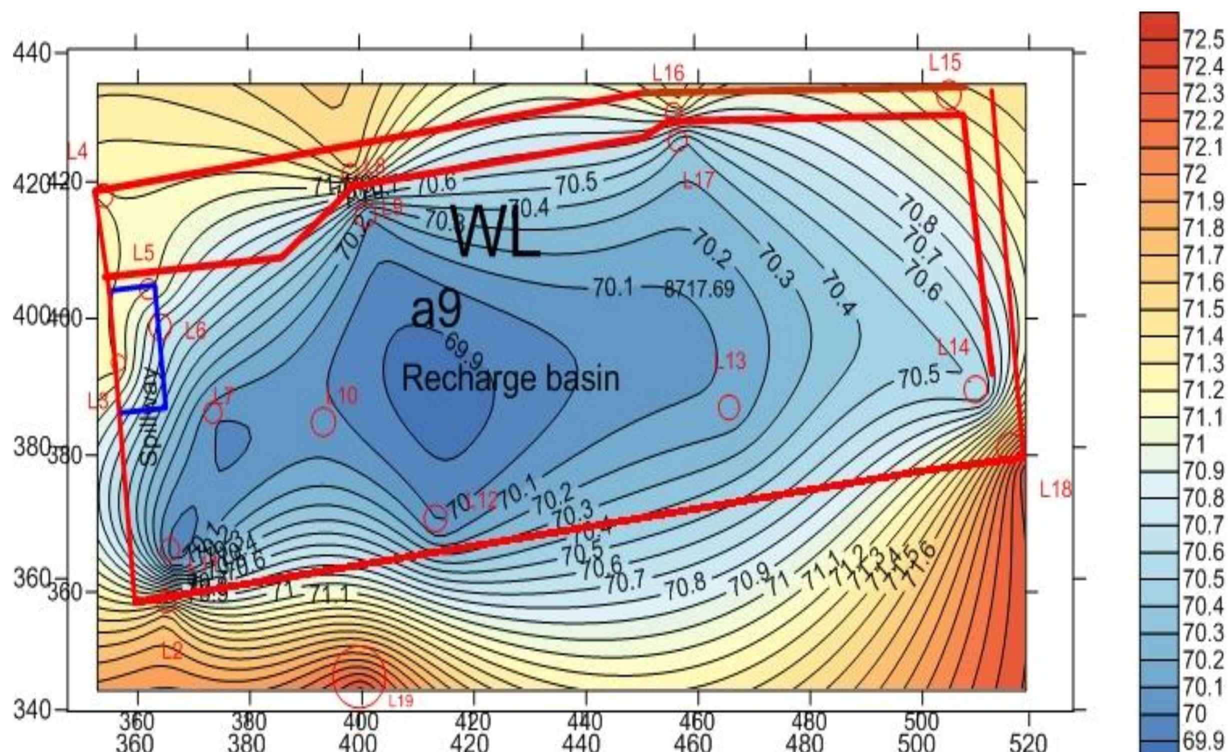


**Fig.5** Water spread area – stage curve of basin

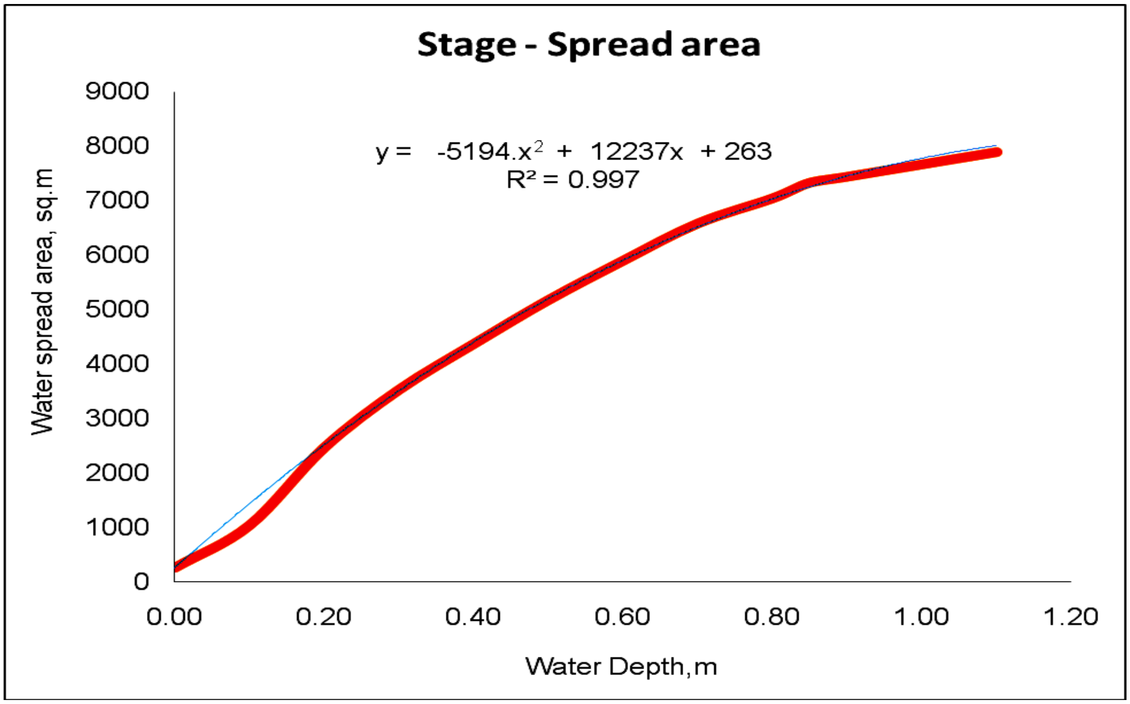



**Fig.6** Rainfall, runoff and retention capacity of the basin

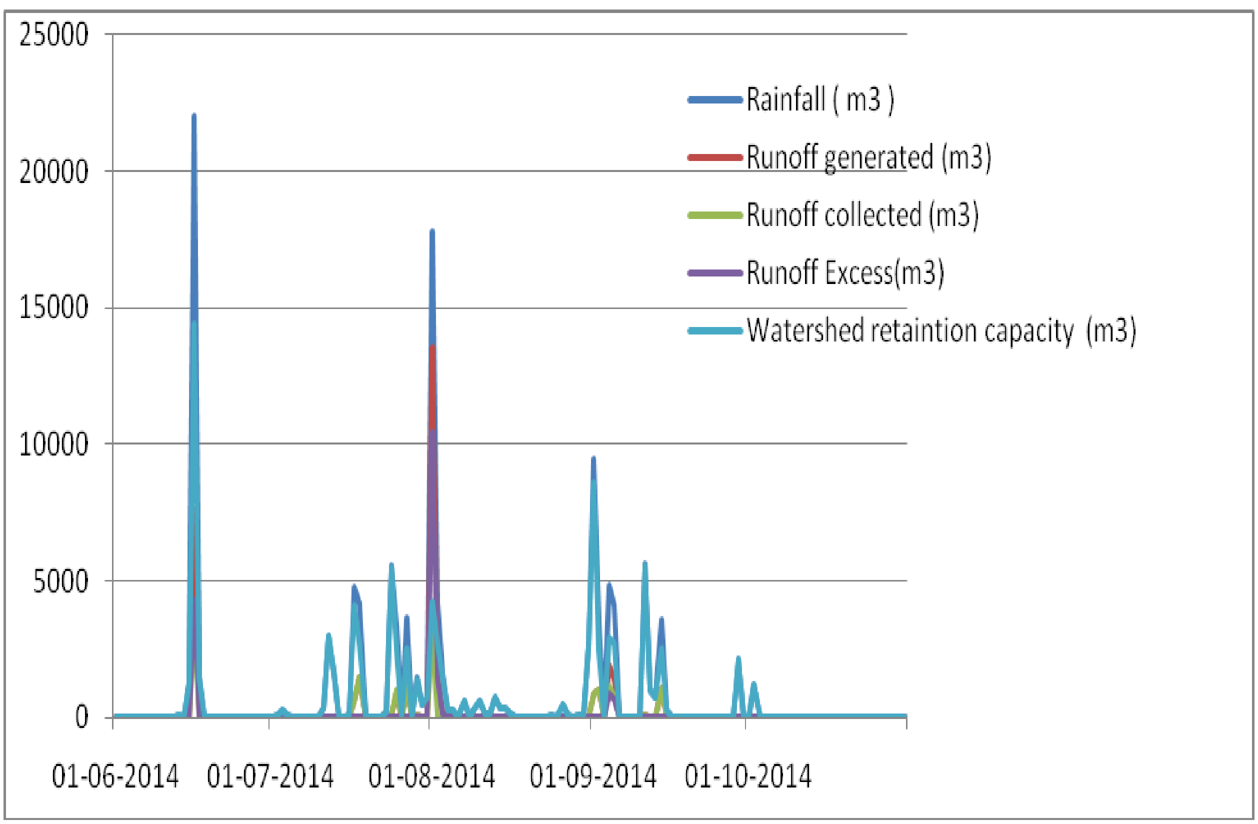
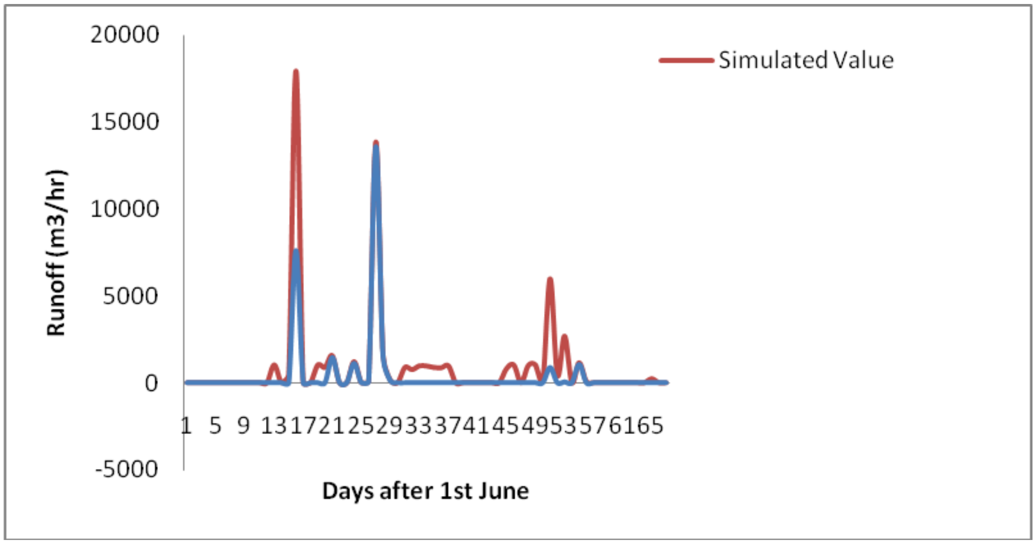


**Fig.7** Observed and simulated runoff generated after 1st June in 2014




**Water spread area stage curve**

The curve of water spreading area versus depth of water was prepared using contour map of basin to determine evaporation loss and presented in Figure 4.

**Runoff generated**

Figure 6 show the rainfall, runoff and retention capacity of the basin was calculated and shown in graph. The rainfall for the year 1957 to 2014 was collected. The runoff generated was measured at the basin structure and simulate it with calculated runoff using CN method. It was observed collected volume of runoff i.e. observed volume of runoff was lesser than simulated volume of runoff show Figure 7. It was observed from hydrograph, days on 16$^{th}$ June, 18$^{th}$ July, 1$^{st}$ 2$^{nd}$ & 3$^{rd}$ August and 5$^{th}$ September, 2014 having higher runoff.

**Recharge**

Paring water balance, daily runoff from catchment area, minus spill over escaped water, evaporation loss were determined. Rainfall data analysis of Junagadh showed average annual rainfall of Junagadh is 937 mm, highest 2794 mm, lowest 146 mm and rainfall of 15 years return period is 1533 mm. Also rainy days maximum, average, minimum and 15 years return period of rainy days are 76, 40, 13 and 54 respectively recorded for Junagadh. The curve number technique was adopted for the estimation of annual runoff from catchment area of basin. It was found maximum, average, minimum and 15 years return period of runoff 1830 mm, 253 mm, 0 mm, 516 mm respectively. It was found that highest, average, lowest and 15 years return period of per day runoff 976 mm, 107 mm, 0 mm, 190 mm respectively. Recharge basin maximum storage capacity and maximum water spread area were estimated 3182 cu.m and 7057 sq. m respectively. During monsoon season total 33381 cu.m of runoff volume was generated from catchment area of recharge basin, out of that 15510 cu. m was collected in the basin and 17870 cu.m was escaped from the basin. Evaporation loss from the basin was estimated as 657 cu.m. So, Total recharge observed was 14853 cu.m.

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