GROUND WATER RECHARGE IN WAGARWADI WATERSHED THROUGH RECHARGE PROCESS AND GROUND WATER FLOW MODELS

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ABSTRACT The Wagarwadi watershed covering 324 ha in Parbhani District, Maharashtra, India is in the semi tropics and receives a mean annual rainfall of 900 mm. The recharge of the aquifer, due mainly to rainfall during the monsoon season, was modeled using daily rainfall and pan evaporation data for 11 years. The recharge water balance accounts for interception loss, surface runoff, evapotranspiration and soil moisture status. Aquifer parameters viz., transmissivity and specific yield were estimated through pump tests. The aquifer system was modeled as a single weathered leaky aquifer using integrated finite technique on a nested square grid. Steady state conditions were simulated assuming an equilibrium condition during May 1997 which was considered as the initial water level. During steady state calibration, the transmissivity values were modified in some pockets to match the computed and observed water level contours. Irrigation return seepage was found to be contributing significantly to the groundwater regime. The monthly recharge estimates of the model were fed as input to the aquifer model in transient condition. The aquifer model was refined and the monthly recharge estimates were found to be adequate for simulation of water table behaviour. The monthly recharge estimates are very helpful in determining the magnitude of time – variant input due to rainfall to the aquifer system. The soil and water conservation practices in the watershed have increased the soil moisture status and recharge of water in the wells. Ultimately there was an increase in the area under double cropping along with assured irrigation for orchards.

Keywords: Ground water, Recharge process, Watershed, Modeling, Simulation.

INTRODUCTION The Wagarwadi watershed, covering about 324 hectares in Parbhani district, Maharashtra has been developed by Marathwada Agricultural University, Parbhani since 1992 (Fig.1). The rainfall occurs mostly during the southwest monsoon during June – September with a minor input during northeast monsoon and the total normal annual rainfall is about 990 mm. Two watercourses form a dendritic drainage and join the stream leaving Aundha tank. Groundwater occurs under phreatic and semi-confined conditions in the weathered and fractured basaltic rocks at shallow depth. Dug wells tap groundwater for irrigation and drinking water use. The water table data has been

monitored for every month and the regional water table configuration indicates that there is no flow entering the watershed from the east and west, whereas some small lateral flow could enter the region from north. Groundwater outflow and surface runoff from the watershed escapes through the stream channel in the south. Hydraulic gradient is steep towards the stream course and as such stream gains water from groundwater effluence from the aquifer. The aquifer thickness along the stream is about 30 m (Gore et al, 1998).
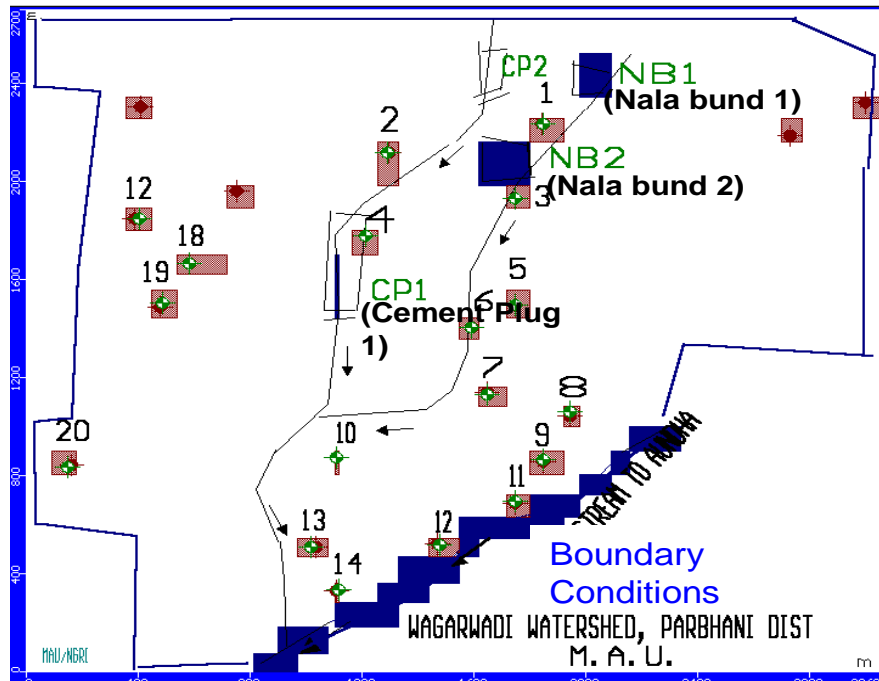

Fig.1. Location of water harvesting structure in Wagarwadi watershed, Parbhani district, Maharashtra

AQUIFER SYSTEM Groundwater occurs under phreatic conditions within the saturated intergranular pore spaces in weathered rocks and also in the secondary porous vesicles associated with red bole intertrappean beds of weathered, jointed and fractured basaltic strata. The permeability in the basaltic rocks is due to vesicular fractures and interconnections between them and the weathered horizons on the top. The cooling joints, formation of the typical columnar structure and the joint system are mainly responsible for percolation of rainwater to the weathered zone.

The red bole inhibits movement of groundwater but its position in the lava sequence indicates the presence of a permeable water-bearing zone underneath it. Weekly water table data has been collected in 16 observation wells since January, 1992 (ref. Fig.1). Groundwater fluctuations are about 2-5 m and water table follows the topography (Gore, 1995). Under normal conditions, about 90% of the area forms the catchment for groundwater recharge, whereas under pumping conditions even the rest of area could contribute to groundwater recharge. Water levels in dug wells and bore wells indicate same elevation, therefore there seems to be good interconnection between phreatic and piezometric heads in the watershed.

Central Ground Water Board (CGWB) had carried out aquifer performance tests on selected dug wells in Deccan traps to a depth of 10-15 m in the Godavari River Basin, comprising parts of Aurangabad and Parbhani districts, Maharashtra (Agarwal, 1987).They reported that the water discharged during pumping tests was mainly withdrawn from the storage of the well and estimated transmissivity values are in the range of 5- 40 m^2/day. The transmissivity value estimated in the Wagarwadi watershed is 80 m^2/day with a specific yield of 2-3% (Gore, 1995). Narayanpetkar et al (1993) had reported transmissivity values for basaltic formations of western Maharashtra varying in the range of 2 – 200 m^2/day. The simulated permeability is varying from 1 – 1.4 m/day in the model (ref. Fig. 2). Groundwater recharge has been estimated from the water balance model using daily rainfall and pan evaporation data during 1983 – 1993 period. The average annual recharge worked to be 131.8 mm for an average annual rainfall of 990 mm (Gore et al, 1996). The groundwater recharge occurs mostly during late July, August and September due to monsoon rainfall.
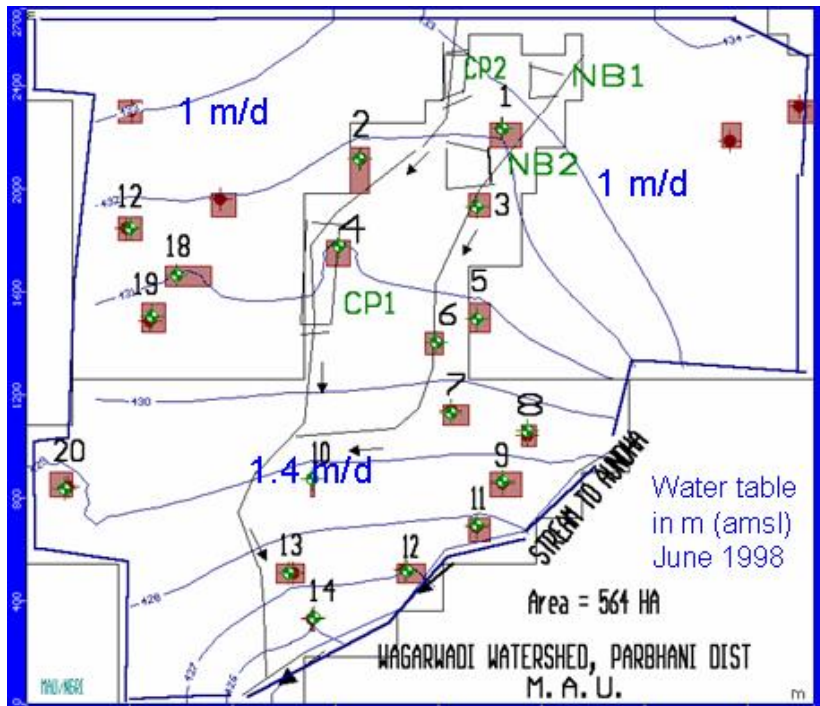
Fig.2. Computed Water table contours in m (amsl) June 1998 in

Wagarwadi Watershed

GROUNDWATER FLOW MODELING Two nala bunds and two cement plugs have been constructed on the stream channels in the watershed. The details of average values of impounded water in both nala bunds 1& 2 and cement plug 1 have been shown in Table 1. The water table configuration of June 1997 has been assumed to be under equilibrium condition and thus has been considered as the initial water level for steady state condition. As per the water level contours of June 1997, no flow could enter from the east and west boundaries. The wells are pumping at the rate of 50 m^3/day and it has been assigned to each well in the model. Lateral inflow occurs through the north and stream nodes have been simulated through river package of visual MODFLOW (Guiger and Franz, 1996). The groundwater heads for steady state condition in the model have been computed using MODFLOW (McDonald and Harbaugh, 1988). The computed water levels and observed water levels are found matching closely and the general flow direction is towards the stream (ref. Fig. 2).

Table 1 Water harvesting structures in Wagarwadi Watershed & average values during 1997-2000

Water Harvesting Structure	Catchment Area (hectares)	Water Spread Area	Average impounded Water (in m^3)	Seepage Loss (in m^3)
Nala Bund 1	41	100 m x 150 m	22500	12168 (54%)
Nala Bund 2	59.6	140 m x 180 m	36400	21923 (60.2%)
Cement Plug 1	4.4	3 m x 300 m	6880	5600 (80%)

Specific yield of 0.015 has been uniformly assigned to all cells for carrying out transient simulation in the groundwater flow model. Normal monthly rainfall recharge has been assigned in monthly time steps during transient simulation during 1997-98 to 1999-2000. Additional recharge through the impounded water in the water harvesting structures has been simulated through river package using monthly stage readings in the nala bunds and cement plug. The intervening hydraulic connection between the nala bund and aquifer has been given as 200 m^2/day. The river stages in the nala bunds have been assigned for about 9 months period starting from June to March. The computed hydrographs have been compared with observed hydrographs at the observations wells OB1, OB3 and OB4 close to the nala bunds 1& 2 and cement plug 1 respectively (Figs. 3, 4 & 5).
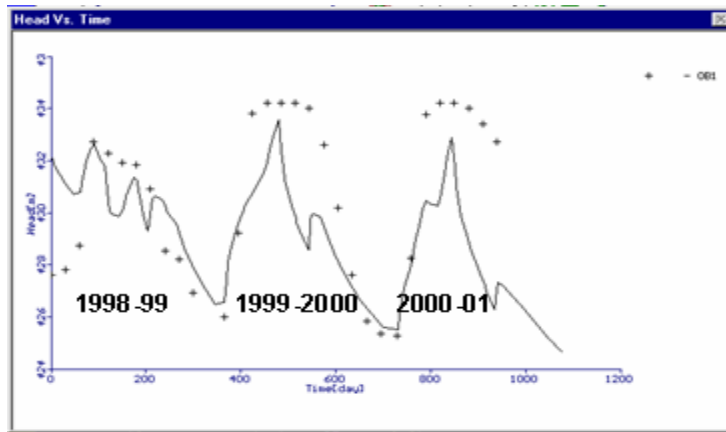
Fig.3. Comparison of Well hydrographs at OB1 near Nala Bund 1
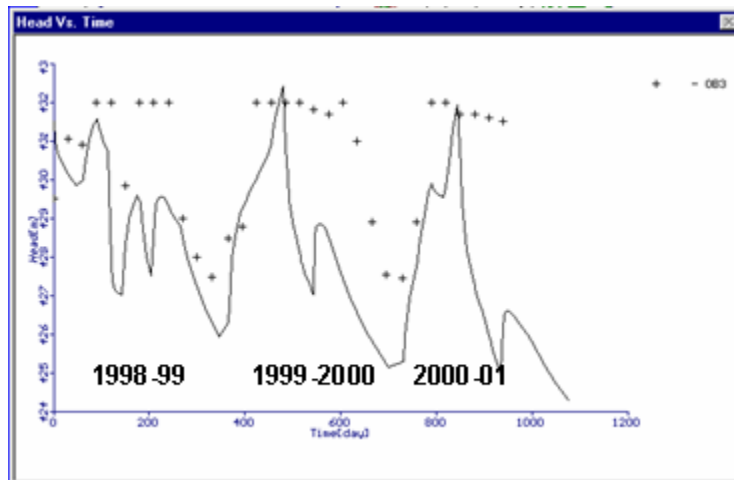during 1998-2001

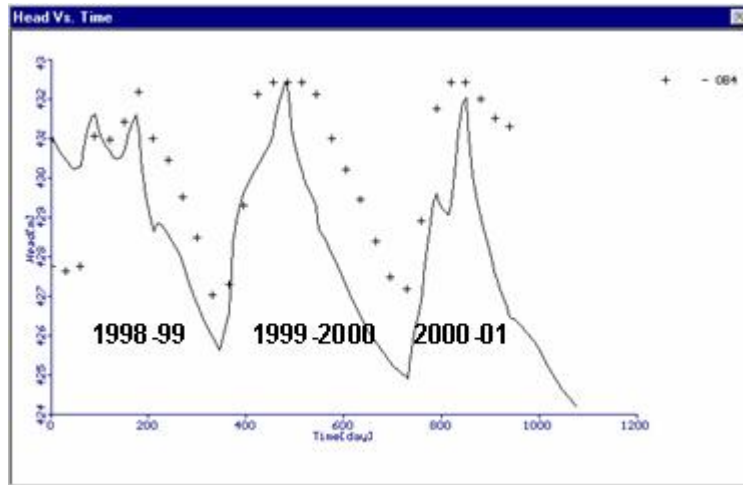Fig.4. Comparison of Well hydrographs at OB3 near Nala Bund 2

during 1998-2001

Fig.5. Comparison of Well hydrographs at OB4 near Cement Plug 1

during 1998-2001

IMPACT OF WATER HARVESTING STRUCTURES Further the groundwater budget of the model has been worked out by defining zones around Nala bund and cement plug and through deploying of zone budget package of visual MODFLOW. The zone budget has been computed for every month for different zones for the three-year period and average for year has been worked out and has been compared with impounded water in the water harvesting structures (ref. Table1). Zone budget indicate that there has been about 54% of impounded water from Nala bund 1 is replenishing the groundwater regime. Nala bund 2 seems to be contributing about 60.2% of the impounded water to the groundwater regime (Ref. photograph). The cement plug 1 is able to contribute about 80% of the ponded water to the groundwater regime (Ref. photograph). Generally there has been an overall increase in the water table elevation owing to the augmented recharge from the impounded water in the water harvesting structures.

Cement plug CP1 with impounded water

Nala bund 1 with impounded water October 1998

Nala bund 2 with full storage capacity

CONCLUSION The groundwater modeling study has helped quantify the impact of impounded water in the water harvesting structures on groundwater regime in quantitative terms. The nala bunds have been contributing about 54 - 60% of impounded water to the groundwater regime whereas cement plug 1 has been contributed about 80% of impounded water to the groundwater regime in the Wagarwadi watershed in the basaltic terrain. Cement plug has large cross sectional area surrounding the aquifer zones compared to the nala bunds could be one of the reason for higher seepage losses from them compared to nala bunds. Under watershed development programme a number of

watersheds have been developed over last few years. Groundwater flow modeling can be used as a tool for quantifying the impounded water contribution reaching the groundwater regime. The methodology followed in the modeling can be replicated to study the quantum of augmented water to the groundwater regime from the water harvesting structures in similar geologic formations elsewhere.

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