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Modelling of an Aquifer System in Greater Noida Region, U.P.

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I. INTRODUCTION

Gautam Buddha Nagar district with geographical area of 1442 Sq. Km with headquarters at industrial city of Greater Noida has three Tehsils and four developmental blocks viz. Bisrakh, Dadri, and Dankaur & Jewar. According to 2011 census, the total population of the district was 1105292 and average population density was 766 persons per sq. km. It comes under the purview of the National Capital Region of Delhi. The city was developed based on Greater Noida Master Plan 2001, 2021 plan report (2013). The notified area of Greater Noida comprising of 124 villages and about 40,000 hectare of area is broadly bounded by National Highway 24 in the north-west. Also River Hindon lies in the western side of the city. Due to nearness to Delhi, both these towns being are developed rapidly. Due to the pressure for development of Greater Noida, the number of industries during the last decade has grown more than ten times. Accordingly the problems related to environmental degradation have increased many folds. In summer i.e. from March to June the weather remains hot and average temperature ranges from minimum of 23^0 C in winter to maximum of 45^0 C in summer. Monsoon season prevails during mid-June to mid-September with an average rainfall of 93.2 cm (36.7 inches). Average temperature falls substantially down to as low as 3 to 4 C at the peak of winter. Total land use is 13,570 hectares with the total institutional area around 1,970 hectares along with 30 hectares of commercial area. The area is divided into different zones for water supply such as tube wells, overhead tanks and trunk and other supply lines. At present approximately 500 km length of water supply lines with approximately 460 km length of sewerage network and approximately 500 km length of drainage exists. The general slope of the ground water movement is from eastern side towards river Hindon in the west.

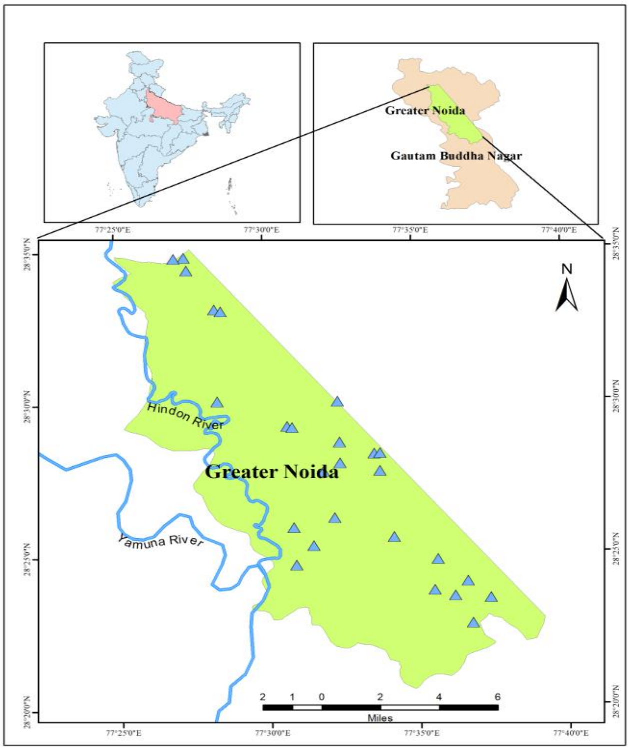

Fig 1. Study Area

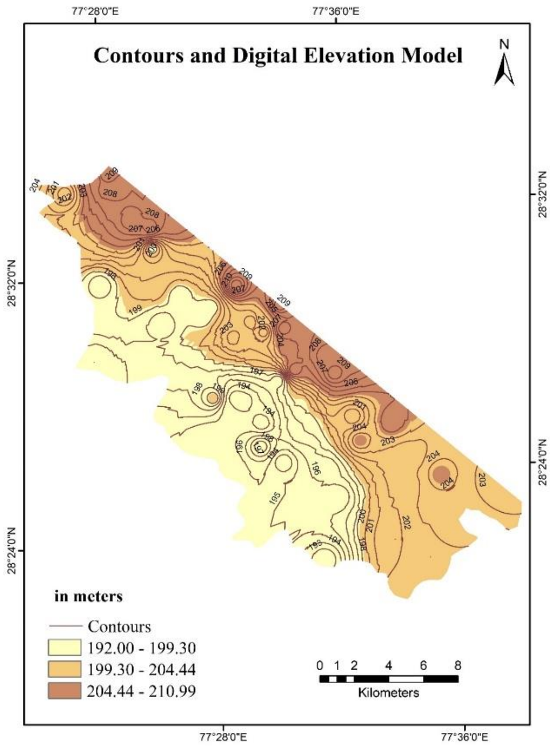

Fig 2. Contours and Digital Elevation Model

TABLE1: Locations and Elevations

S.NO.	Sampling Site	Latitude	Longitude	Elevation(m)
1.	Buland Khera	28.378239	77.613739	204
2.	Salempur Gurjar	28.413320	77.594895	202
3.	Bilaspur	28.395584	77.644306	202
4.	Gautam Buddha University	28.421663	77.525443	193
5.	Chi IV	28.431766	77.514645	199
6.	Omicron	28.471521	77.560365	209
7.	Swarn Nagari	28.462086	77.531846	196
8.	Omicron I	28.462131	77.563375	210
9.	Beta II	28.486314	77.514700	202
10.	Eta II	28.500340	77.535780	211
11.	Beta 2nd	28.487070	77.511868	204
12.	Ecotech II	28.501139	77.473065	197
13.	Sector 3	28.572869	77.457290	209
14.	Sector 2	28.578080	77.451630	211
15.	NIIT	28.411120	77.515698	195
16.	Kasna	28.436763	77.537579	198
17.	Sector MU I	28.471749	77.563615	208
18.	Khanpur	28.425747	77.570532	205
19.	Dalelgarh	28.393345	77.604249	204
20.	Rampur Majra	28.401183	77.611367	205
21.	Khera village	28.551346	77.472358	208
22.	Knowledge Park V	28.550212	77.475933	209
23.	Bagpur village	28.396619	77.592738	202
24.	Birondi	28.478029	77.541162	206
25.	Patwari	28.579910	77.455855	210
26.	Accher	28.466540	77.541162	207

Model Conceptualization and development

A conceptual model is used to understand the field problem and linked the associated field data so that the classification can be analyzed more eagerly. Conceptualization is a process of to synthesis and framing up of data relevant to hydrology, geology, hydrogeology and meteorology.

Fresh water resources are shrinking due to the continuously increasing the water demand for domestic, agricultural and industrial uses. Declining ground water in the study area has led to harmful effect to the ground water resources and domestic, agricultural and industrial users. An average decline of 0.88m/year shows the trend of long term ground water level. In many aspects ground water is preferred over surface water irrigation such as operational costs and pumping are low,it is easily assessable and pumped due to shallow depth, sympathetic treatment to farmers in the form of free tube well installation providing subsidized electricity policy in early 60's. Various investigations of hydrogeological parameters were mainly carried out by Central Ground Water Board (CGWB) and Groundwater Department of Uttar Pradesh (U.P.) government and were found the first group of aquifer. Conjunctive use of groundwater and surface water along with stream aquifer interactions was assessed in Daha region.The river–aquifer interaction was quantified in Ganga– Mahaba sub-basin.

Groundwater modeling has become a standard tool for effective groundwater management with rapid increases in computational ability and wide availability of computers and model softwares.

The present work investigates the effects of groundwater development and is also helpful to study the groundwater flow system in Yamuna-Hindon intersteam region using steady state groundwater models.

The partial differential equation for three dimensional anisotropic and heterogeneous flow of groundwater having constant density is expressed as:

$$\frac{d}{dx}\left[Kxx\frac{dh}{dx}\right]+\frac{d}{dy}\left[Kyy\frac{dh}{dy}\right]+\frac{d}{dz}\left[Kzz\frac{dh}{dz}\right]-W = Ss\frac{dh}{dt}$$

Where, Kxx, Kyy, Kzz are components of the hydraulic conductivity in x, y, z directions respectively,

h is potentiometric head, W is source or sink term, Ss is specific storage and t is time.

To simulate the groundwater flow in the study area, the above equation was used in finite difference computer based MODFLOW software.

Ground water level data

To monitoring water level of the study area, 26 tubewells were selected. In December 2013, the water level monitoring programme was initiated and supposed to monitor per year four times.During the month of May and November, water level data of the pre-monsoon and post-monsoon season were collected. In this period, the entire region can be divided into different zones on the basis of depth to water ranges. It was found that large area has shallow to moderate depth to water conditions. In heretic aquifer, the range of water level was found 3.75 to 15.14mbgl during pre-monsoon period while these ranges vary from 2.30 to 12.87mbgl during the post monsoon season. It was also found that the water level of non command areas was greater than 10mbgl.

Aquifer geometry

To define hydrostratigraphic units for the conceptual model with information on hydrogeological properties including cross sections, well logs and geological maps were combined together. Four distinct aquifer groups were reported in the area on the basis of electrical and lithological logs. These groups range at a depth of 82-132, 95-213,238-375,375-450 metres below ground level mbgl. First group of aquifers was restricted in this present study. For sketching horizontal and vertical disposition of aquifers and aquitards in the study area to a depth of 132 mbgl, the lithological data of 26 tubewells were utilized. The alluvial sediments are generally composed of a rapid alternation of sand and clay layers. A granular zone extends the top clay bed downwards upto a maximum depth of 132 mbgl. By the occurrence of sub-regional clay beds, the granular zone is subdivided into two to three subgroups. Local clay lenses are found common throughout the area. The top sandy layer consist the water table with a range from 10-80mbgl.

Aquifer parameters

The different aquifer parameters such as hydraulic conductivity and specific yield/specific storage were projected and assigned to different layers using data consequential from previous studies. The hydraulic conductivity values were choosen to run the model between 0.83 m/day to 5.31 m/day (Avg. 2.63 m/day).The value of specific yield for the entire area was taken 0.18. Hydraulic conductivity values were achieved from twenty six pump tests and were assigned to seven distinct zones using the Thiessen Polygon method. The value of conductivity for the first and third layers remained the same as 4m/day for both the layers are similar in nature.The value of conductivity for second aquitard layer was taken 1m/day while a similar conductivity values was taken for clay layers which was discontinuous. To maintain the interconnectivity between the first and third layers, the higher conductivity zones in the second layer were used.This hypothesis is based on the fact that clay layer is not a continuous layer and parallel confined out and at places the first and third layers converge with each other to present a single bodied aquifer.

Recharge

The Groundwater Estimation Committee (1997) stated that the groundwater will be recharge through many sources such as rainfall, canal seepage and irrigation return water. The following formula was used to recharge the groundwater by rainfall,

$R_{rf} = h * S_y * A + D_G - R_C - R_{SW} - R_{gw} - R_{wc}$,

Where, where, R_{rf} is the gross recharge due to rainfall and other sources including recycled water, h is the rise in groundwater level, A is the area of recharge assessment, S_y is specific yield, D_G is gross groundwater draft, R_C is recharge due to seepage from canal, R_{SW} is recharge from surface water rrigation, R_{gw} is recharge from groundwater irrigation, and R_{wc} is recharge from water conservation structure.

Surface water irrigation and groundwater irrigation was calculated separately to recharge the groundwater and it was obtained from the following formula,

$R_F = R_C * Q$

The seepage factor was used as $0.15 < R_C < 0.45$ (GEC 1997).

Recharge through canal seepage was evaluated with the following expression.

Canal seepage = length × wetted perimeter× total running days× specific loss

The estimation of discharge and recharge parameters were accomplished for monsoon and non-monsoon periods. The assessed values were then applied to the particular grid in the model utilizing recharge boundaries. The entire recharge evaluated was as per water table fluctuation strategy and Groundwater Estimation Committee (GEC 1997) philosophy for groundwater asset estimation. Recharge through irrigation system returns and drainage through unlined waterways was evaluated utilizing standards prescribed by GEC-97. Site explicit recharge information are frequently utilized simply as fitting parameters during model calibration where site explicit data is accessible and an accepted part of this is generally appointed as the recharge boundary condition. Such presumptions are satisfactory for the long haul propagation of provincial groundwater flow framework and were utilized during the present study.

Groundwater draft through pumping

During the period of December 2013 to November 2018, several fields visited to the study area and collected the existing tubewell data. For the same purpose, census from the Statistical Department was also used. It is found that the discharge rate of tubewell varies from 1500 L/min to 3000 L/min.

Boundary Conditions

Boundary conditions are required for every model to represent the system's relationship with the surrounding area. Northern, Southern and Eastern parts of study area were assigned general head boundary conditions.Previous water level data of heads were assigned as general head boundary. The western part representing the hindon river having the river head and bed bottom elevations at the initial and end points are 199 m and 198 m amsl and 194 and 193m amsl, respectively. It has river bed conductance between 200 to 260 m^2/day. The reason for utilizing this boundary condition is to maintain a strategic distance from pointlessly stretching out the model area outward to meet the component impacting the head in the model.

Model Calibration

Model Calibration comprises of changing estimations of model input parameters trying to coordinate field conditions inside an adequate foundation. Calibration is done by experimentation alteration of parameters. After a number of trial runs, computed water levels, Heads, Drawdown were matched fairly reasonably with observed values by changing hydraulic conductivity, specific yield and recharge values.

Steady State Calibration

The steady state condition is a condition that existed in the aquifer before any advancement had happened. Coordinating the initial heads watched for the aquifer with the hydraulic heads recreated by MODFLOW is called steady state calibration. The calibration was mentioned utilizing 26 tube wells monitored during December 2013. Pumping test was used as initial values of hydraulic conductivities for steady state simulation. The conductivity values were increased by trial and error calibration during various sequential runs till the match between the simulated and observed water level contours were obtained.

LITHOLOGS OF FEW LOCATIONS IN STUDY AREA (Fig 3)

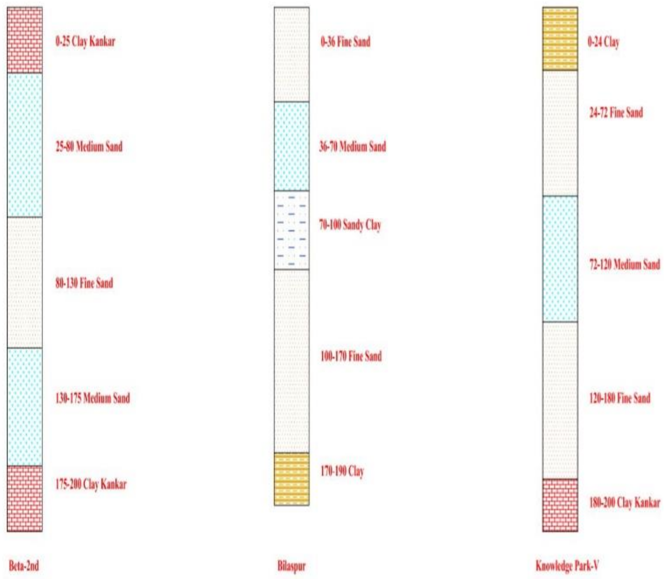

Fig 3: Few Lithologs of Study Area

Table 2: Rainwater harvesting potential of study area

S. No	Different type of catchments	Area (A) m^2	Runoff Coefficients (C)	Annual Rainfall (I) (m)	Volume of the water collected (Q=CIA) (cu.m)
1.	Concrete Roof	331002.874	0.95	0.600	188671.638
2.	Concrete Road	117389.466	0.95	0.600	66911.996
3.	Vegetation	67287.513	0.10	0.600	4037.251
4.	Bare land	130641.314	0.3	0.600	23515.436
	Total	**646321.167**			**283136.321**

RESULT AND DISCUSSION

Aquifer Modelling using MODFLOW:

From the mass balance chart of MODFLOW, it was observed that the inflow is greater than outflow before the land use master plan whereas in the case of after land use master plan outflow is greater than inflow. Therefore to overcome this deficit, it is suggested to use rainwater harvesting to recharge the groundwater. (Fig 8 (a), 8 (b))Unplanned urbanization has drastically altered the drainage characteristics of natural catchments by increasing the volume and rate of surface runoff. Over exploitation of ground water sources like wells for drinking water and industrial use has also resulted in depleted water levels and drying up of bore wells due to the imbalance of inflow and outflow for sub-surface water. The original permeable ground surface has reduced due to urbanization. Pavements, roads and construction of storm water drains to drain the rain water as quickly as possible to natural stream, river to avoid flooding of grounds. These surfaces and quick run off gives no scope for percolation of rain water to replenish the sub-surface aquifer causing the dropping of water levels or drying up of wells. In addition to this, land use and land cover changes have contributed to the regional and global climate changes, resulting in irregular, reduced, erratic and uncertain rainfalls. Protection and reasonable administration depict helps in the reclamation of the regular affinity. In this context, rainwater harvesting is seen as a viable alternative to replenish the groundwater.

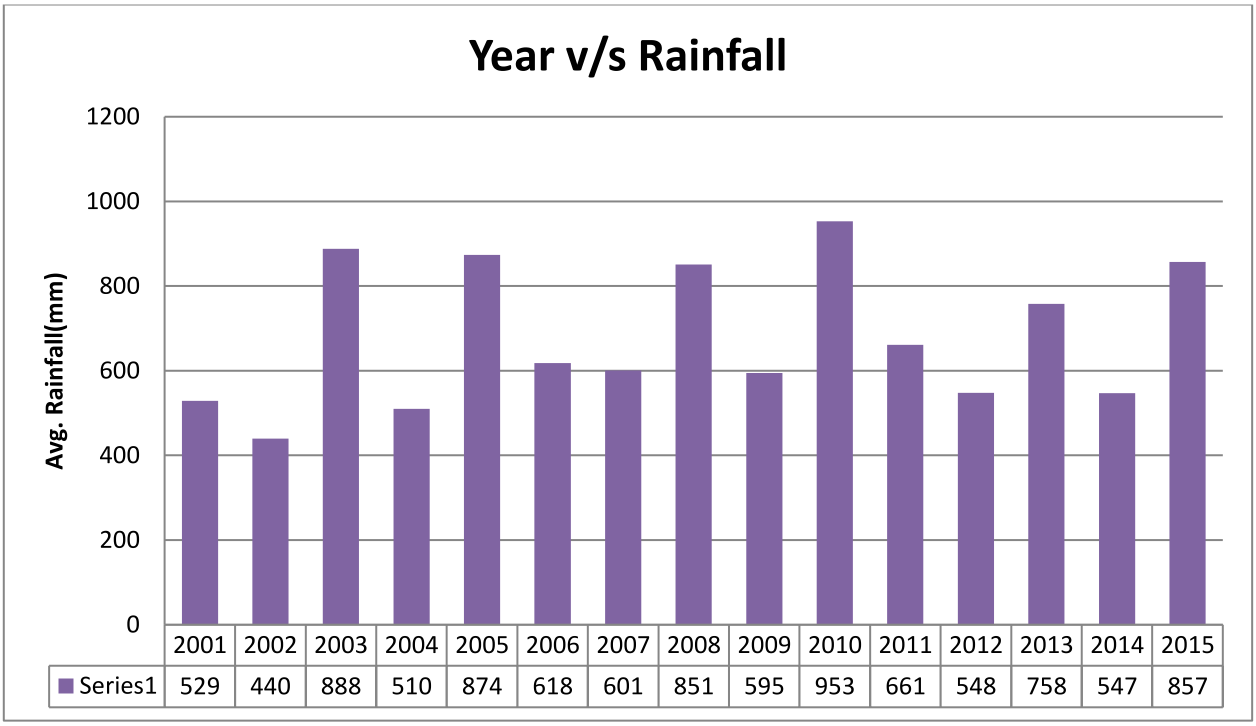

Fig 4 : Rainfall Chart

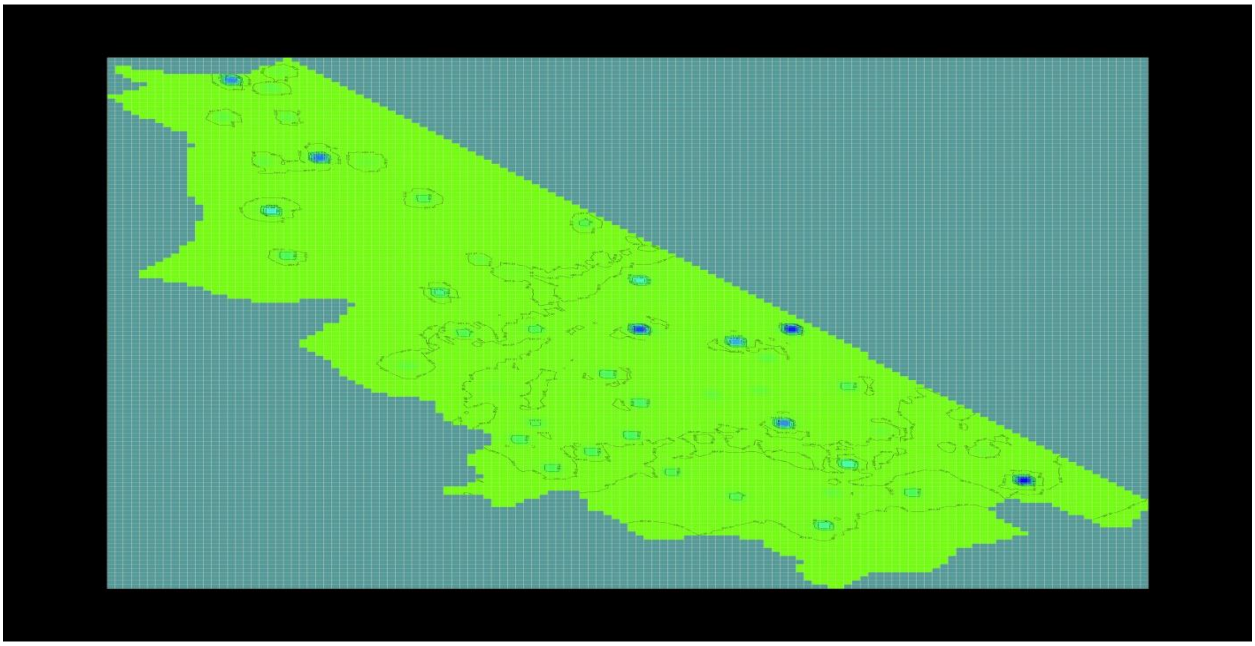

Fig 5 : Heads

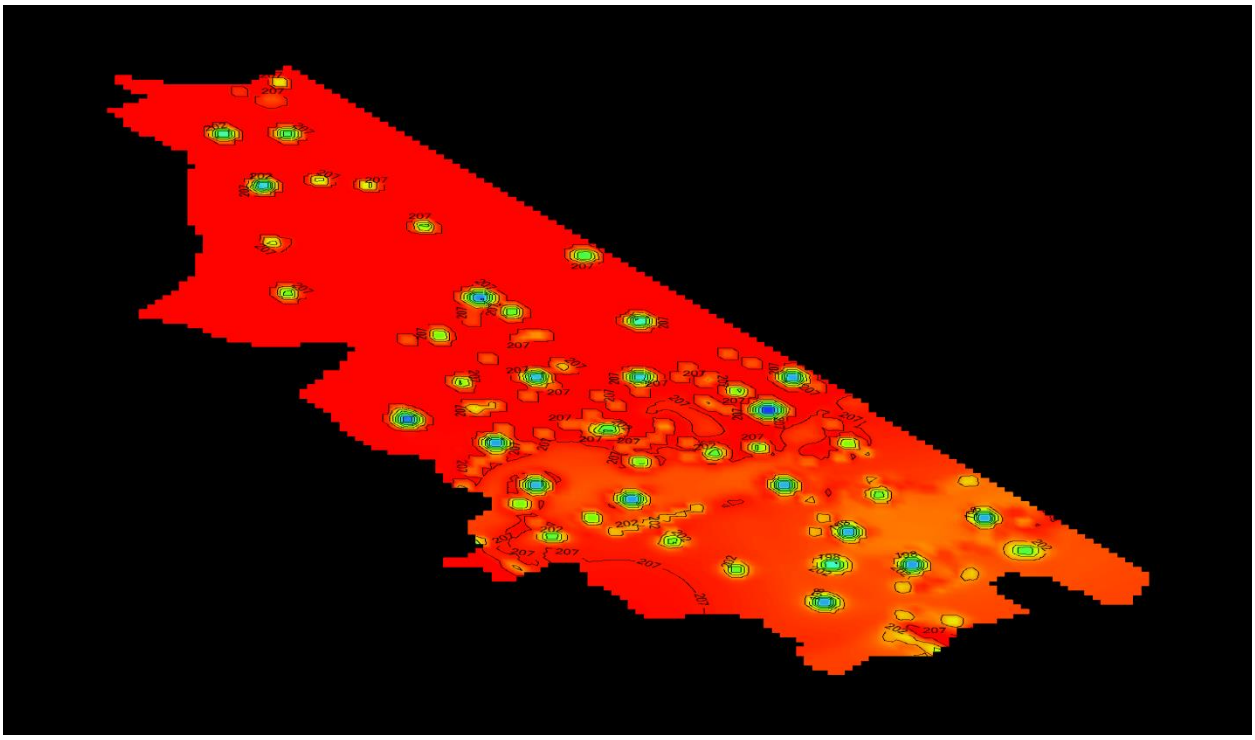

Fig 6 : Water table

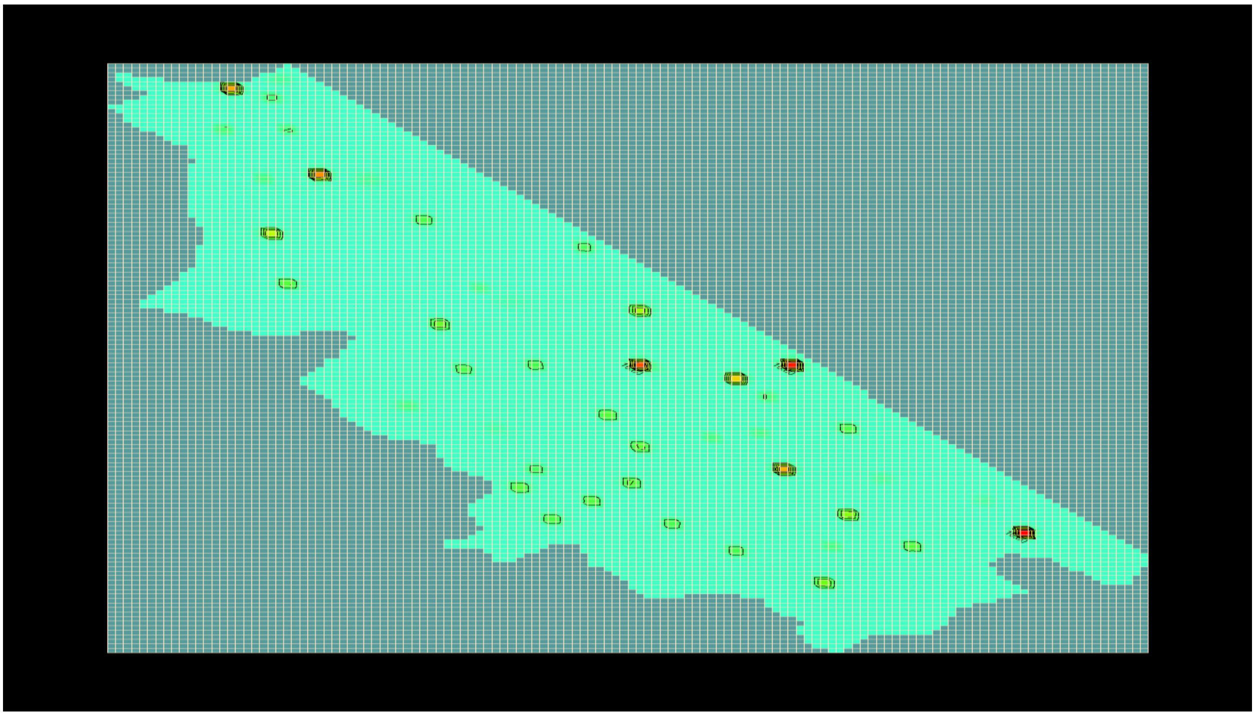

Fig 7 : Draw down

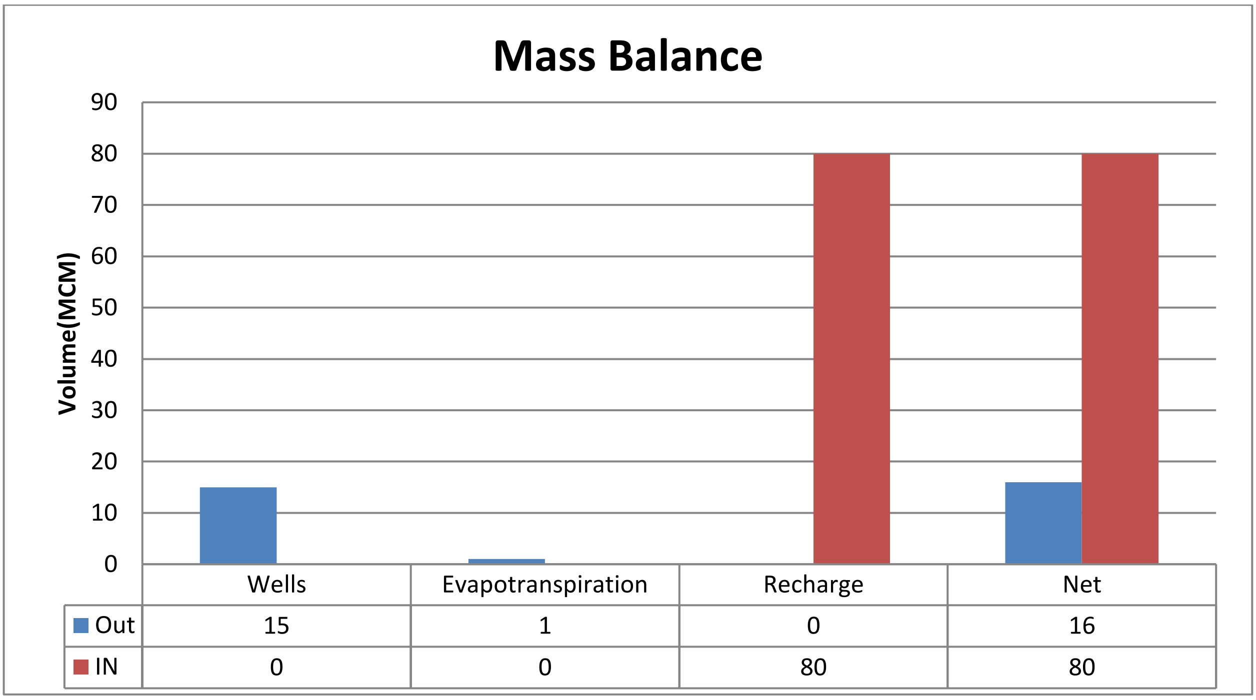

Fig 8(a) : Mass balance before land use master plan

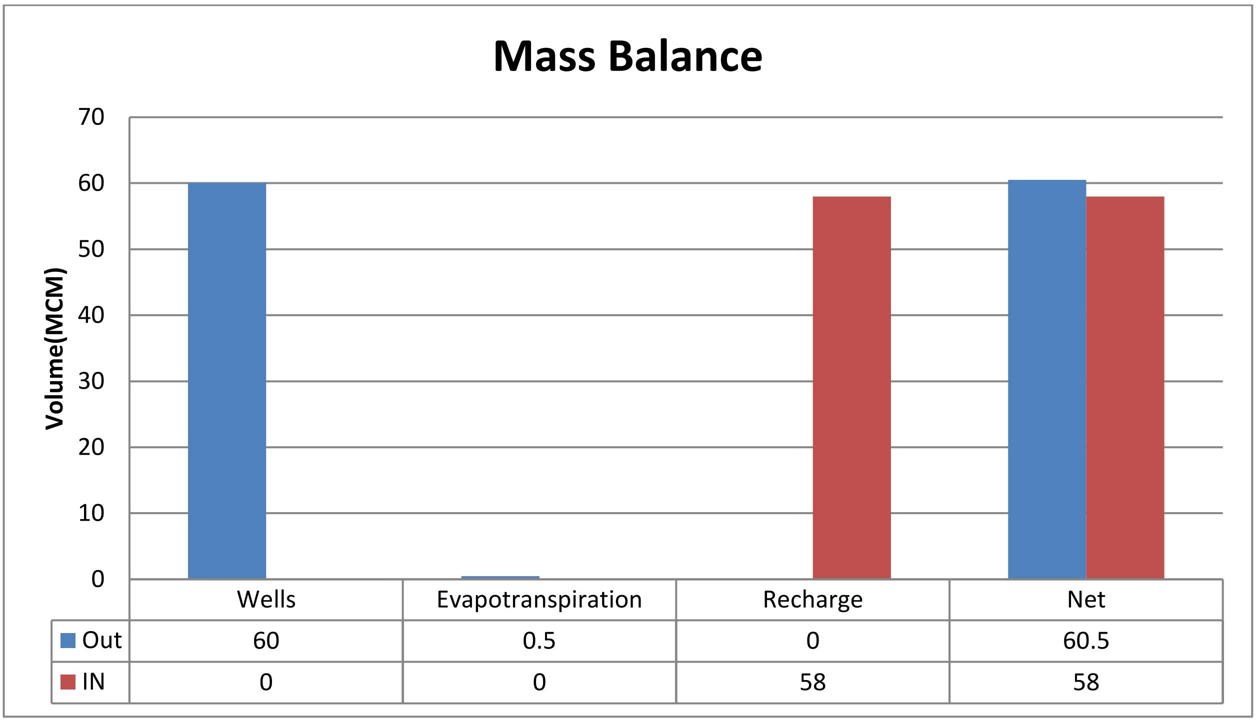

Fig 8(b) : Mass balance after land use master plan

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