SIMULATION MODEL OF GROUND WATER SYSTEM
OF
LAKHAOTI BRANCH COMMAND

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INTRODUCTION

Lakhaoti Branch is a part of the Madhya Ganga system which has been constructed to supply surface water to the dry areas in the overall command of the Ganga canal system and to supplement the supplies in the command area during monsoon period. Lakhaoti branch command is an area between Nim Nadi and Kalinadi (east).This area was not getting any surface water. The farmers were using ground water for irrigation. Simulation model of the ground water system of the area was prepared to understand the present behaviour of the system and how it is going to respond to the introduction of the surface water for Kharif irrigation during monsoon.

GROUNDWATER SYSTEM MODEL

Simulation of a ground water system refers to the construction and operation of model whose behaviour assumes the appearance of the actual aquifer behaviour.The model can be physical, analog or mathematical.A mathematical model is a set of equations which, subject to certain assumptions, describes the physical processes active in the aquifer.While the model itself lacks the detailed reality of the ground water system, the behaviour of a valid model approximates that of the aquifer.After the mathematical model is formulated the next step is to obtain a solution using analytical or numerical approaches.For complex system such as ground water system of an area where analytical models can not be used, the partial differential equation can be approximated numerically.The numerical models are most appropriate for general problems involving aquifers having irregular boundaries, heterogeneities, or highly variable pumping and recharge rates.

Application of a ground water model to an aquifer system involves several areas of efforts which include data collection and preparation, history matching or calibration and predictive simulation.The model should not be used as a predictive tool only, but as an aid in conceptualizing the aquifer behaviour.The data collection first involves determination of boundaries of the region to be modeled, dicretization of the model area, assignment of aquifer parameters and initial conditions for the grid. Computed results generally consist of hydraulic head at each of the grid points throughout the aquifer.These spatial distribution of hydraulic head at each of a sequence of time levels cover the period of interest.

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Initial estimates of aquifer parameters constitute the first step in a trial and error procedure known as history matching or calibration.Aquifer tests generally provide the initial estimates for storage coefficients and transmissivities.The calibration procedure is used to refine the initial estimates of aquifer parameters and to determine the areal and vertical extent of the boundaries, flow conditions at the boundaries, and the estimated pumping and recharge.The input data is modified until all the observed and calculated water levels compare sufficiently well.No hard and fast rules exist to indicate when satisfactory match is obtained.Once the calibration is completed, the model can be used to predict the future behaviour of the aquifer system. Confidence in the predicted results depends on the understanding of the model limitations, accuracy of the match and knowledge of data reliability and aquifer characteristics.

MATHEMATICAL MODEL

Incorporated in the model are the following featurs and restrictions :

1. The aquifer is treated as a two dimensional flow system.
2. Only one aquifer system is modelled with one storage coefficient in vertical direction.
3. The aquifer is bounded at the bottom by an impermeable layer.
4. The upper boundary of the aquifer is an impermeable layer (confined aquifer), a slightly permeable layer/semi confined aqauifer) or the free water table/unconfined aquifer).
5. Darcy's law (Linear resistance to laminar flow) and Dupuit's assumption (vertical component of flow velocity can be neglected) are applicable in the aquifer.
6. The aquifer has impervious boundary, leaky or semipervious boundary or the aquifer is in free or partial contact with a large water body.
7. The processes of the infiltration and percolation of rain and surface water and of capillary rise and evapotranspiration, taking place in the unsaturated zone of an aquifer (above the water table), cannot be simulated. This means the net recharge to the aquifer must be calculated manually and prescribed to the model.

The model is based on the two well known equations,Darcy's law and the equation of conservation of mass.The unsteady two dimensional flow through an unconfined aquifer is given by :

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right) = S_y \frac{\partial h}{\partial t} + Q \qquad (1)$$

Where

T = coefficient of transmissibility

h = piezometric head

S_y = specific yield

Q = volumetric flow rate per unit area in vertical direction

The solution of Eq.1 is possible by knowing the hydrologic, initial and boundary conditions. Hydrologic conditions comprise transmissivity and specific yield which describe the capacity of the aquifer to transmit, store and release water respectively. Initial and boundary conditions such as potential, geologic boundaries of the model, etc. have to be specified. Analytical solution of Eq.1 is not possible for complex natural systems. Hence, Integrated Finite Difference Method (IFDM), which is modification of finite difference method has been used.

FINITE DIFFERENCE METHOD (FDM)

Numerical approach based on finite difference approximation has been applied successfully to ground water flow equation.Solution of partial differential equation using FDM requires establishment of a grid system throughout the area to be modelled.The grids for the two dimensional flow could be square or rectangular and regular or irregular.Integrated finite difference method(IFDM) utilises an arbitrary grid. In this method the modelled area is divided into polygons referred to as nodel area around a nodal point.Nodal points are used for mathematical purposes to connect each polygon to adjoining polygons. It is assumed that all recharge or withdrawal to and from the nodal area occur at the nodal point and the water level in the nodal area is same as at the node point. Therefore, polygon size should be kept reasonably small in size to obtain desired accuracy.

The finite difference form of the differential Eq.1 is given by :

$$\Sigma\,(h_i - h_m)\, y_{im} = A_m S_m \frac{dh_m}{dt} + A_m Q_m \qquad (2)$$

Where

h_i = piezometric head at node i

h_B = peizometric head at node B

y_{iB} = T_{iB} (J_{iB} / L_{iB}) = a conductance factor

T_{iB} = transmissibility at mid point between node i and B

J_{iB} = length of perpendicular bisector associated with node i and B

L_{iB} = distance between nodes i and B

A_B = polygonal area of node B

S_B = shortage coefficient of node B

Q_B = volumetric flow rate per unit area at node B

Eq.2 after being solved by implicit numerical integration technique reduces to the following form at the Jth time interval

$$\Sigma\,(h_i^{J+1} - h_B^{J+1})\,y_{iB} = \frac{A_B\,S_B}{\Delta t}\,(h_B^{J+1} - h_B^{J}) + A_B\,Q_B^{J+1} \qquad (3)$$

Where

Δt = time step

and Subscript 'j' denotes the points along time horizon.

COMPUTATIONAL PROCEDURES

The computational procedure is essentially that of Gauss-Seidal. The initial values of $h_B(0)$ are first recorded as h_B^J (B=1,2.....,N), N = No. of interior nodes. For a given set of coefficients y_{iB}, S_B and Q_B^{J+1}, the values of h_B^{J+1} are implicity determined at the end of a time step t. Once determined, these values become the initial water elevations for the next succeeding step in time. The sequence of one interation is as follows :

$$\text{Subsurface flow} = QQ_B^{J+1} = \Sigma\,(h_i^{J+1} - h_B^{J+1})\,Y_{iB} \qquad (4)$$

$$\text{Vertical flow} = AQ_B^{J+1} = A_B\,Q_B^{J+1} \qquad (5)$$

$$\text{Change in storage} = STORE_B^{J+1} = \frac{A_B\,S_B}{\Delta t}\,(h_B^{J+1} - h_B^{J}) \qquad (6)$$

Eqs.4, 5 and 6 are balanced for each node by setting their sum equal to a residual term as given below :

$$RES_B^{J+1} = QQ_B^{J+1} + AQ_B^{J+1} - STORE_B^{J+1} \qquad (7)$$

The assumed values of heads are then modified by a magnitude of residual attenuated by a relaxation coefficient as below :

$$h_m^{J+1}\ (\text{modified}) = h_m^{J+1}\ (\text{previous}) + RELAX_m * RES_m^{J+1} \qquad (8)$$

Having modified the values of heads as above for all the free nodes, sum of the absolute values of the residuals at each node is worked out and compared to a predetermined tolerance level acceptable. If the sum of the residual is more than the prescribed tolerance level, then the above calculations are repeated till the residual becomes less than or equal to the tolerance level. In the latter case the computations for the head are complete for the time step under consideration.

The magnitude of correction in water level is obtained by the product of the residual and relaxation coefficient. Since the residual represents a flow rate, the relaxation coefficient has to be a reciprocal of conductance i.e. impedance. The relaxation coefficient can be taken as :

$$RELAX_m = \frac{1}{\Sigma Y_{im} + (A_m\ S_m)/\Delta t} \qquad (9)$$

DESIGN OF NODAL NETWORKS

To discretize a ground water basin into nodal areas, a network of rectangles, squares or polygons is superimposed upon it. It is impossible to give any hard and fast rules on what network to apply and how to design it. Because of different geological and hydrogeological conditions, a network that is appropriate in one basin may be inappropriate in another. When designing a nodal network the following factors must be considered :

1. the type of problem to be solved
2. the required accuracy of the result
3. the homogeneity of the aquifer
4. the availability of data
5. the shape of the boundaries
6. the number of nodes

Also the number of node point depends on the following factors :

1. Number of observation wells in the study area
2. The storage capacity of the computer
3. Time available at modeller's disposal
4. Presence of congested canal/river network require higher number of nodes for better representation
5. Greater number of nodal points in region of greater fluctuation of ground water levels or aquifer parameters
6. Availability of fund
7. Level of accuracy desired.

Nodal points are suitably selected so as to include maximum number of observation wells, such that by joining these nodes points the triangles formed have internal angles less than or equal to 90°. External curved boundaries are approximated by straight lines. Nodal polygons are then constructed by drawing the perpendicular bisectors of lines joining these nodes.

STUDY AREA

The area intended to be studied is the command area of Lakhaoti Branch which lies between Kali Nadi and Nim Nadi. However these do not form a well defined hydrologic boundary. Therefore, the study area has been extended to cover the area bounded by Upper Ganga canal on southern side, Lower Ganga Canal on eastern side and Anupshahar branch canal on the northern side. The total area occupied is 446879 hectares.

The area experiences moderate type of sub-tropical and monsoonic climate. The temperature rises upto 40°C in summer and fall down upto 2°C in winter. Monsoon generally sets towards end of June and lasts till end of September. Most of the precipitation occurs during the months of July, August and September. The winter rains are scanty. The normal rainfall is about 626 mm. The average rainfall of the four years under consideration is given in Table 1. The main crops grown in the area are sugarcane, wheat, barley, maize, millet and paddy. The area is drained by Kali Nadi (East) and Nim Nadi.

Table 1 : Avrage Rainfall in the study Area

Sl. No.	Period	Non-monsoon rainfall(mm)	Monsoon rainffall(mm)	Annual rainfall (mm)
1.	1984-85	116.0	673.5	789.5
2.	1985-86	194.6	587.6	782.2
3.	1986-87	109.8	254.4	364.2
4.	1987-88	86.5	850.3	936.8

The area is part of the Indo-Gangetic alluvial plain of quartenary age. It is made up of recent unconsolidated fluiviatile formation comprising sand, silt, clay and kankar with occasional beds of gravel. The thickness of alluvium in Indo-Gangetic plain is known to be roughly 2500 m to 3000 m. The water bearing strata ranges from 30% to 75% with an average of approximately 40 percent of the total material encountered down to 90 meter depth. Geologically the sediment are favourably embeded for occurence of ground water in major part of the area. A study of geologic cross-section of the area indicates that the aquifer have lenses of clay almost every where.

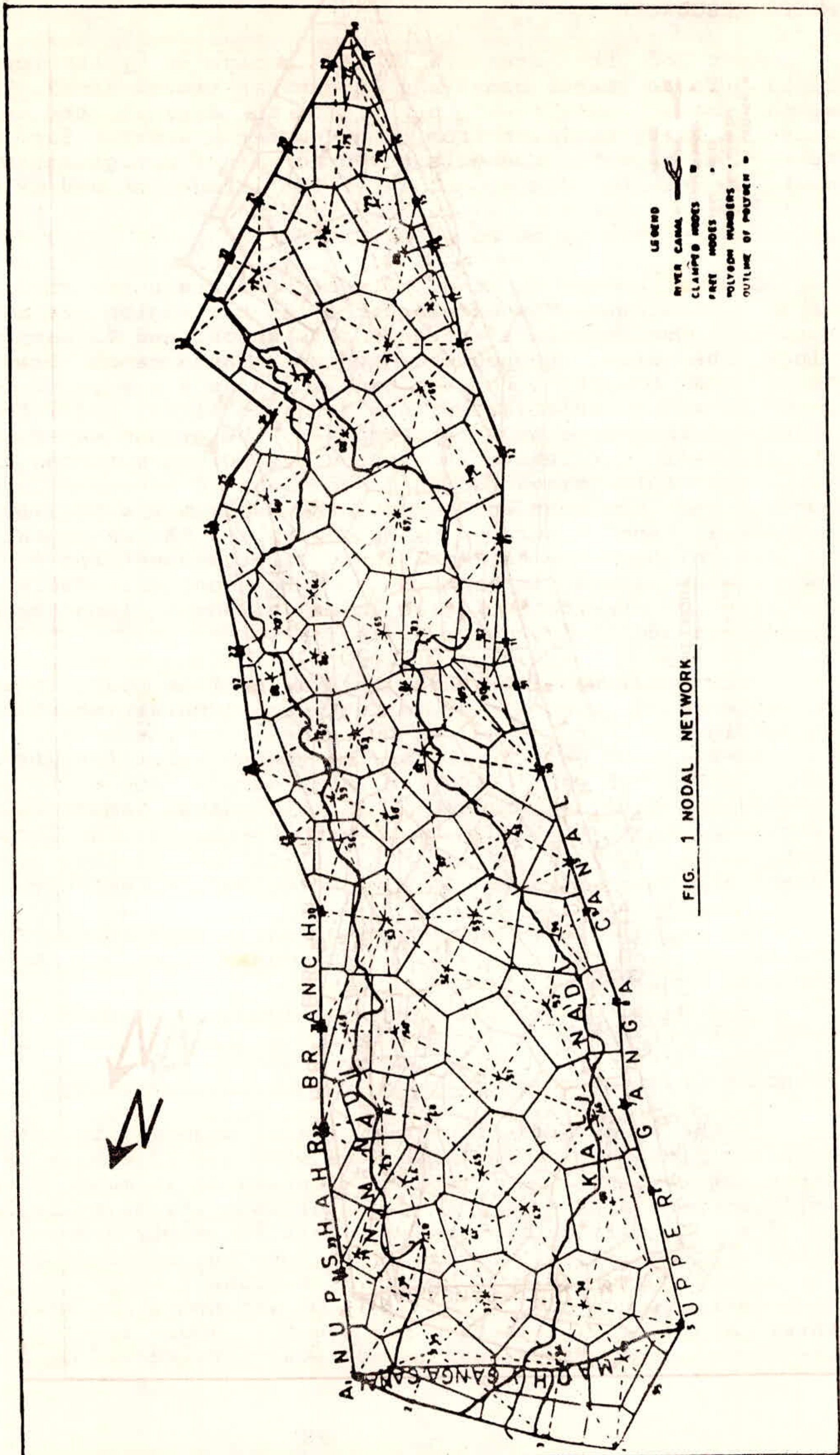

FIG. 1 NODAL NETWORK

WATER RESOURCES

Part of the area is being irrigated by the Upper Ganga canal, Lower Ganga canal and Anupshahar branch canal. The canal supply is not sufficient to irrigate the area and the additional water is being utilised from ground water reservoir through state tubewells, private tubewells and other minor irrigation works. To meet increasing demand of water for irrigation and to maintain hydrologic balance in the area, conjunctive use of surface and ground water has to be adopted.

Ground water in the study area occurs under shallow water table conditions. The main aquifers of the region are sand beds. Most of the aquifers are generally unconfined to semiconfined. Since the area is bounded by Upper Ganga canal, Lower Gangal canal and Anupshahar branch canal. and as a result of this, the depth to water table varies from 1.8 m to 11.0 m below the ground level. Main source of water supply to the ground water reservoir is rainfall infiltration which occurs during monsoon. The water table therefore, rises during monsoon due to increase in storage. During the non-monsoon period the water table declines due to withdrawal from the ground water reservoir. The water table rises to the highest level immediately after monsoon and declines to the lowest level immediately before monsoon. The study area contains 39 observation wells, of which 4 are along the external boundaries and 35 fall within the area.

The quality of ground water varies from place to place and is determined largely by extent and composition of dissolved solids in it. A knowledge of the same is very essential in order to assess the suitability of the ground water for its intended use. U.P.I.R.I. collected the water sample from state tubewells located in different tubewell tracts of Ganga Yamuna Doab. It is concluded that the quality of ground water in the Ganga Yamuna doab is in general good for irrigation and that most of the waters are non-corrosive and non incrusting in character.

The actual alignments of the canals which form the external boundaries are approximated by straight lines. The index map of the area is given in Figure 1.

MODEL PREPARATION

Boundary Conditions

In the study area, the selection of boundary is based on the consideration that it can either be represented easily by clamped nodes or by no-flow boundary containing as many observation wells as possible. More the number of observation wells,better it is for the calibration of the model. The study area contains 39 observation wells, of which 4 are along the external boundaries, the area is bounded by Upper Ganga Canal, Lower Ganga Canal, Anupshahr branch canal. The UGC, LGC and Anupshahr branch on the three sides of the area which are continuous running channels, are considered fixed head boundaries, represented by 35 clamped nodes. The area is represented by 63 free nodes, 39 of them are observation wells. Irregular boundaries are approximated by straight lines.

Nodal Network and Polygon Geometry

The study area have been sub-divided into 98 polygons. The salient features of the 98 nodal polygons, taken up for study, are given below :

a) Total modelled area : 446879 Ha

b) Average area of a node : 4560 Ha

c) Smallest nodal area
(node No.18) : 148.5 Ha

d) Largest nodal area
(node No.67) : 12515.7 Ha

After finalization of nodal network, computations of polygonal geometry was taken up by using the computer programme developed for this purpose.The polygonal areas and the ratios of perpendicular bisectors to the distance between the connected nodes were obtained. The conductance factors Y_{is} are then calculated.

Fixation of Time Step

Selection of time step mainly depends on the purpose of study, availability of data and accuracy required. All the time steps need not be equal.

In this study, each year is broken up into two seasonal time steps. The non monsoon season, 8 months, starting from Ist October to 31st May and monsoon season of 4 months duration, starting from Ist June to 31st September.Since the initial values are taken at October 1984, the first time step (DELTA) is thus taken 8 months, followed by 4 months.These time steps are used alternatively through out the calibration period of four years.

Tolerance Level

The selection of tolerance level depends on the accuracy of the computation needed.The adoption of large tolerance level leads to inaccuracy, whereas very small tolerance level consumes excess computer time. So the tolerance level must be chosen carefully so that the required degree of accuracy can be attained without wasting of computer time. A guiding value of tolerance level may be estimated as follows :

Tolerance level =(total area of unclamped node)*(desired level of accuracy)

In the present study tolerance level was taken for the study as 250 ha-m.

MODEL CALIBRATION

Before the model can perform its task of predicting the future water table behaviour it must be calibrated.This means that a check must be made to see whether the model can correctly generate the past behaviour of the water table as it is known from historical records.

Calibration is done for the period for which historical records are available. In this study the calibration was done for the period from 1985 to 1988.The relevant hydro-geological information and historical data were fed into the computer which calculate the water table elevation for each nodal point. These values were then compared with the water table elevations as they are known from historical records.The geohydrological information is modified and the water levels were re-evaluated till the calculated values satisfactorily matched the historical ones.

Sources of Errors

Errors in input data can stem from two categories of sources :

a) Errors in the physical properties of the aquifer

1. Transmissivity 'T'
2. Specific yield , 'S_y'
3. Water table elevation
4. Type of aquifer

b) Errors in the hydrological stress exerted on the aquifer

1. Recharge from precipitation, seepage from conveyance system and field seepage
2. Seepage from or to derainage/rivers
3. Lateral ground water flow through boundaries
4. Groundwater abstraction

As this list shows almost all input data are subjected to error.The deviation between the calculated and historical water levels will often be the result of a combination of these errors. Of course, errors can also be made in feeding the data in the computer and it is advisable to first check whether any such error have been made.

Calibration Procedure

As deviation between calculated and historical water tables can be due either to errors in individual input parameters or to a combination of such errors, the problem one faces in changing input parameters is where to start and what to change.

The best place to start is in those few nodal areas where the largest deviation occur.This is advised for two reasons.Firstly, if input data are changed in too many nodal areas simultaneously, it will be difficult to see what the individual effects of these changes are. secondly deviation in a certain nodal areas may well be result of errors in input data of other nodal areas, where the input data for the nodal area itself are good.Changing an input parameter in one nodal area will have an effect, either good or bad, in other nodal areas.

In this study the model was calibrated node wise for the eight seasons by adjusting values of parameters and vertical flows through trial and error method until the computed levels matched with the historical records .The sequence followed was, first modifications were carried out in the values of T,next modification were made in the values of S and then necessary corrections were made in the values of vertical flows.Before taking up calibration, the value of S_y were calculated from the water balance of each node for the non-monsoon periods.These values were used for selecting the value of S_y for each node.In some cases the recorded water levels were inconsistant and necessary modifications were made in these water levels also.

The first calibration run gave the average difference between the historical and computed levels as 0.735m for all nodes and 0.720 m for important nodes.The maximum error was 5.0 m and 3.58 m for all nodes and important nodes respectively.Few initial runs were devoted to check sensitivities of the model to various parameters. It was found that the model is very sensitive to change in specific yield, S_y, values as compared to change in other parameters.

It was found that an increase in 'T' values between two nodes increase flow across the boundary between the two polygons.Computed water levels in the nodes adjoining clamped nodes, tend to rise/fall so as to approach the level of clamped nodes. In order to check this tendency and thereby reduce error, the values of'T' for nodes connecting to clamped nodes were reduced. An increase in the value of'T' results in increasing the conductance factor, which results in greater subsurface flow, rise in water level and reduce water table gradient between the nodes and vice versa.An increase in the value of' S_y' results in less fluctuation.

Since the study area is quite large, the intensity of ground water structure and therefore, rate of abstraction/recharge varies from node to node.Rate of abstraction from each node was estimated on the basis of its area falling in different blocks and intensity of ground water structures in respective blocks.These were adjusted during calibration if found necessary.

An increase in recharge coefficient increase the computed water level whereas an increase in abstraction coefficient decreases the water level.

First few runs were devoted to bring down the maximum errors by changing 'T' values in nodes connected to clamped nodes and changing the value of 'S_y'. In the ninth run the average error in all nodes was found to be 0.45m and average error for important nodes was found to be 0.445 m. In the 37th run the average and maximum errors for all nodes were 0.13m and 0.62 m respectively. Average and maximum error for important nodes, at this stage, were 0.128m and 0.55m respectively. In the 85th run the average and maximum error in all nodes was found to be 0.057m and 0.2m respectively.

The last few runs were used for finer adjustments by slightly changing different recharge/abstraction parameters. As the average error is quite low, further calibration was not considered necessary.

From the final calibration run, the values of 'S_y' varies from 5 to 25% with a weighted average value of 14.98%. The value of 'T' for the connections between various nodes range between 0.5 to 5.75 ha/month. The weighted average monsoon rainfall recharge for the total modelled area varies from 18.39 to 21.08 percent of the total rainfall. The lower rainfall being for the year 1987 which was a drought with annual rainfall equals 36.4 cm and the higher rainfall recharge being in the year 1988 which was a wet year of annual rainfall of 93.7 cm.

Superposition of contour maps of observed water levels and computed water levels indicated that the two contours are very close to each other.

Recharge due to canal seepage worked out as 25.75% of the total canal input and that from irrigated field as 13.75 percent of the total canal input. Since the modelled area is bounded by U.G.C., L.G.C. and Anupshahar branch canal, the seepage from these canals varies from 10598.4 to 12205.82 ha.m. annually. Maximum seepage took place in the two years 1986-87 and 1987-88 and that is because of the drought in 1987. The input from rainfall to the ground water reservoir varies from 37 to 60 percent of the total annual input. Lowest value being obtained in 1986-87 which was a drought year with annual rainfall of 36.4 cm.

GROUND WATER BALANCE

In term of hydrologic cycle for a particular ground water basin, a balance must exist between the quantity of water supplied to the basin and the amount stored within or leaving the basin. The ground water balance equation provides a quantitative statement of such a balance.

The various components of the water balance equation for total modelled area are taken from the output of the final calibration run.

It is seen that the recharge factor for rainfall varies from 18% to 21%. The lateral flow from main canals, (UGC, LGC and Anupshahr branch) to the area varies from 10598 ha.m. to 12205 ha.m. annually. More lateral flow is observed in the year 1987 and 1988 and this is because of the depression of the water table due to the drought in the year 1987. The rate of seepage from the main canals varied from 0.69 to 0.8 m/sec/10^6 m with an average value of 0.75 m /sec/10^6 m of wetted perimeter area.

The water balance for the modelled area for the Lakhoati branch command area indicates that the total annual recharge to the Lakhoati command varies between 39670 and 66725 ham from 1984 to 1988. The minimum recharge has taken place during the year 1987 which was a drought year and maximum recharge has taken place during the year 1988. During the period 1984-1987, there has been mining of ground water varying between 7253 and 30,000 ham. As a results of this there has been progressive lowering in water table during this period. During the year 1988, there has been increase in storage by about 3267 ham as it was a relatively wet year. Gross annual pumping has varied between 63,937 and 76927 ham, 75 to 80 percent of which has taken place through shallow tubewells and other privately owned minor irrigation structures and the remaining through state tubewells.

PREDICTION

Calibrated model can be used to determine what the long term behaviour of the ground water system would be if certain plans for the development of ground water were implemented.`A prediction run' is the term used when the model simulates future recharge and abstraction as if a certain development plan has been implemented.Such plans may introduce either recharge or abstraction or both that is different from the recharge and abstraction in the past. A new irrigation scheme, for example, introduces additional recharge through seepage losses in canals and fields and leaching practices, if any.A new pumping station for M & I or for irrigation may introduce new, locally high, abstraction rates.A more complex situation is one in which an area is being irrigated with water from a river but, since the river flows vary greatly, a plan may be drawn up to use ground water as an auxiliary supply.Such a plan implies rates of ground water abstraction that will vary in accordance with the river water availability.In a complex situation like this, the model enables the planner to examine what consequences a certain development plan will have on the water table.This is the real strength of the model. It also allows to study the consequences of a number of alternatives within the development plan.The model can be used to study whether irrigation canals should be lined or not and which is the best site for pumping station.

By simulating such alternatives, one can provide the decision maker with a sound basis on which to select the most appropriate plan.

The period over which the model can be used to simulate the future conditions in prediction runs depends upon several factors which includes period for which the model had been calibrated and the pattern of developmental activities during the calibration as well as prediction period.Faust and Mercer (1980) suggest that one should not predict more than about twice the period used for calibration, and that too only under similar pumping conditions.

Prediction Runs

The period of prediction was taken as five years, from October 1988 to October 1993.Thus the prediction has been attempted for ten seasons, with an assumption of 2% increase of abstraction during Rabi Season.Various recharge/abstraction parameters used in the prediction has been averaged out from the calibrated model.Thus monsoon period parameters for the prediction have been represented by average monsoon parameters in the calibrated model.The introduction of irrigation through lakhaoti Branch has been suitably accounted for by changing the input for canal and field seepage. In the absence of actual data, the introduction of irrigation by the above mentioned branch has been assumed to extend in stages over the entire prediction period.Recharge factors have been worked out accordingly. Model was also run to predict the ground water levels if Lakhaoti branch and its distributaries are lined. Proposed canal input through Lakhaoti Branch is shown in Table 2. Rainfall data for monsoon and non-monsoon seasons were averaged out from the calibrated model.The predicted levels for the different seasons with and without lining of Lakhaoti branch were computed.In general, the tendency of the water level is to fall at a decreasing rate if canal is unlined. However, if the system is lined the water table continues to fall at a rate of 0.3 m per year .

Table 2 : Proposed Canal Water Input Through Lakhaoti Branch

S.No.	Year	Canal input (ha m)	Proposed Irrigated area (ha m)
1.	1989	11437.7	48,224
2.	1990	19236.1	82,112
3.	1991	28594.3	123,304
4.	1992	35872.9	157,433
5.	1993	43671.3	193,000

The subsurface inflow to the study area from the adjoining areas has been computed.Itis seen that the subsurface inflow from adjoining areas increases from 6700 Ham in 1984 to 8900 Ham in 1990, after that the subsurface inflow more or less becomes stable, and in 1993 it is 8800 Ham.This means that the introduction of Lakhaoti branch system is likely to stabilise the water table in the study area which leads to reduction of the subsurface inflow to the study area from the adjoining areas receiving water from Upper Ganga canal, Lower Ganga canal and Anupshahar branch canal.

Effect of Introducing Lakhaoti Branch

The area between east Kali nadi and Nim nadi, previously served by state and private tubewells, has been taken as the command area for Lakhaoti branch canal.Surplus monsoon runoff of the Ganga river will be utilised for kharif irrigation in this dry pocket.The clutural command area of the branch is 193000 hectares, and the proposed paddy irrigation is 49550 ha.The length of the main canal is 72 Km while the length of distributaries and minors provided in various discharge ranges is 1030 km.

The results of calibration and prediction runs indicate that the average weighted water levelin the area had gone down by about 1.6 m from 1985 to 1988.This tendency of progressive lowering in water table is likely to be checked after introduction of Lakhaoti branch, which will increase recharge by about 17,000 ham due to seepage from unlined distribution system and irrigated fields. The inflow from adjoining area is likely get stabilised at full development of canal irrigation to a rate of about 9000 ham per year.

It is also seen that during the calibration period the weighted average depth of the water table below ground level in the study area had gone down from 10.5 to 12.0 metres.As a result of this the cost of pumping of ground water increased by about 8 percent from 1985 to 1988. After introduction of Lakhaoti branch this tendency in the lowering of water table is checked and cost of pumping will start going down slightly.The averageweighted water table depth is likely to get stabilised atabout 12.2 m below ground level.

Comparison between Predicted and Observed Levels

A check for the prediction runs can be done by comparing the predicted water level with the observed water levels in the two year 1988-89 and 1989-90 as shown below :

Node	Season		Predicated level	Observed level	Differernce
36	6	1989	196.74	195.79	- 0.95
36	10	1989	197.57	197.76	0.19
36	6	1990	196.46	195.78	- 0.68
36	10	1990	197.29	196.06	- 1.23
37	6	1989	192.60	192.67	0.07
37	10	1989	193.15	193.65	0.50
52	6	1989	185.45	185.12	- 0.33
52	10	1989	186.00	186.25	0.25
60	6	1990	177.85	178.29	0.44
60	10	1990	178.54	178.89	0.35
93	6	1989	203.06	202.72	- 0.34
93	10	1989	203.96	203.56	- 0.40
93	6	1990	203.02	202.12	- 0.90
93	10	1990	203.94	203.62	- 0.32

A perusal of the above table gives an indication that the predicted water levels are not matched with the observed water levels. But this variation is because of many reasons such as :

1. An increase of 2% of abstraction in rabi season was assumed but this assumption may not be satisfied.
2. Average rainfall from the calibrated model was taken but the actual rainfall may be different from that assumed.
3. Input from Lakhaoti branch canal was assumed to be uniformly distributed over the whole area of 193000 ha, but in reality the area will be cover in stages as shown Table 2.

CONCLUSION

Tyson and Weber mathematical model was developed to simulate the ground water flow for Lakhaoti area.In this study the clamped nodes were taken as small as possible.

The study area of 446879 hectare was divided into 98 nodal polygons.Average area of the node is 4560 hectares. There are 36 clamped nodes and 62 free nodes out of these 39 were located on observation wells. The model was calibrated for historic ground water levels for the period from October 1984 up to October 1988, by adjusting the estimated aquifer parameters and various recharge and abstraction values.

The average error between computed and historic levels for the important nodes was 0.056 m and that for all node was 0.05 m. from the final calibration, the values of the specific yield varies from 5% to 25% with an average value of 14.98%.The values of the transmissibility varies from 0.5 to 5.75 ha/month.

Average rainfall recharge varies from 18.35 to 21.05 percent of the annual rainfall.Recharge from canal seepage and from irrigated fields was 39.5 percent of the total canal input, since the modelled area is bounded by U.G.C., L.G.C. and Anupshahar branch, the seepage from these canals varies from 10598 to 12206 ha-m annually. Maximum seepage was found to take place during the years 1986-87 and 1987-1988 and that was because of the drought in 1987.

The input from rainfall to the ground water basin varies between 37% to 60% of the total annual input.Lowest value being obtained in 1986-87 which was a drought year with annual rainfall of 36.4 cm.

From the predicted results it was clear that if Lakhaoti branch system is lined, the water table will continue to go down progressively.The subsurface inflow to the study area from the adjoining irrigated areas will decrease after introduction of the Lakhaoti branch system.The cost of pumping ground water which has been progressively increasing will stabilise after 1992, if Lakhaoti branch is not lined.

The flow from the clamped (boundary) nodes to the interior nodes works out from 10598 to 12205 ha-m. The average seepage works out 0.75 $m^3/sec/10^6m^2$ of the canal wetted perimeter. This worksout to be slightly on the lower side of the normal seepage loss from the unlined canals.Some studies by U.P. I.R.I. indicates that the seepage loss from the Upper Ganga canal is about 1.25 $m^3/sec/10^6m^2$. However the entire canal seepage does not reach the subsurface reservoir. If 75% of it assumed to reach subsurface reservoir, the canal contribution could be at 0.93 $m^3/sec/10^6m^2$, against the computed value works out 0.75 $m^3/sec/10^6m^2$.