Ministry of higher eduction
And scintific research
Univirsty of technology
Deparment of buliding & constriction
Water & Dams Branch

Artificial Recharge of Ground Water

A Project
Submitted to the Department of buliding & constriction division in partial fulfillment of requerment for the degree B.sc

By:
Hager Ahmed Mosa

Supervisor :
Dr. Ibtesam Raheem

2011 م **1432هـ**

University of Technology

بسم الله الرحمن الرحيم

(وَمِنْ آيَاتِهِ أَنَّكَ تَرَى الْأَرْضَ خَاشِعَةً فَإِذَا أَنْزَلْنَا عَلَيْهَا الْمَاءَ اهْتَزَّتْ وَرَبَتْ ۚ إِنَّ الَّذِي أَحْيَاهَا لَمُحْيِي الْمَوْتَىٰ ۚ إِنَّهُ عَلَىٰ كُلِّ شَيْءٍ قَدِيرٌ)

سورة فصلت – الاية ٣٩

(وَفَجَّرْنَا الْأَرْضَ عُيُونًا فَالْتَقَى الْمَاء عَلَى أَمْرٍ قَدْ قُدِرَ)

سورة القمر- الاية ١٢

(وَجَعَلْنَا مِنَ الْمَاء كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ)

سورة الانباء-الاية٣٠

الاهداء

الى من اطفؤ نور اعينهم لينيرو لي الطريق

الى من تحملوا هموم الدنيا ومشاقها

لكي يصلوا بي الى هذا الطريق

امي و ابي

الى من استمد منهم الحنان والراحة والامان

اخوتي

الى من ساعدني وساندني في محنتي وارشدني في حيرتي

زوج اختي

الى طريق العلم والنور والمحبة

أساتذتي

الشكر و التقدير

نتقدم بالشكر والتقدير لكل من ساهم في إنجـــــاز مشروعنا

المتواضع و نخص بالشكر المشرف على هذه الجهود المتواضعة

الأســــتاذة الفاضــــــــــــــــلة

الدكتوره ابتسام رحيم

التي عاونــــتــــنا وساهمت في معلوماتها القيمة و الــــــتي

كانت لنـــــــــا بمثابة الأم والأستاذةالفاضلة والتي لم تبخل

علينـــا بتوجيهاتها القيمة التي ادت إلى اتمــــــام

هـــــــــــــذا المشروع المتواضع

فلـــــــــــماجزيل الشكر وخالص التقدير.....

طالبة المشروع

هاجر احمد موسى

I certify that the project titled artificial recharge of ground water which is being submitted by Hager Ahmed in partial fulfillment of the requirement of B.S.C of science in water and Dams, is a bona fide record of work carried out by him under my supervision.

Signature:

Name: Ibtesam Raheem

Data:

Contents

List Figure

Figure **page**

Summary

Ground water recharge may be explained as the process where by the amount of water present in or flowing through the interstices of the subsoil increases by natural or artificial means. Rainfall is the principal recharge of ground water. Moisture movement in the unsaturated zone is controlled by suction pressure moisture content and hydraulic conductivity relationships .objective from of the project were to increases level of ground water and to study the responsibility of the ground water to the artificial recharge. One of the main purposes of aquifer simulation is to predict aquifer response to various plans of its exploitation and operation. Computer program (package) called MODFLOW is used for this purpose. The information about the area have been collected from application example .The other required input data to the MODEFLOW are either computed from available data obtained from previous studies or assumed. The steady-state (natural) head distribution prior to pumping has been obtained by two method .In the first the study –state choice of the program was selected .In second method the program was run for unsteady-state condition but with sources or sinks (injection or production wells) for a very long period until the head values become constant (or nearly so) with time. Both methods gave nearly similar results in all the cases which are considered. The benefit of ground water is used to uses human, industrial and irrigation purposes and it's time in of drought

CHAPTER ONE

Chapter one

Introduction

1-1 General

Ground water recharge may be explained as the process where by the amount of water present in or flowing through the interstices of the sub-soil increases by natural or artificial means. The amount of water that may be extracted from an aquifer without causing depletion is primarily dependent upon the ground water recharge. Rainfall is the principal source for replenishment of moisture in the soil water system and recharge of ground water. Other sources include recharge from rivers, streams, irrigation water etc. Moisture movement in the unsaturated zone is controlled by suction pressure, moisture content and hydraulic conductivity relationships. The amount of moisture that will eventually reach the water table is defined as natural ground water recharge, which depends on the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type.

Fresh water is constantly formed anew. This is due to the fact that all the water on earth, either as water vapor in the atmosphere, as subsurface water in streams, lakes, seas and oceans or as ground water in the interstices in the sub-soil, is not at rest, but in a continuous circulatory movement known as the hydrological cycle. The increasing demand for water has increased awareness towards the use of artificial recharge to augment ground water supplies. Stated simply, artificial recharge is a process by which excess surface water is directed into the ground – either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration – to replenish an aquifer. It refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage (NRC, 1994)

1.2 Aim The study of the research

_This research aims to study the responsibility of the ground water to the artificial recharge . An effective method of artificial recharge by water wells is chosen . The pro design and construction of water wells is highly required in order to maximize the benefits from water wells therefore this study deals with the optimum design and constructions techniques of water wells for a presumed case study (application example) .

Also the research aims to use a software for designing the water wells of artificial recharge to facilitate the design steps.

CHAPTER TWO

Chapter two

Methods of artificial recharge

2.1methods of artificial recharge

These can be broadly classified as:

1- Spreading Method

- Spreading within channel

- Spreading stream water through a network of ditches and furrows

- Ponding over large area

2- Recharge Shafts

- Vertical Shafts

- Lateral Shafts

3- Injection Wells

4- Induced Recharge

5- Conjunctive Wells

6-Ditches

2.1-1 Spreading basins

This method involves surface spreading of water in basins that are excavated in the existing terrain. For effective artificial recharge highly permeable soils are suitable and maintenance of a layer of water over the highly permeable soils is necessary. When direct discharge is practiced the amount of water entering the aquifer depends on three factors - the infiltration rate, the percolation rate, and the capacity for horizontal water movement. In a homogenous aquifer the infiltration rate is equal to the percolation rate. At the surface of the aquifer however, clogging occurs by deposition of particles carried by water in suspension or in solution, by algal growth, colloidal swelling and soil dispersion, microbial activity ect. Recharge by spreading basins is most effective where there are no impending layers between the land surface and the aquifer and where clear water is available for recharge; however, more turbid water can be tolerated than with well recharge. The common problem in recharging by surface spreading is clogging of the surface material by suspended sediment in the recharge water or by microbial growth. In coarse grained materials removal of fine suspended sediment is difficult. Playa Lakes or wet weather lakes are depressions that collect water after rainfall or periods of snowmelt. Playa lakes in Texas, New Mexico and Colorado have been used in artificial recharge projects (O'Hare et al., 1986). Many Playa lakes have tight clay deposits that restrict leakage of water. Most of the water is lost by evaporation or by non-beneficial growth of vegetation in the lake. Heavy clay soils can be broken up and the lake bottom regarded for maximum recharge. In a demonstration project near Lubbock, Texas, playa lakes were modified by excavating concentration pits and using the excavated soil to raise the elevation of some of the previously flooded lands.

2.1-2 Recharge Shafts

Conditions that permit surface spreading methods for artificial recharge are relatively rare. Often lenses of low permeability lie between the land surface and water table. In such situations artificial recharge systems such as pits and shafts could be effective penetrate the less permeable strata in order to access the dewatered aquifer. The rate of recharge has been found to increase as the side slopes of the pits increased.

Unfiltered runoff waters leave a thin film of sediment on the sides and bottom of the pits which require maintenance in order to sustain the high recharge rates. Shafts may be circular, rectangular, or of square cross-section and may be backfilled with porous material. Excavation may terminate above the water table level or may be hydraulic connectors and extend below the water table.

Recharge rates in both shafts and pits may decrease with time due to accumulation of fine grained materials and the

- VERTICAL RECHARGE SHAFT

The vertical recharge shaft can be provided with or without injection well at the bottom of the shaft.

Without Injection well

1- Ideally suited for deep water levels (up to 15 m B.G.L).

2- Presence of clay is encountered within 15 m.

3- Effective in the areas of less vertical natural recharge.

4-Copious water available can be effectively recharged.

5-Effective with silt water also (using inverted filter consisting of layers of sand, gravel and boulder

- LATERAL RECHARGE SHAFT

Ideally suited for areas where permeable sandy horizon is within 3 m below ground level and continues up to the water level – under unconfined conditions Copious water available can be easily recharged due to large storage and recharge potential Silt water can be easily recharged

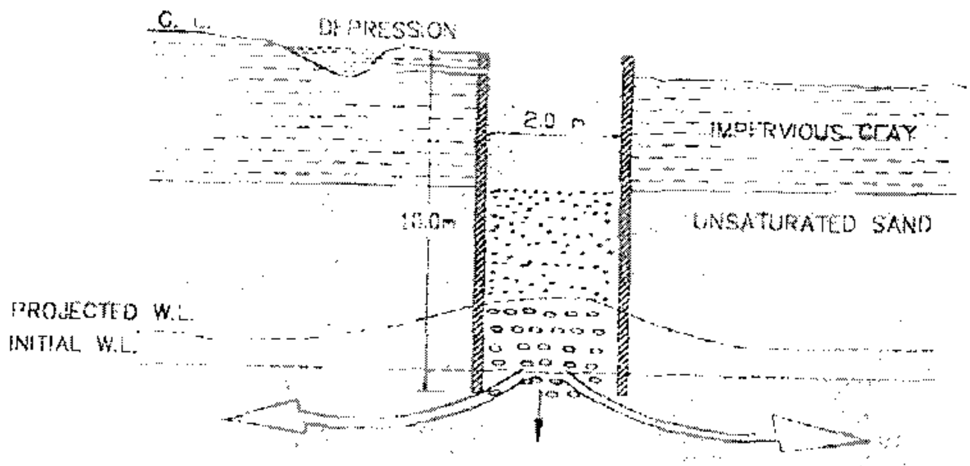


Fig (2-1) Lateral Recharge Shaft

2.1-3 Recharge Wells

Recharge or injection wells are used to directly recharge water into deep water-bearing zones. Recharge wells could be cased through the material overlying the aquifer and if the earth materials are unconsolidated, a screen can be placed in the well in the zone of injection. In some cases, several recharge wells may be installed in the same bore hole. Recharge wells are a suitable only in areas where a thick impervious layer exists between the surface of the soil and the aquifer to be replenished. They are also advantageous where in areas where land is scarce. A relatively high rate of recharge can be attained by this method. Clogging of the well screen or aquifer may lead to excessive build-up of water levels in the recharge well. In ideal conditions a well will accept recharge water at least as readily as it will yield water by pumping. Factors that cause the build up of water levels in a recharge well to be greater than the corresponding drawdown in a discharging well may Factors that cause the build up of water levels in a recharge well to be less than the corresponding drawdown in a discharging well may include the following.

2.1-4 Enhanced Streambed Infiltration (Induced infiltration)

This method of induced recharge consists of setting a gallery or a line of wells parallel the bank of a river and at a short distance from it. Without the wells there would be unimpeded outflow of groundwater to the river. When small amounts of groundwater are withdrawn from the gallery parallel to the river, the amount of groundwater discharged into the river decreases. The water recovered by the gallery consists wholly of natural groundwater. Each groundwater withdrawal is accompanied by a drawdown in the water table. For high recovery rates this drawdown tends to lower the groundwater table at the shoreline below that at the river. Thus, surface water from the river will be induced to enter the aquifer and to flow into the gallery. In areas where the stream is separated from the aquifer by materials of low permeability, leakage from the stream may be so small that the system is not feasible.

2.1-5 Conjunctive Wells

A conjunctive well is one that is screened in both a shallow confined aquifer and a deeper artesian aquifer. Water is pumped from the deeper aquifer and if its potentiometric surface is lowered below the shallow water table, water from the shallow aquifer drains directly into the deeper aquifer. Water augmentation by conjunctive wells has the advantage of utilizing sediment-free groundwater which greatly reduces the damage of clogging well screens.

Other benefits are:

- It reduces the amount of evapotranspiration water loss from the shallow water table.
- Reduces flooding effects in some places.

Environmental effects from the conjunctive well method must be carefully studied to assure that unwanted dewatering of wetlands or reduction of base flow will not occur. The possibility of coagulation due to mixing of chemically different groundwater's should also be investigated

2.1-6 Ditches

A ditch could be described as a long narrow trench, with its bottom width less than its depth. A ditch system can be designed to suit the topographic and geologic conditions that exist at a given site. A layout for a ditch and a flooding recharge project could include a series of ditches trending down the topographic slope. The ditches could terminate in a collection ditch designed to carry away the water that does not infiltrate in order to avoid ponding and to reduce the accumulation of fine material .

2.2 Advantages of Artificial Recharge Ground water

Artificial recharge has several potential advantages:

- The use of aquifers for storage and distribution of water and removal of contaminants by natural cleaning processes which occur as polluted rain and surface water infiltrate the soil and percolate down through the various geological formations.
- The technology is appropriate and generally well understood by both the technicians and the general population.
- Very few special tools are needed to dig drainage wells.

- In rock formations with high, structural integrity few additional materials may be required (concrete, soft stone or coral rock blocks, metal rods) to construct the wells.
- Groundwater recharge stores water during the wet season for use in the dry season, when demand is highest.
- Aquifer water can be improved by recharging with high quality injected water.
- Recharge can significantly increase the sustainable yield of an aquifer.
- Recharge methods are environmentally attractive, particularly in arid regions.
- Most aquifer recharge systems are easy to operate.
- In many river basins, control of surface water runoff to provide aquifer recharge reduces sedimentation problems.
- Recharge with less-saline surface waters or treated effluents improve the quality of saline aquifers, facilitating the use of the water for agriculture and livestock.

2.3 Disadvantages Of Artificial Recharge Ground water

Artificial Recharge has some disadvantages too:

- In the absence of financial incentives, laws, or other regulations to encourage landowners to maintain drainage wells adequately, the wells may fall into disrepair and ultimately become sources of groundwater contamination.
- There is a potential for contamination of the groundwater from injected surface water runoff, especially from agricultural fields and roads

surfaces. In most cases, the surface water runoff is not pre-treated before injection.

- Recharge can degrade the aquifer unless quality control of the injected water is adequate.
- Unless significant volumes can be injected into an aquifer, groundwater recharge may not be economically feasible.
- The hydrogeology of an aquifer should be investigated and understood before any future full-scale recharge project is implemented. In karstic terrain, dye tracer studies can assist in acquiring this knowledge.
- During the construction of water traps, disturbances of soil and vegetation cover may cause environmental damage to the project area.

CHAPTER THREE

Chapter three

Literature Review & Theoretical Background

3-1 Literature Review

- Macfdyen (1938) presented the first general study on the ground water rescores in Iraq in their work geological information were presented on the area just west of the Euphrates and along the Iranian border
  Macfdyen report included meteorological data on various part of the Mesopotamian plain topography and geological information. The date also include existing water supplies drilled wells hand dug wells quality of water chemical analyses and ground water movement
- Krusny 1982 in his hydro geological and hydrochamical studies complied data available on the area of Kut Ali Al-ghribi , and al-teeb geological information obtained on the Mesopotamian have been utilized in his work in addition to the data obtained from the drilled wells as document in the data bank by the state organization for ground water . he did not attempt to treat the various aquifers separately but general evaluation has been done for the water bodis existing within few tens of meters . the depth of water ranges from 10 to over 20 meter below surface . water movement is to towards south-west from the mountainous area
- In 1996 the department of defiance (USA) published the ground water modeling system (GMS) . it is a comprehensive graphical user environment for performing ground water simulation the enters GMS consists of a graphical user interface (the GMS program) and a number

of analysis codes (Mode flow,MT3D,M Mod path,FEMWATER). The GMS interface was developed by the Engineering computer graphics laboratory of Brigham University in partnership with the U.S. Army Engineer Water ways Expiries Station . GMS was designed as a comprehensive modeling environment .Several types of models are supported and facitaties are provided to share information between different models and data types tools are provided for site characterization , model conceptualization mesh and grid generation ,geostatistics,and post-processing.

A finite-element groundwater flow model HYDRUS2D was used by V.GOYAL, B.S. JHORAR, R.S.Malik and T.Streek to simulate draw up and drawdown of piezometric pressur head in the aquifer storage recovery cycles of varying buffer storage volumes and residence time in a highly brackish semi-confined aquifer under shallow water-table condition. Physical flow region implemented in HYDRUS 2D involved a soil profile of 500m width and 69m depth ,with an exocentric elliptical cavity of 1m radius at 54 m depth

- SAMAHAER ABDIL-RASOSOL LAZIAM B.S. 1999 studed the possibility of using ground water from the bakhtiari and upper fars formation in BAZURGAN area the economic evolution and suitability for human and in diastral usage

3-2 Theoretical background

The theory here is related specifically to the industry –standard code MODFLOW that is used in the present work and which present wide range of alternative in choosing the technique of solution and presentation of input \output data .It may be used to simulate steady or unsteady ,two or three dimensional flow in \unconfined aquifer .It may be used to simulate a relatively complex multilayer system with all the input \output component (Domenico and Schwartz1998)

In the finite difference method , the governing differentials equation for ground water flow is replaced by a difference equation that embodies conservation principal of the original differential equation Three dimensional flow may described by the flowing equation:

$$\frac{\partial}{\partial x}\left(K\,xx\frac{\partial}{\partial x}\right)+\frac{\partial}{\partial y}\left(Kyy\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(Kzz\frac{\partial}{\partial z}\right)+W=Sc\frac{\partial h}{\partial t}\text{............2-1}$$

Where:

Kxx,kyy and kzz are values of hydraulic conductivity a long the X,Y and Z coordinate axes (L/T)

h= hydraulic head (L)

W=flux that accounts for pumping recharge or other source and sinks ($L^3/T/L^3$) rate of withdrawal per unit volume

Sc= specific storage (1/L)

X,y, and z = coordinate direction (L), and t =time (T)

Sc,kxx,kyy and Kzz can be function of space while W and h are function of space and time .

Equation describes unsteady flow of ground water in anisotropic and homogeneous media , at the exception of simple cases the analytical solution of equation above is difficult for complicated cases with the basin as the unit of study moreover the available analytical methods can not treat nonhomogeneous conditions the numerical techniques allow the treatment of the system as discrete number of small sub-system for each of which Eq. above may be applied.

The development of the finite deference flow equation is based on the printable of continuity which state that the sum of flow into and out of any cell is equal to the time rate of storage plus or minus additions of water from source or sinks . This may be express mathematically as

$$\sum Qi = Sc\frac{\Delta h}{\Delta t}\,\Delta V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

Where:

Qi : account for flow components into or out of the cell from adjacent cells

Δ h : the change in heade over ,The time interval Δt , and Δv is the volume of the cell

The finite difference approximation of equation (2.1) may be written as (domino and Schwartz, 1998)

$$CR_{i,j-1/2,k}(h_{i,j-1,k}-h_{i,j,k})+CR_{i,j+1/2,k}(h_{i,j+1/2,k}-h_{i,j,k})+CC_{i-i/2,j,k}(h_{i-1,j,k}-h_{i,j,k})+CC_{i+1/2,j,k}(h_{i+1,j,k}-h_{i,j,k})+CV_{i,j,k-1/2}(h_{i,j,k-1}-h_{i,j,k})+CV_{i,j,k+1/2}(h_{i,j,k+1}-h_{i,j,k})+p_{i,j,k}h_{i,j,k}+Q_{i,j,k}=Ss_{i,j,k}(r_jc_iv_k) \ldots\ldots\ldots(2.3)$$

Where:

CR,CC and CV are hydraulic conductance in the row ,column and

$Ss_{i,j,k}$ is the specific storage

$r_j c_{ik}$ are the volume of cell I,j,k

$h_{i,j,k}$ approximate finite difference value for head change with time.

The final form of the finite difference equation can be expressed as (Domenic and Schwartz, 1998):

$$CV_{I,J,K-1\backslash 2}h^{m}_{i,j,k-1}+CC_{I,-1\backslash 2,J,K}h^{m}_{i-1,j,k}+CR_{I,J-1\backslash 2,K}h^{m}_{i,j-1,k}+(-CV_{I,J,K-1\backslash 2}-CC_{I-1\backslash 2,J,K}-CR_{I,J-1\backslash 2,K}-CR_{I,J-1\backslash 2,K}-CC_{I-1\backslash 2,J,K}-CV_{I,J,K+1\backslash 2}+P_{I,J,K}-)h^{m}_{i,j,k}+CR_{I,J+1\backslash 2,K}h^{m}_{i,j,+1,k}+CC_{I+1\backslash 2,J,K}h^{m}_{i+1,j,k}+CV_{I,J,K+1\backslash 2}h^{m}_{i,j,k+1}=-SCI_{I,J,KI,j,} \quad \text{2-4}$$

Where:

$sci_{I,j,k}=Ss_{i,j,k}\, v_j\, c_i v_k$

m= is the time at which the head are unknown and

m-1= is the previous time step

The mathematical solution of this system of equation provides the hydraulic head at each nodal point for the given time step

3-3 Computer modeling of ground water flow

The use of digital computers in ground water rescores evaluation has grown rapidly within the past few years. computers are now widely available that allow solution of large sets of simultaneous that are involved in studying case and effect relationship in heterogeneous aquifer system with a wide verity of boundary condition .the digital computer deal with problems of much greater complexity than is practical with electric analog or analytical methods . Whoever digital computer will not because analytical methods or electric analog simulators to become obsolete. Seed in conjunction with other tools available to the hydrologist digital computers can greatly improve the analysis of ground water problems.

Discussion of the digital techniques in includes the necessary mathematical background documented program listening and field applications selecting the appropriate program for a modeling job involves matching modeling needs with the capabilities and controls of available grams there are numerous programmers for use ground water modeling the modular one is provided by the united states geological survey (department of defense 1998) named as ground water modeling (GMS) which provide a comprehensive graphical environment for numerical modeling tools for site characterization modeling conceptualization mash and grid generation and geostatistics several types of numerical codes are supported by GMS

A GMS package has been used in the present study because:

1-It has numerical features necessary to model the study area

2-It is well documented and widely used.

3-It is available through the public domain.

A graphical interface to the ground water model (MODE FLOW)

Is provided in GMS. MODE FLOW is a qusi three dimensional cell centered finite difference saturated flow model which can perform both steady state and transient analyses and has a wide variety of boundary

Conditions and out option.

GMS support mode flowas a pre- and – post p processor. The input date for mode flow are generated by GMS and saved to a set files of these files are then read by MODEFLOW when MODEFLOW is executed the output from MODEFLOW is then imported to GMS for post processing

MODEFLOW views a quasi three dimensional system as sequence of layers. the horizontal grid is generated in the usable way by specifying grid dimensions in the X and Y direction as with all finite difference grid the horizontal grid must be the same for each layer

The approach of modeling the aquifer included three major steps:

1-devloping a steady state model

2-devloping the transient mode

3-assempling the data sets and running the model for predictive runs

The MODE FLOW is a USGS two and three dimensional ground water flow model. It is a flexible and powerful ground water flow simulation model that can be applied to a relatively simple or very complex aquifer system. MODE FLOW has emerged as the standard code for aquifer simulation the original code was developed with an extensive users guide and released in 1984, this version was superseded by the first modified visual version of MODE FLOW that was published by USGS (McDonald and hrarpaugh 1988).

Many enhancements have been made to the mode flow since 1988 the ability of the model to simulate ground water and surface water interaction was developed by Produce 1989 a new equation solver was introduced be Hill 1990 new approach to accommodate the rewriting of cells in the model that become dry was made by McDonald et .al .1991 techniques to represent a transitivity field that is smoothly varying were carried out by good and apple 1992 the capability to treat narrow horizontal barriers (e.g. faults) that may impede made the mode flow code tremendously powerful and capable of handling a verity of ground water condition

CHAPTER FOUR

Chapter four

Application Example

4-1 Design of grid

The grid system is referenced in terms of row, column and layer numbering scheme with block-centered nodes. No uniform mesh of (7500) rows and (7500) columns has been designed to simulate the aquifer as shown in fig (4-1)The nodal areas of grid range from (500m) to (500m) .In this design considerations were given to the change in the hydraulic properties well locations hydraulic gradient reliability of information and the nature and distance from the boundaries.

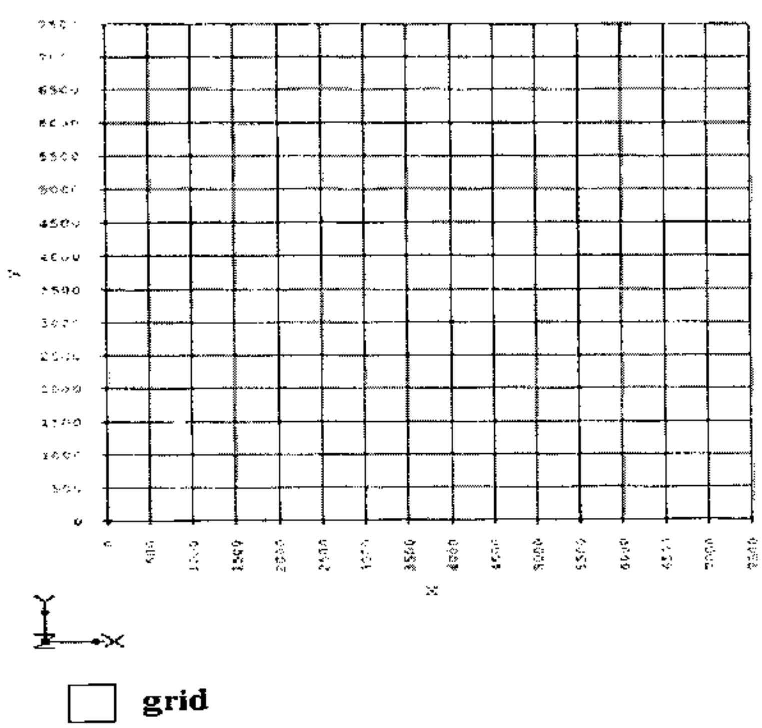
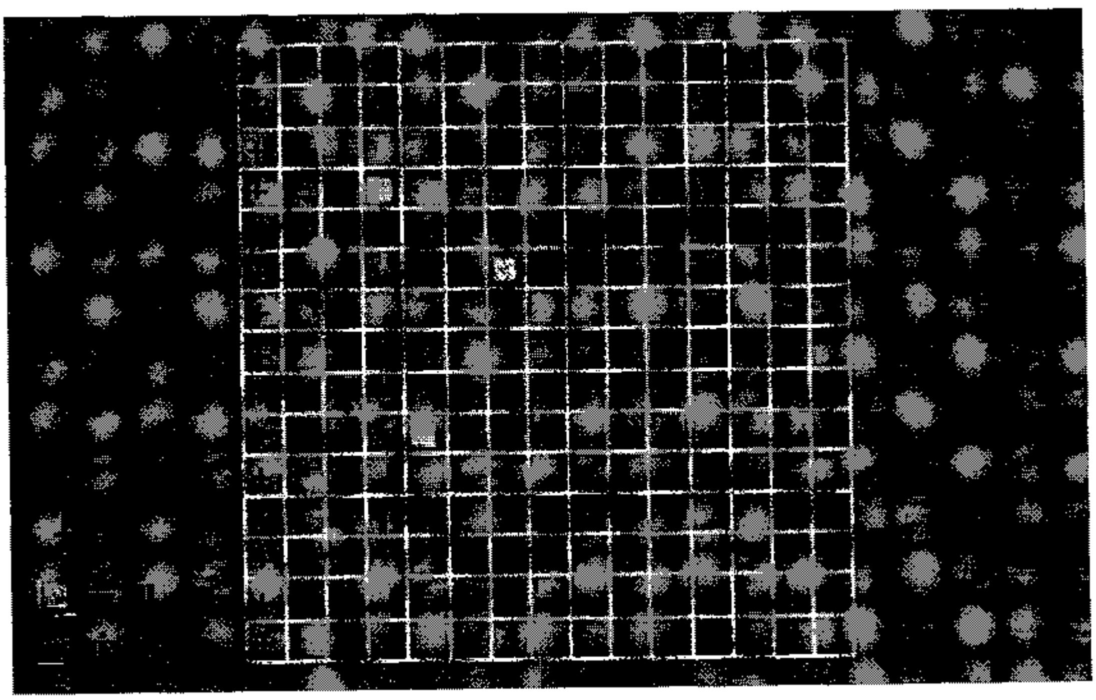


Figure (4-1) Design of grid

4-2 Recharge wells

Three recharge well were assumed to be distributed in the river itself recharge lugged through the study area, fig (4.2)to recharge the ground water from the river. The net change in water table due to well recharge for particular time period was noticed and it was deducted from total head (the head due to river and recharge tube well together) observed at the end of the same time period to determine expected head due to recharge tube well only. The bottom of the recharge tube well was selected as datum elevation. The recharge taking place above the water table elevation (in unsaturated zone) would be controlled by local hydraulic gradient. The recharge in saturated zone would depend upon regional gradient as well as transmissivity of the aquifer layers. The expected heads due to recharge tube well were used to calculate the recharge rate according to equation:

$$Q = \pi K (h_1^2 - h_2^2) / \ln (r_1/r_2) \quad \text{...(4-1)}$$



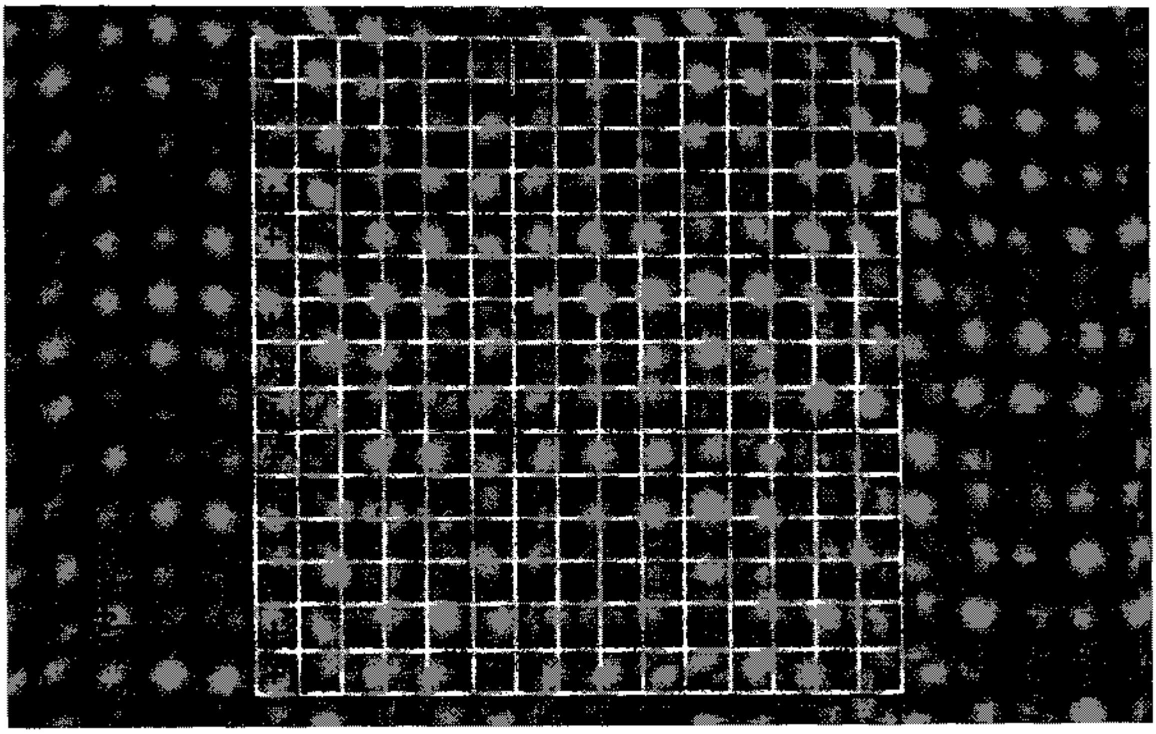
Figure(4-2)Location of recharge well in the application area

4-3 Model Boundaries And Initial Conditions

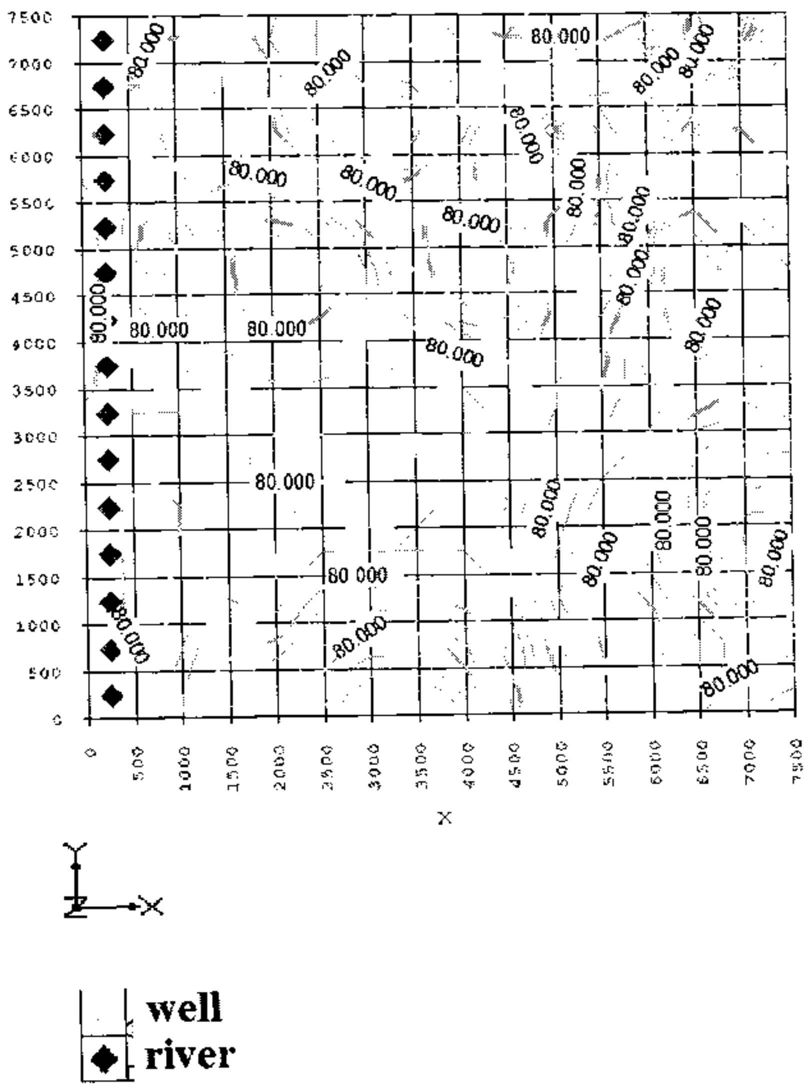
The boundary condition of system are well stated in this example which assumed to be no flow boundaries through north, south and the eastern sides of the area while the western side is assumed to be constant flow boundary as shown in fig.(4.3a)as proportional to head difference between the water surface in the river and the water table. The part of the upper aquifer simulated as specified head boundaries by setting the head at these boundary nodes equal to down head values. Concering lower aquifer the western boundary was defined as constant head boundary while other sides were assumed to be the same as the upper aquifer.

It should be maintained that the numerical model in the study area was considered upper and lower limits for the system. The upper limit is the water table in the unconfined aquifer and the lower limit is the impervious layer which is the bottom of the leaky aquifer. All nodes outside the boundary of the node led region are assigned fixed head nodes (inactive cells).The internal cells were considered variable head cells.

The initial condition in the steady state is the head distribution within the model area at initial time (t = 0).The head distribution of the lower aquifer was assumed to be the same as for the upper aquifer which means that the water table and the piezometric level coincide, fig.(4.3b). The initial heads were considered as the initial condition for the steady state calibration.



Figure(4.3a)Boundary Condition



Figure(4.3b) Initial Condition

4-4 Input data

1-Hydraulic conductivity along the x,y and z coordinate axes l/T witch assumed of to be=0.05m/d

2-Storage coefficient, which assumed of to be=0.03

3-Surface elevation, which assumed of to be=90m

4-Surface bottom, which assumed of to be=8om

5-Recharge rate to wells, which assumed of to be=10m^3/d

4-5 Output data

After interning data and running the program with several iterations the head of ground water in this example was found to be as in fig (4.4) and (4.5)

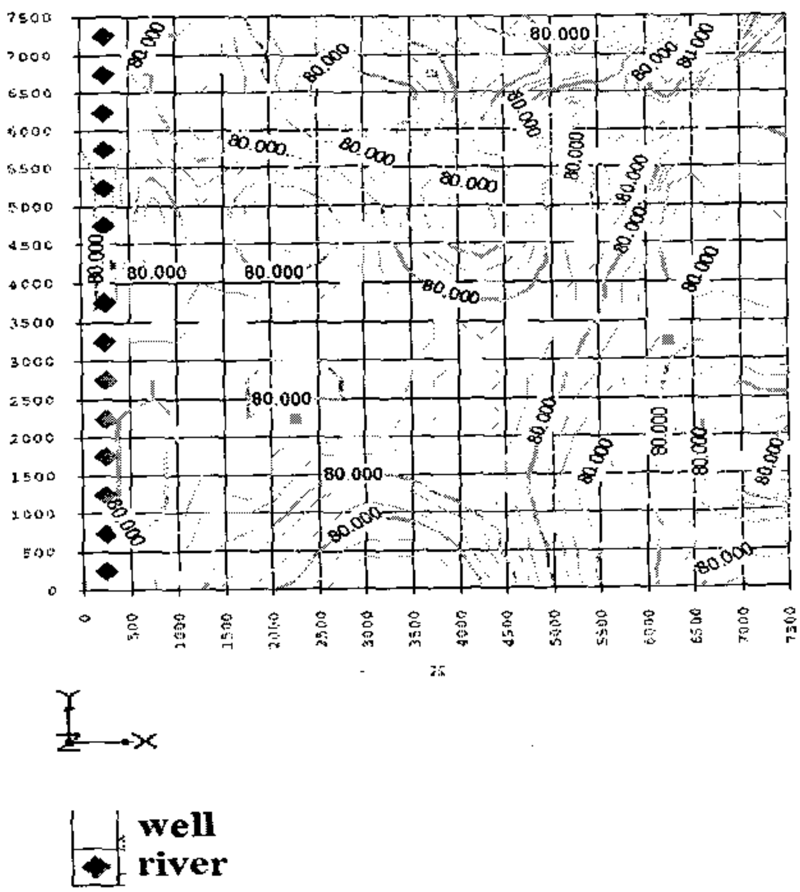


Figure (4.4)Steady state ground water contour map

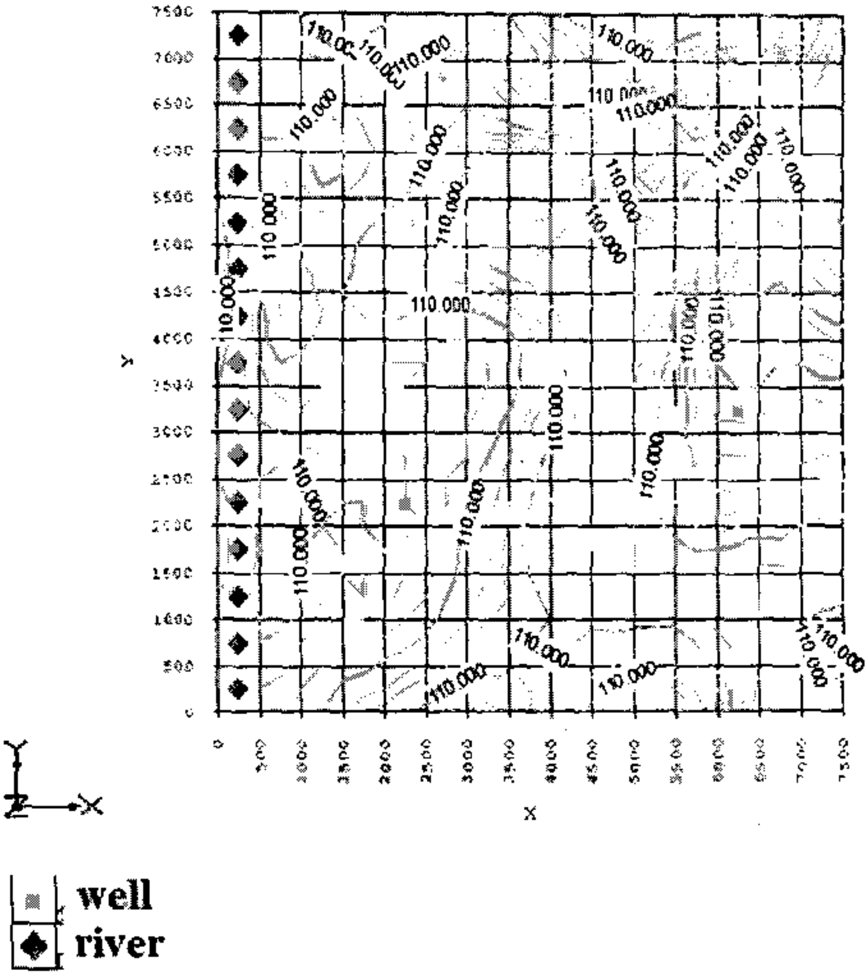


Figure (4.5) Ground water contour map of the area After 30 days from the operation with recharge

CHAPTER FIVE

Chapter Five

Conclusions & Recommendations

5-1 Conclusions

The application area is assumed to be with dimension (7.5km*7.5km) and its divided to portion called grid with dimension (0.5km*0.5km) .The area is assumed to be supplied with three wells and main sours from river in order to increasing recharge of the ground water by injection wells to that area .The ground water may be used for injecting to maintain the pressure in well, however further investigation testing analysis are required to check the suitability of water for long period of an injection program. The area is simulated by a mathematical model that can be use for prediction of aquifer response for various plans of exploitation the efficiency of the model results depends on the accuracy of the input data. Accordingly the model may be largely improved when more and accurate data become available.

The results show that the recharging from the injection wells raised the water table to the required level according to the rate of recharge.

5.2 Recommendations

1- Use a real case study instead of application example for available data.

2- Use different types of recharge in order to choose the appropriate method

3-Study the quality of recharge water in order to state the field use of this water.

Reference

- National Research Council. 1994. Groundwater Recharge Using Waters Of Impaired Quality
- O'Hare, M.P., Fairchild, D.M., Hajali, P.A., Canter, L.W., 1986. Artificial Recharge Of Groundwater.
- Proceedings Of The Second International Symposium On Artificial Recharge Of Groundwater, 1994. Artificial Recharge Of Groundwater-2.
- Pyne, R.D.G., 1995,Groundwater Recharge And Wells Artificial Recharge in Delhi Area,Central Ground Water Board, Northern Water RegionChandigarh.
- Dovlopment & Augmentation of Ground Water Resourses in NCT of Delhi.
- Ground Water Recharging Peoples participants in Jamnagar Region, Prof. G.G. Parthasarthi andA.S. Patel, Indian Water Works ASSOCIATES Jan 1997.
- (Domenico and Schwartz1998)
- Guide on Artificial Recharge to Ground Water "by Central Ground Water Board" Ministry ofWater Resourses.
- Guide on Artificial Recharge to Ground Water, Central Ground Water Board, Ministry of water resourses,New Delhi 2000.
- Indian Metrological Department (Monthly and Annual Rainfall Data).
- Kesari, P, and Singh,S.K.(2005) " Sustainable Development of Ground Water in Delhi through Rain Water Harvaisting" , Journal of Indian Buildings Congress Vol12,No.1
- Mahi, S.P. and Prakash, O.(2005)"Artificial Recharge to Grounder Water in Railway ResidentialComplex in Delhi " Journal of Indian Buildings Congress Vol.12, No.1 Pal, S, and Sharma,S.K.(2005) " Rain Water Harvesting and Artificial Recharge " Journal ofIndian Buildings Congress, Vol.12 No.1
- Roof Top Rain Water Harvesting for Augmentation Ground Water Storage in NCT DelhiCentral Ground Water Board" Ministry of Water Resourses

الخلاصة

تتلخص فكرةالمشروع بتغذية المياه الجوفيةو بالوسائل الاصطناعية حيث ان المصدر الرئيسي لتغذية المياه الجوفية هي مياه الامطار وكذلك هناك مصادر اخرى مثل النهر والجداول وغيرها التي يمكن من خلالها شحن مناسيب مياه الجوفيه وكذلك الرطوبه في المنطقه الغير المشبعه تحت سيطره ضغط الامتصاص وعلاقات التوصيل للرطوبه الارضيه والهيدروليكيه بالكمية المناسبة التي ستصل مستوى الماء في النهايه والطلب المتيزايد للماء زاد وعيا نحو استعمال التغذية الاصطناعيه لاعادة الشحن .

ولقدتمت الدراسه لهذا المشروع على مساحه معينه افتراضيه وكان الهدف من هذا المشروع هوه زياده ورفع منسوب المياه الجوفية وذلك من خلال اخذ ثلاث ابار افتراضيةومصدر تغذيتها من النهر حيث تم استخدام برنامج جاهزModflowليتم حساب الحالة المستقرة لتوزيع منسوب مياه الجوفية الطبيعي بدون اي تاثيرات خارجية من خلال معاملة البرنامج للحالة المستقرة. وتم حساب توزيع الزيادة في منسوب المياه الجوفية كدالة للموقع والزمن بتاثير الابار الموجودة وتم الحصول على نتائج نهائية لمناسيب المياه الجوفية على شكل خرائط كنتورية خلال فترة زمنيةمعينة