A STUDY ON SPECIFIC CAPACITY AND COST OF WELL IN A MULTI-AQUIFER SYSTEM

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
IRRIGATION WATER MANAGEMENT

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CANDIDATES DECLARATION

I hereby declare that the work which is presented in this dissertation entitled **"A STUDY ON SPECIFIC CAPACITY AND COST OF WELL IN A MULTIAQUIFER SYSTEM"** , in partial fulfillment of the requirements for the award of the degree of MASTER OF ENGINEERING IN IRRIGATION WATER MANAGEMENT (IWM) submitted in Water Resources Development Training Centre (WRDTC), University of Roorkee, Roorkee, which is record of my own work carried out during period August 17, 2000 to December 7, 2000 under the supervision of **DR.G.C.MISHRA**, Professor, WRDTC, University of Roorkee Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other Degree or Diploma.

(MUHAMMAD SAMSUL HUDA)

This is to certify that above statement made by the candidate is correct to the best of my knowledge.

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SYNOPSIS

Ground water prospecting and exploration is needed in first instance to determine whether the water occurs under condition that would permit its utilization through wells or tube wells.

The specific capacity is an important parameter which enables to predict, select type of pumps, estimate the cost of pumping. Through the specific capacity of well, it is possible to determine the *transmissivity and* storage coefficient of an aquifer.

Under field condition the aquifer rarely conforms to concept of one aquifer system. Often aquifer pumped is part of a complex aquifer system.

This thesis provides an analysis in respect of dependable yield of well and economic cost of construction of well in a *multi-aquifer system.* Using the analysis it is possible to predict the economical depth of ground water exploitation.

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CHAPTER I

INTRODUCTION

1.1. GENERAL

Ground water prospecting and exploration is needed in the first instance to determine whether regional ground water occurs under condition that would permit its utilization through well or tube wells. The knowledge of geological condition and hydrologic parameter then assumes importance in deciding the optimum location and the type of the structure of well or tube wells.

Various There are surface and sub surface ~~methods~~ investigations are required to determine the aquifer parameter.

The methods of exploration of ground water are as follows :

a. Surface.
  - Geological field reconnaissance and making use of all the available geology map and data.
  - Geophysical surveys

b. Sub surface
  - Test drilling
  - Geophysical method
  - Collection of lithological and other logs of existing bor-holes, wells and lithological correlation on the basis of these logs.

Test drilling or well test provides information about the yield, drawdown of the well and well characteristic. These data can be used for determining the specific capacity of the well, for selecting the type of pump and for estimating the cost of pumping.

Hydrogeological parameters like hydraulic conductivity, transmissivity, storage coefficient, specific yield and porosity form part of the model input in most of the ground water model studies. Estimation of these hydrogeological parameters through conventional pumping test methods is expensive and need time. Therefore, use of empirical formulae and graphical methods which are faster and cheaper are preferable. The required preliminary data can easily be acquired from the field studies and with the help of these preliminary and raw data one can estimate the approximate values of these hydrogeological parameters.

These properties can be estimated with reasonable accuracy by some of the indirect methods based on analysis of water level fluctuation, specific capacity data of wells and well log, etc.

The specific capacity is the most important parameter to predict, select type of pump, and estimate the cost of pumping and through the specific capacity of wells we can also determine transmissivity, storage coefficient and other hydrological parameter.

Under field condition the aquifer rarely conforms to concept of one aquifer system. Often aquifer pumped is part of a complex aquifer system. To select the aquifers which can be exploited economically, it is required in a multiaquifer system to compute the specific capacity under different pumping schedule with different well radius.

1.2. ECONOMIC FACTOR.

The economic feasibility of using ground water has le to its rapid use.

Wells are increasingly used for both public an private exploitation of ground water. Ground water may b particularly valuable in augmenting surface water supplie during relatively short period of peak demand. Such syste based on wells can be brought into operation much mor rapidly and efficiently than system based on reservoi construction which may take a number of years to complete.

With this widespread expansion in ground wate resources development, the economic factor related to it production has become increasingly important.

1.3. PURPOSE OF THE STUDY

The purpose of the study is to carry out an analys to decide the number of aquifers to be tapped by mult aquifer well and to describe method for determining the tota cost function of ground water use relating to the depth the aquifers, diameter of well and specific capacity.

CHAPTER II

REVIEW OF LITERATURE

2.1 RADIAL UNSTEADY FLOW TO A WELL

Figure 2.1 shows well fully penetrating an artesian aquifer overlain and underlain by aquicludes. The aquifer is homogenous, isotropic, infinite in areal extent, and is of the same thickness throughout.

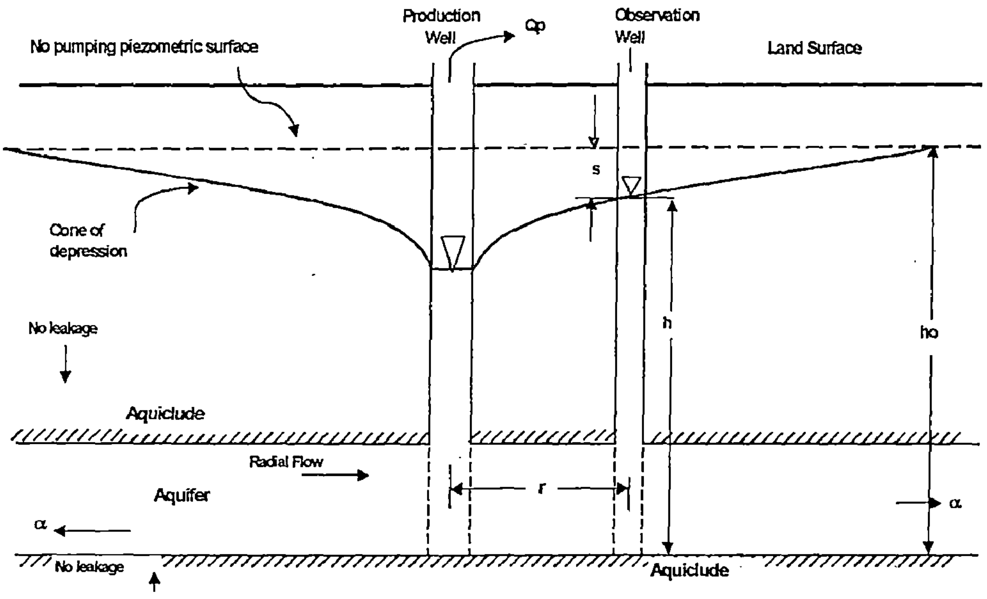

Figure 2.1. Aquifer with fully Penetrating

Theis (1935) presented a solution for a vertical well fully penetrating a confined horizontal isotropic aquifer of infinite extent. When this well is ~~pumping~~ pumped at a constant rate, the influence of the hydraulic head difference extends outward with time. The problem is axisymetric around the well axis.

Using mathematical developments of heat conduction, Theis (1935) obtained a solution as :

$$S\ (r,\ t)\ =\ \frac{Q}{4\,\pi\,T}\int_{r^2\Phi/(4Tt)}^{\infty}\frac{e^{-U}}{u}\,du \qquad \ldots\ldots. (2.1)$$

S is the drawdown at time t since start of pumping and r is distance from the production well (pumping well) to the point of observation where drawdown S occurs; Q is the constant pumping rate; T is the transmissivity of the aquifer; and Φ is the storativity of the aquifer.

The above integral ~~in~~ is denoted by W(u) in the well hydraulic. This has been designated as the exponential integral function Ei(u), defined as :

$$Ei(u)=-\gamma-\ln u+u/(1.1!)-u^2/2.2!)+u^3/(3.3!)+u^4/(4.4!) \quad \ldots\ldots(2.2)$$

Where ;

$\gamma = 0.5772156649\ \ldots$ (the Euler constant)

Equation (2.1) may be written as:

$$S(r,t)=\frac{Q}{4\pi T}\left[E_1\left(\frac{r^2\Phi}{4Tt}\right)\right] \qquad \ldots\ldots.. (2.3)$$

Drawdown at at well face is found from equation (2.3) for $r = r_w$:

$$S(r_w,t)=\frac{Q}{4\pi T}\left[E_1\left(\frac{r_w^2\Phi}{4Tt}\right)\right] \qquad \ldots\ldots.. (2.4)$$

2.2 SPECIFIC CAPACITY

The productivity of production well is generally expressed by the term specific capacity, which is defined as the ratio of the pumping rate and the drawdown caused. The Specific capacity indicates how much water the well will produce per metre of drawdown.

Specific Capacity = Q/S_T

where;

Q = discharge rate,

S_T = Total drawdown.

Total drawdown S_T in production well has all or some of the following components: the drawdown S (aquifer loss) due to laminar flow of water through the aquifer towards the well plus the drawdown S_{WL} (well loss) due to the turbulence flow of water through screen or well face and inside the casing to the pump intake, plus the drawdown S_p due to partial penetration of pumping well, plus drawdown S_d due to dewatering a portion of an aquifer, plus the drawdown S_b due to barriers of the aquifer, minus the buildup S_r due to recharge boundaries of the aquifer.

Stated as an equation.

$$S_T = S + S_{WL} + S_p + S_d + S_b + S_r$$

In many ground water investigation, especially in the reconnaissance type, the specific capacity of well provides the only basis for estimating the transmissivity of the aquifer. Generally, high specific capacity indicates a high coefficient of transmissivity, and low specific capacity indicates low coefficient of transmissivity.

Specific capacity of wells can not be an exact criterion of the coefficient transmissivity because specific capacity is often affected by partial penetration, well loss and hydrogeological boundaries. Actual coefficient of transmissivity is greater than the coefficient of transmissivity computed from specific capacity data. Because of the usefulness of rough estimation of T (transmissivity), an examination of the relation between the coefficient of transmissivity and specific capacity is useful.

2.3 DECLINED HEAD (HEAD LOSS)

The decline in head in a pumping well has two components. The first, termed as formation loss, is a function of both pumping rate, and pumping period. It may be expressed as the product of the pumping rate, Q, and formation loss factor, B, and can be expressed for confined aquifer by the following equation :

$$S_a = \frac{Q}{4\pi T} W(u)$$

$$= BQ$$

where,

$B = W(u) / (4\pi\ T)$

$W(u)$ = well function

The second component of head loss is the well loss. It depends on the pumping rate alone and does not vary with time. It represents the head loss due to resistance to flow of water as it enters the well through the screen and moves up inside the casing to the pump intake. The flow velocities in the vicinity of the well being quite high, the flow is turbulent, The Darcy's equation no longer holds and the well loss component increases rapidly with the pumping rate. Well loss may be expressed as the product of ~~the~~ a well loss factor C and some power of Q depending on the nature of the flow in and around the well and may be represented by the following equation :

$$S_b = CQ^n$$

Where ;

S_b = well loss
Q = Discharge rate
C = a well loss factor

The value of exponent n will depend on whether the flow velocities lie within the laminar or turbulent range. If the pumping rates are sufficiently low, the flow in the vicinity of the well is essentially laminar ($Re < 10$) and in that case the well loss component is directly proportional to the pumping rate or in other words the value on index n is one. In case the flow is turbulent ($Re > 10$), the value of the exponent n will be equal to 2 or even higher.

Jacob in his investigations did not consider the possibility of laminar flow and assumed the well loss as proportional to the square of the pumping rate. Rorabough, however, observed that under the usually occurring turbulent flow conditions near the well, the well loss is more accurately proportional to the pumping rate raised to some power greater than 2. He has suggested a representative value of 2.5, although some of the results of his analysis indicate that the exponent n may go as high as 3.5.

The formation and well loss components of drawdown in fully penetrating well without barrier or recharge boundaries can thus expressed as,

$$\begin{aligned} S_w &= S_a + S_b \\ &= BQ + CQ^n \end{aligned}$$

where,

S_a = aquifer loss

S_b = well loss

2.4 TOTAL COST (ECONOMIC COST)

The total cost of pumping water from ground water storage is influenced by two types of cost, one is called fixed cost and the other is called recurrent or variable cost. Fixed cost include the initial cost of exploration, data collection, analysis, drilling and installing a system, while recurrent cost include those of energy, lab operation and, maintenance.

2.4.1 Fixed Cost

The fixed cost depends on such factor as the depth the aquifer, diameter of the well, well screen lengt drilling cost which depend on the situation a hydrologeological condition of the site, design dischar ground water level and the drawdown.
Other factor considered are the location of the well, co and availability of different types of energy. The latt is important for the selection of the best type of pump purchase in which has a significant effect on the tot fixed cost.

2.4.2 Recurrent Cost

They are mainly the operation and maintenance cos Recurring cost are considered one of the main components total ground water production costs. They include cost th are function of the duration of operation, like ener cost, labor cost for control and operation plus and co derived from repairing equipment and installation.

CHAPTER III

ANALYSIS OF SPECIFIC CAPACITY OF A WELL IN A MULTI-AQUIFER SYSTEM

3.1 GENERAL

Under field condition an aquifer system rarely conforms to the concept of a single aquifer system. Often an aquifer pumped is part of a complex aquifer system. The option of an aquifer to be pumped depends on the depth of the aquifer and its parameters such as transmissivity and coefficient of storage. Sometimes a number of aquifers need to be correctly chosen so that the production cost of pumping water is optimum.

The productivity of a production well is generally expressed by the term specific capacity , which is defined as the ratio of the pumping rate and the resulting drawdown. The specific capacity of a well indicates how much water the well will produce per metre of drawdown. Specific Capacity = Q/S_T, where; Q=discharge rate, S_T = drawdown. Since drawdown varies with time and drawdown increases with time during pumping, the specific capacity decreases with time.

3.2 PROBLEM DESCRIPTION

A multiaquifer system comprising of several aquifers separated by aquicludes is shown in Figure 3.1. The aquifers have different transmissivity and storativity. In the multi-aquifer system it is possible to construct a fully penetrating multiaquifer well tapping several of the aquifers (five aquifers). The interaction among the tapped aquifers takes place through the well screen.

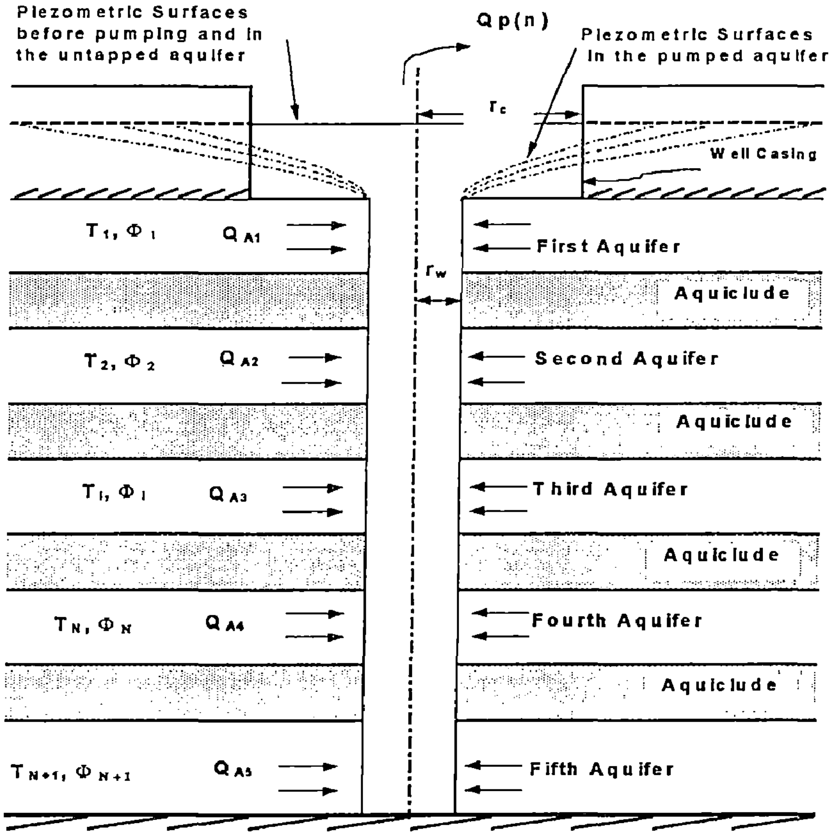

Fig. 3.1 Fully Penetrating Well on Multiaquifer

It is necessary to determine drawdown at the multi-aquifer well during a constant pumping. Beside, it is aimed to study the specific capacities of the possible multiaquifer wells and select the best multiaquifer well so that production cost is minimum.

The required steps for solving the problem are:

- The first step is to find contribution from each of the aquifers tapped by the multi-aquifer well and then to find the drawdown in each aquifer.
- Second step is the calculation of specific capacity in the multi-aquifer well.

3.3 ANALYSIS

The following assumptions have been made :

1. The initial piezometric surfaces in all the aquifers are same.
2. The well discharges at a constant rate equal to Qp.
3. At any time, drawdown in the aquifer at the well face is equal to that in the well.
4. The time parameter is discrete; within each time step the abstraction rates of water derived from each of the aquifers and well storage are separate constant.

When a multi aquifer well is pumped, there is contribution from each of the tapped aquifers to the pumping through their respective well screen besides contribution from well storage.

Let, $Q_{A1}(n)$, $Q_{A2}(n)$, $Q_{A3}(n)$, $Q_{Ai}(n)$, $Q_{AN}(n)$, and $Q_W(n)$ be the contributions from aquifer 1, 2, 3,.... i,..N and well storage respectively during time step n. At any time the algebraic sum of the abstraction from the number of aquifers and well storage will be equal to the pumping rate. Hence,

$$Q_{A1}(n)+Q_{A2}(n)+Q_{A3}(n)+\ldots Q_{Ai}(n)+\ldots Q_{AN}(n)+Q_{W}(n) = Q_{P}(n) \ldots (3.1)$$

The drawdown at the well face at the end of time step n in the i^{th} aquifer is given by:

$$S_{Ai}(n) = \sum_{\gamma=1}^{n} Q_{Ai}(\gamma) \cdot \delta_{i}(n-\gamma+1) \qquad \ldots\ldots\ldots\ldots (3.2)$$

where;

$$\delta_{i}(m) = \frac{1}{4\pi T_{i}}\left[E_{1}\left(\frac{r_{w}^{2}}{4\beta_{i}m}\right) - E_{1}\left(\frac{r_{w}^{2}}{4\beta_{i}(m-1)}\right)\right] \quad \ldots (3.3)$$

$\beta_{i} = \frac{T_{i}}{\phi_{i}}$

= hydraulic diffusivity of the i^{th} aquifer

$E_{1}(.)$ = Exponential integral.

The drawdown at the well at the end of time step n due to abstraction from well storage is given by:

$$S_{w}(n) = \frac{1}{\pi r_{c}^{2}}\sum_{\gamma=1}^{n} Q_{w}(\gamma) \qquad \ldots\ldots\ldots\ldots\ldots (3.4)$$

Where; $Q_w(\gamma)$ is the withdrawal from well storage during time step γ .

According to the assumption, at any time drawdowns in all the aquifers tapped by the well at the well face are same and equal to that in the well.

Since, $S_{A1}(n) = S_{A2}(n) = S_{A3}(n) \ldots = S_{Ai}(n) \ldots = S_{AN}(n) = S_w(n)$, therefore, from the drawdown equations (3.2).

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) = \sum_{\gamma=1}^{n} Q_{A2}(\gamma)\,.\,\delta_2(n-\gamma+1) \quad \ldots(3.5)$$

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) = \sum_{\gamma=1}^{n} Q_{A3}(\gamma)\,.\,\delta_3(n-\gamma+1) \quad \ldots(3.6)$$

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) = \sum_{\gamma=1}^{n} Q_{Ai}(\gamma)\,.\,\delta_i(n-\gamma+1) \quad \ldots(3.7)$$

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) = \sum_{\gamma=1}^{n} Q_{AN}(\gamma)\,.\,\delta_N(n-\gamma+1) \quad \ldots(3.8)$$

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) = \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n} Q'_{w}(\gamma) \quad \ldots\ldots\ldots\ (3.9)$$

Rearranging the equations (3.5), (3.6), (3,7), (3.8), and (3.9):

$$Q_{A1}(n)\,.\,\delta_1(1) - Q_{A2}(n)\,.\,\delta_2(1) = \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\,.\,\delta_2(n-\gamma+1)$$

$$- \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\,.\,\delta_1(n-\gamma+1) \quad \ldots\ldots(3.10)$$

$$Q_{A1}(n)\cdot\delta_1(1) - Q_{A3}(n)\cdot\delta_3(1) = \sum_{\gamma=1}^{n-1} Q_{A3}(\gamma)\cdot\delta_3(n-\gamma+1)$$

$$-\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \qquad \text{......(3.11)}$$

$$Q_{A1}(n)\cdot\delta_1(1) - Q_{Ai}(n)\cdot\delta_i(1) = \sum_{\gamma=1}^{n-1} Q_{Ai}(\gamma)\cdot\delta_i(n-\gamma+1)$$

$$-\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \qquad \text{......(3.12)}$$

$$Q_{A1}(n)\cdot\delta_1(1) - Q_{AN}(n)\cdot\delta_N(1) = \sum_{\gamma=1}^{n-1} Q_{AN}(\gamma)\cdot\delta_N(n-\gamma+1)$$

$$-\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \qquad \text{.....(3.13)}$$

$$Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) - \frac{Q_w(n)}{\pi\, r_c^2} = \frac{1}{\pi\, r_c^2}\sum_{\gamma=1}^{n-1} Q_w(\gamma)$$

$$-\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \qquad \text{......(3.14)}$$

The set equations (3.10), (3.11), (3.12),(3.13),(3.14) and (3.1) can be written in the following matrix form :

$$\begin{pmatrix} \delta_1(1) & -\delta_2(1) & 0 & 0 & 0 & 0 \\ \delta_1(1) & 0 & -\delta_3(1) & 0 & 0 & 0 \\ \delta_1(1) & 0 & 0 & -\delta_i(1) & 0 & 0 \\ \delta_1(1) & 0 & 0 & 0 & -\delta_N(1) & 0 \\ \delta_1(1) & 0 & 0 & 0 & 0 & -\dfrac{1}{\pi r_c^2} \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix} \cdot \begin{pmatrix} Q_{A1}(n) \\ Q_{A2}(n) \\ Q_{A3}(n) \\ Q_{Ai}(n) \\ Q_{AN}(n) \\ Q_w(n) \end{pmatrix} =$$

$$\begin{pmatrix} \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\cdot\delta_2(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{A3}(\gamma)\cdot\delta_3(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{Ai}(\gamma)\cdot\delta_i(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{AN}(\gamma)\cdot\delta_N(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n-1} Q_w(\gamma) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ Qp(n) \end{pmatrix} \tag{3.15}$$

Hence,

$$\begin{pmatrix} Q_{A1}(n) \\ Q_{A2}(n) \\ Q_{A3}(n) \\ Q_{Ai}(n) \\ Q_{AN}(n) \\ Q_w(n) \end{pmatrix} = \begin{pmatrix} \delta_1(1) & -\delta_2(1) & 0 & 0 & 0 & 0 \\ \delta_1(1) & 0 & -\delta_3(1) & 0 & 0 & 0 \\ \delta_1(1) & 0 & 0 & -\delta_i(1) & 0 & 0 \\ \delta_1(1) & 0 & 0 & 0 & -\delta_N(1) & 0 \\ \delta_1(1) & 0 & 0 & 0 & 0 & -\frac{1}{\pi r_c^2} \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}^{-1} \cdot$$

$$\begin{pmatrix} \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\cdot\delta_2(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{A3}(\gamma)\cdot\delta_3(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{Ai}(\gamma)\cdot\delta_i(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \sum_{\gamma=1}^{n-1} Q_{AN}(\gamma)\cdot\delta_N(n-\gamma+1) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n-1} Q_w(\gamma) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(n-\gamma+1) \\ Qp(n) \end{pmatrix} \tag{3.16}$$

Thus, $Q_{A1}(n), Q_{A2}(n), Q_{A3}(n), Q_{Ai}(n), Q_{AN}(n)$ and $Q_W(n)$ can be solved in succession starting from step 1.

In particularly for time step 1.

$$\begin{pmatrix} Q_{A1}(1) \\ Q_{A2}(1) \\ Q_{A3}(1) \\ Q_{Ai}(1) \\ Q_{AN}(1) \\ Q_{w}(1) \end{pmatrix} = \begin{pmatrix} \delta_1(1) & -\delta_2(1) & 0 & 0 & 0 & 0 \\ \delta_1(1) & 0 & -\delta_3(1) & 0 & 0 & 0 \\ \delta_1(1) & 0 & 0 & -\delta_i(1) & 0 & 0 \\ \delta_1(1) & 0 & 0 & 0 & -\delta_N(1) & 0 \\ \delta_1(1) & 0 & 0 & 0 & 0 & -\dfrac{1}{\pi r_c^2} \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}^{-1} \cdot \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ Q_p(1) \end{pmatrix}$$

.... (3.17)

3.4 RESULT AND DISCUSSION.

The following steps have been followed to compute aquifers' contribution and drawdown at the well face :

- The pumping period is discretised to n units of equal time step.
- The discrete kernels $\delta_i(m)$ are generated making use Eqn.(3.3) for each aquifer for different integer value of m.
- For known value Qp(n), the value Qi(n) and Qw(n) have been found in succession starting from time step 1 making use of matrix Eqn. (3.16) and (3.17).
- The drawdown is calculated making use one of the equations (3.2) and (3.4).
- After the value of drawdown is obtained, the specific capacity is calculated (the ratio of pumping rate to drawdown at different time).

3.4.1 Effect of Transmissivity on Specific Capacity

The contributions of aquifers to a multiaquifer well tapping three aquifers are presented in Table 3.1. The three aquifers have equal diffusivity. It is seen that the well storage contributions is only 0.6 percent towards the pumping rate, Qp(n), at the end of one day. The aquifers contribution is $Q_p(n) - Q_w(n)$. For aquifers having equal hydraulic diffusivity, the contribution of each aquifer is proportional to its transmissivity value. When contribution of well storage vanishes, the contribution from each aquifer does not vary with time.

The temporal variations of $Q_{A1}(n)/Q_p$, $Q_{A2}(n)/Q_p$, $Q_{A3}(n)/Q_p$ with non dimensional time parameter $4\bar{T}t/\bar{\Phi}r_w^2$, where $\bar{T} = (T_1+T_2+T_3)/3$, $\bar{\Phi} = (\Phi_1:\Phi_2:\Phi_3)/3$, are shown in Fig. 3.2. The temporal variations are nearly time invariant during which well storage contribution is almost zero.

Table 3.1. Flow From Different Aquifers Having Equal Hydraulic Diffusivity and Different Transmissivity T_1= 100 m2/day, T_2= 200 m2/day, and T_3=300 m2/day. Φ_1= 0.01, Φ_1= 0.02, Φ_1= 0.03

t (day)	Q_{A1} (m3/day)	Q_{A2} (m3/day)	Q_{A3} (m3/day)	Q_W (m3/day)	Q_P (m3/day)	$4\bar{T}t/(\bar{\phi}r_w^2)$
1	16.566	33.131	49.697	0.606	100	4000000
2	16.661	33.323	49.984	0.032	100	8000000
3	16.664	33.328	49.991	0.017	100	12000000
4	16.665	33.329	49.994	0.012	100	16000000
5	16.665	33.33	49.995	0.009	100	20000000
6	16.665	33.331	49.996	0.008	100	24000000
7	16.666	33.331	49.997	0.006	100	28000000
8	16.666	33.331	49.997	0.006	100	32000000
9	16.666	33.332	49.998	0.005	100	36000000
10	16.666	33.332	49.998	0.004	100	40000000
20	16.666	33.333	49.999	0.002	100	80000000
30	16.666	33.333	49.999	0.001	100	120000000
40	16.666	33.333	49.999	0.001	100	160000000
50	16.667	33.333	50	0.001	100	200000000
60	16.667	33.333	50	0.001	100	240000000
70	16.667	33.333	50	0.001	100	280000000
80	16.667	33.333	50	0.001	100	320000000
90	16.667	33.333	50	0	100	360000000
100	16.667	33.333	50	0	100	400000000

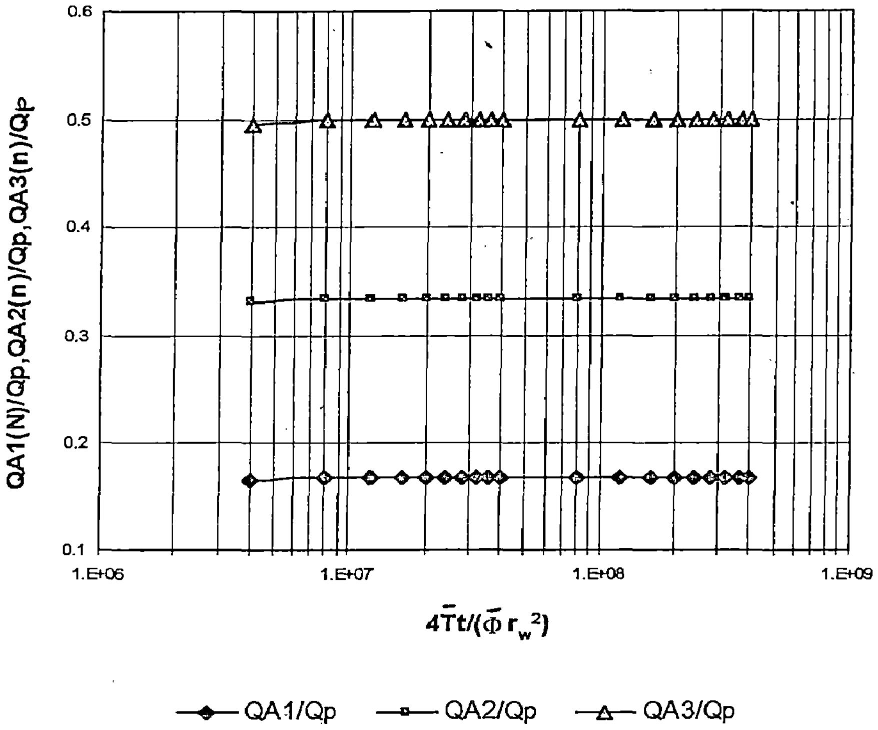

Fig. 3.2 Flow From Different Aquifers Having Different Transmissivity (T_1:T_2:T_3=1:2:3;T_1= 100 m2/day) Φ_1= 0.01,Φ_1= 0.02,Φ_1= 0.03

Another set of aquifer parameters are considered; the aquifers have equal diffusivity, and the transmissivity values are in the ratio 1:2:4. The results are presented in Table 3.2. Thus aquiers having equal diffusivities, contribute in proportion to their respective transmissivity values. In case, the well storage contribution is neglegible, the aquifers contributions are independent of time.

The temporal variations of $Q_{A1}(n)/Q_p$, $Q_{A2}(n)/Q_p$, $Q_{A3}(n)/Q_p$ with non dimensional time parameter $4\bar{T}t/\bar{\Phi}r_w^2$ are shown in Fig. 3.3.

Table 3.2. **Flow From Different Aquifers Having Equal Hydraulic Diffusivity and Different Transmissivity**
T_1= 100 m2/day, T_2= 200 m2/day, and T_3= 400 m2/day,
Φ_1= 0.01.

t (day)	Q_{A1} (m3/day)	Q_{A2} (m3/day)	Q_{A3} (m3/day)	Q_W (m3/day)	Q_P (m3/day)	$4\bar{T}t/(\bar{\phi}r_w^2)$
1	14.369	28.738	56.367	0.525	100	4666660
2	14.434	28.867	56.672	0.027	100	9333320
3	14.431	28.863	56.691	0.015	100	13999980
4	14.429	28.859	56.702	0.01	100	18666640
5	14.428	28.855	56.709	0.008	100	23333300
6	14.426	28.852	56.715	0.007	100	27999960
7	14.425	28.85	56.72	0.006	100	32666620
8	14.424	28.848	56.723	0.005	100	37333280
9	14.423	28.846	56.727	0.004	100	41999940
10	14.422	28.845	56.729	0.004	100	46666600
20	14.417	28.834	56.747	0.002	100	93333200
30	14.414	28.829	56.756	0.001	100	139999800
40	14.412	28.825	56.762	0.001	100	186666400
50	14.411	28.822	56.767	0.001	100	233333000
60	14.41	28.819	56.77	0.001	100	279999600
70	14.409	28.817	56.773	0.001	100	326666200
80	14.408	28.816	56.776	0	100	373332800
90	14.407	28.814	56.778	0	100	419999400
100	14.406	28.813	56.78	0	100	466666000

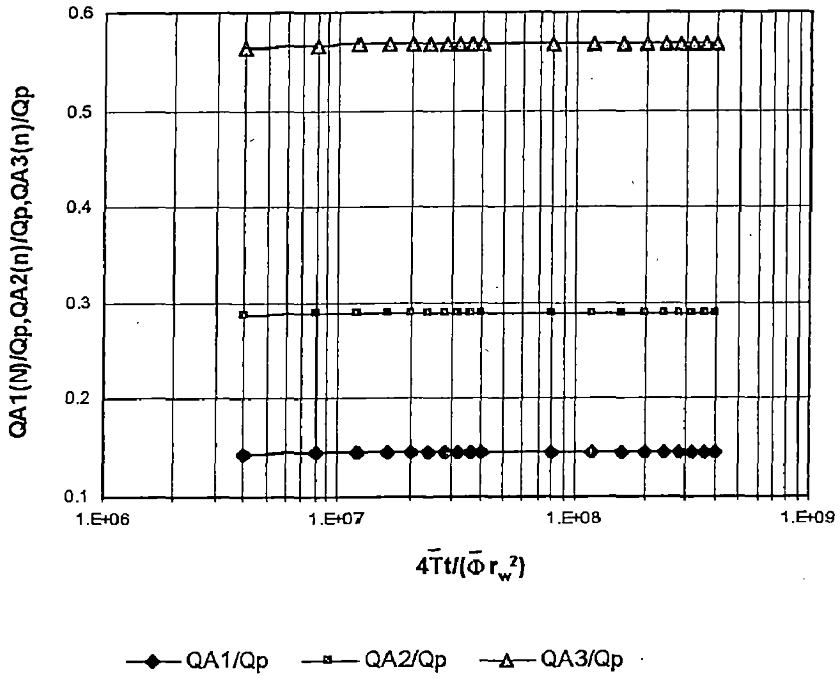

Fig. 3.3 Flow From Different Aquifers Having Different Transmissivity (T_1:T_2:T_3= 1:2:4;T_1= 100 m2/day, T_2= 200 m2/day, and T_3= 400 m2/day)

The variations of specific capacity of a multiaquifer well which taps three aquifers and all aquifer have equal diffusivity are shown in figure 3.4 for two set of aquifer parameters. For one multiaquifer well T_1= 100 m2/day, T_2= 200 m2/day, and T_3= 300 m2/day. For the other multiaquifer well, T_3 = 400 m2/day all others transmissivity values remaining same. It is found that specific capacity of a multiaquifer well tapping aquifer of larger transmissivity is higher than that of a well which taps aquifer of low transmissivity. The specific capacity decreases with time. The numerical values of specific capacity are compared in Table 3.3.

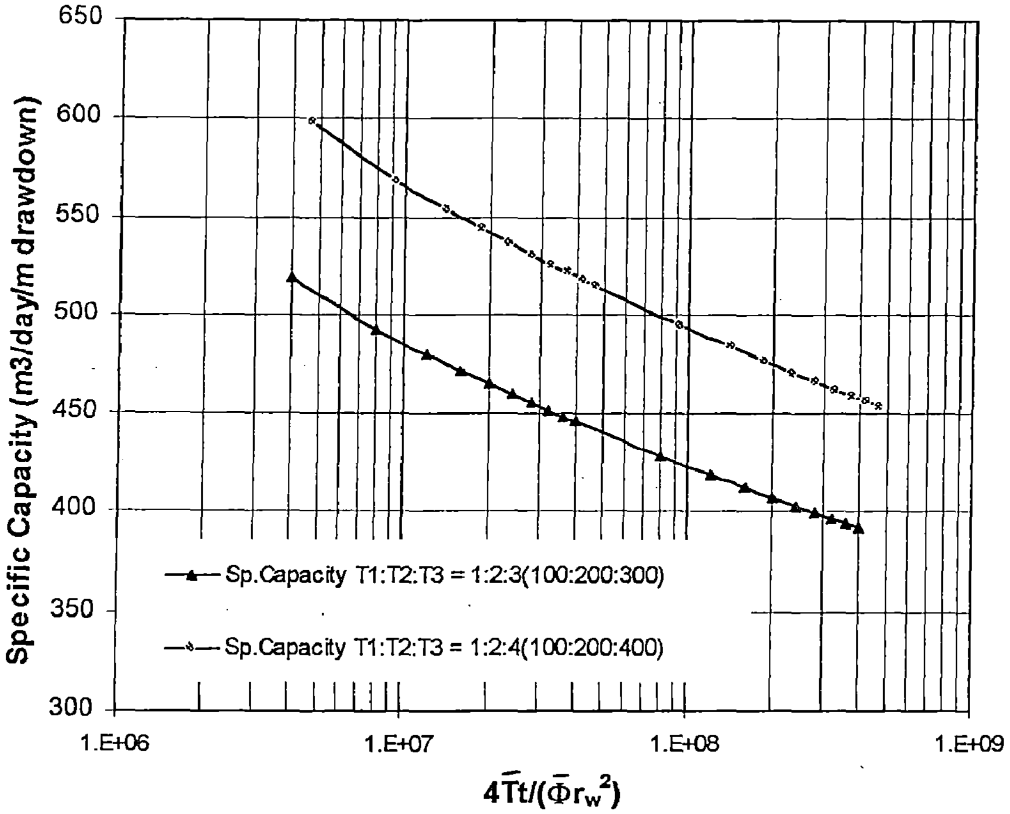

Fig. 3.4 Specific Capacity of Multiaquifer Well Tapping Three Aquifers ($T_1:T_2:T_3$= 1:2:3;T_1= 100 m2/day, and $T_1:T_2:T_3$= 1:2:4;T_1= 100 m2/day,Φ_1= 0.01, and Qp = 100 m3/day)

Table 3.3 Comparison Specific Capacity of Two Multiaquifer Wells Tapping Three Aquifer (T_1:T_2:T_3= 1:2:3; T_1= 100 m2/day,and T_1:T_2:T_3= 1:2:4;T_1= 100 m2/day, Φ_1= 0.01, and Qp = 100 m3/day)

t	When ϕ1:ϕ2:ϕ3=1:2:3 T_1:T_2:T_3=1:2:3		When ϕ1:ϕ2:ϕ3=1:2:4 T_1:T_2:T_3=1:2:4	
(day)	$4\bar{T}t/(\bar{\phi}rw2)$	Specific Capacity	$4\bar{T}t/(\bar{\phi}rw2)$	Specific Capacity
1	4000000	518.7	4666660	597.995
2	8000000	492.515	9333320	568.498
3	12000000	479.693	13999980	553.869
4	16000000	471.029	18666640	543.973
5	20000000	464.53	23333300	536.546
6	24000000	459.356	27999960	530.63
7	28000000	455.072	32666620	525.731
8	32000000	451.427	37333280	521.561
9	36000000	448.26	41999940	517.938
10	40000000	445.466	46666600	514.741
20	80000000	427.923	93333200	494.658
30	120000000	418.292	139999800	483.624
40	160000000	411.718	186666400	476.091
50	200000000	406.76	233333000	470.408
60	240000000	402.797	279999600	465.864
70	280000000	399.506	326666200	462.091
80	320000000	396.699	373332800	458.871
90	360000000	394.255	419999400	456.068
100	400000000	392.095	466666000	453.59

3.4.2. Effect of Well Radius on Specific Capacity.

The variations of specific capacity with well radius at different times during pumping where the well taps only one aquifer is presented in table 3.4. In table 3.5 to 3.8, the results are present for multiaquifer wells tapping 2 to 5 aquifers. The pumping rate is constant for all the multiaquifer wells. It is seen that specific capacity increases with increase in well radius. It also increases as the multaquifer well taps more number of aquifers.

Table 3.4 Variation of Specific Capacity with Radius of Well Tapping One Aquifer at Different Pumping Period (T_1= 100 m2/day and Qp = 100 m3/day)

t (Day)	SPECIFIC CAPACITY OF ONE AQUIFER (m3/day/m drawdown)				
	WELL RADIUS (m)				
	0.1	0.125	0.15	0.175	0.2
1	89.068	91.773	94.112	96.189	98.066
2	82.394	84.861	86.989	88.874	90.574
5	77.493	79.684	81.568	83.232	84.729
10	74.277	76.288	78.014	79.536	80.902
20	71.336	73.189	74.777	76.174	77.427
50	67.799	69.472	70.901	72.156	73.279
100	65.352	66.905	68.229	69.391	70.429
200	63.077	64.522	65.753	66.831	67.794

Table 3.5 Variation of Specific Capacity with Radius of A Multiaquifer Well Tapping Two Aquifer (T_1= 100 m2/day, T_2= 200 m2/day, and Qp = 100 m3/day)

t	SPECIFIC CAPACITY OF A TWO AQUIFER SYSTEM (m3/day/m drawdown)				
	WELL RADIUS (m)				
(Day)	0.1	0.125	0.15	0.175	0.2
1	260.921	269.035	276.053	282.284	287.915
2	246.415	253.808	260.185	265.833	270.928
5	232.308	238.875	244.522	249.51	253.997
10	222.752	228.784	233.961	238.523	242.622
20	213.971	219.531	224.293	228.484	232.243
50	203.383	208.401	212.688	216.453	219.823
100	196.049	200.707	204.68	208.165	211.28
200	189.227	193.562	197.256	200.49	203.378

Table 3.6 Variation of Specific Capacity with Radius of A Multiaquifer Well Tapping Three Aquifer (T_1= 100 m2/day, T_2= 200 m2/day, T_3= 300 m2/day and Qp = 100 m3/day)

t	SPECIFIC CAPACITY OF A THREE AQUIFER SYSTEM (m3/day/m drawdown)				
	WELL RADIUS (m)				
(Day)	0.1	0.125	0.15	0.175	0.2
1	518.7	534.928	548.965	561.425	572.688
2	492.515	507.293	520.044	531.335	541.519
5	464.53	477.662	488.955	498.928	507.902
10	445.466	457.529	467.88	477.005	485.203
20	427.923	439.043	448.567	456.948	464.465
50	406.76	416.795	425.369	432.898	439.639
100	392.095	401.411	409.357	416.326	422.557
200	378.451	387.123	394.509	400.978	406.755

Table 3.7 Variation of Specific Capacity with Radius of A Multiaquifer Well Tapping Four Aquifer (T_1= 100 m2/day, T_2= 200 m2/day, T_3= 300 m2/day, T_4= 400 m2/day and Qp = 100 m3/day)

t (Day)	SPECIFIC CAPACITY AT A FOUR AQUIFER SYSTEM (m3/day/m drawdown)				
	WELL RADIUS (m)				
	0.1	0.125	0.15	0.175	0.2
1	862.405	889.452	912.848	933.615	952.385
2	820.661	845.288	866.534	885.349	902.32
5	774.161	796.045	814.865	831.486	846.442
10	742.417	762.521	779.774	794.982	808.643
20	713.193	731.726	747.599	761.567	774.096
50	677.928	694.653	708.943	721.492	732.727
100	653.489	669.016	682.26	693.875	704.26
200	630.751	645.205	657.515	668.295	677.923

Table 3.8 Variation of Specific Capacity with Radius of A Multiaquifer Well Tapping Five Aquifer (T_1= 100 m2/day, T_2= 200 m2/day, T_3= 300 m2/day, T_4= 400 m2/day, T_5= 500 m2/day, and Qp = 100 m3/day)

t (Day)	SPECIFIC CAPACITY AT A FIVE AQUIFER SYSTEM (m3/day/m drawdown)				
	WELL RADIUS (m)				
	0.1	0.125	0.15	0.175	0.2
1	1233.594	1270.692	1302.714	1331.085	1356.686
2	1177.226	1211.117	1240.298	1266.095	1289.329
5	1113.104	1143.347	1169.311	1192.204	1212.775
10	1069.143	1097.008	1120.881	1141.895	1160.747
20	1028.553	1054.311	1076.337	1095.694	1113.035
50	979.424	1002.745	1022.644	1040.096	1055.704
100	945.28	966.982	985.469	1001.662	1016.126
200	913.444	933.689	950.911	965.976	979.419

Assuming a pumping rate equal to 100 m3/day, the variations of specific capacity with radius at different time for single and multiaquifer wells are also presented in Figs. 3.5 through 3.9. The increase in specific capacity at any specific time with well radius is monotonic.

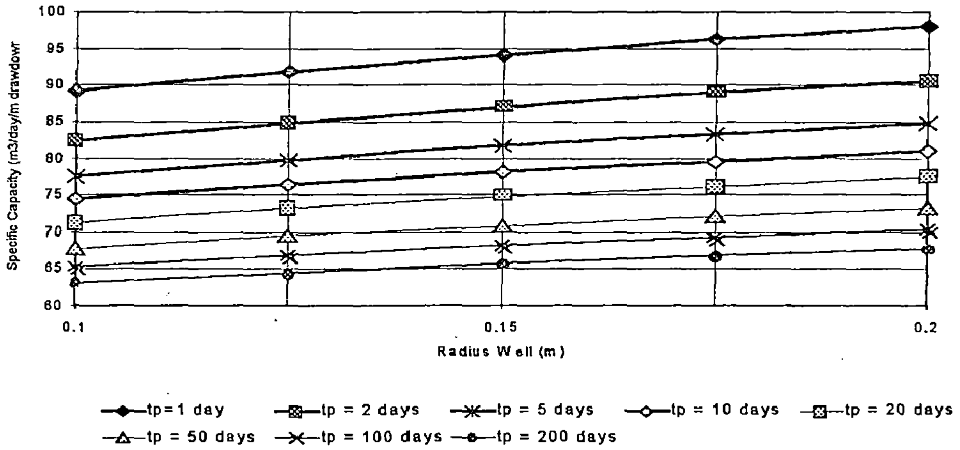

Fig. 3.5 Relationship of Specific Capacity with Radius of a Well Tapping One Aquifer

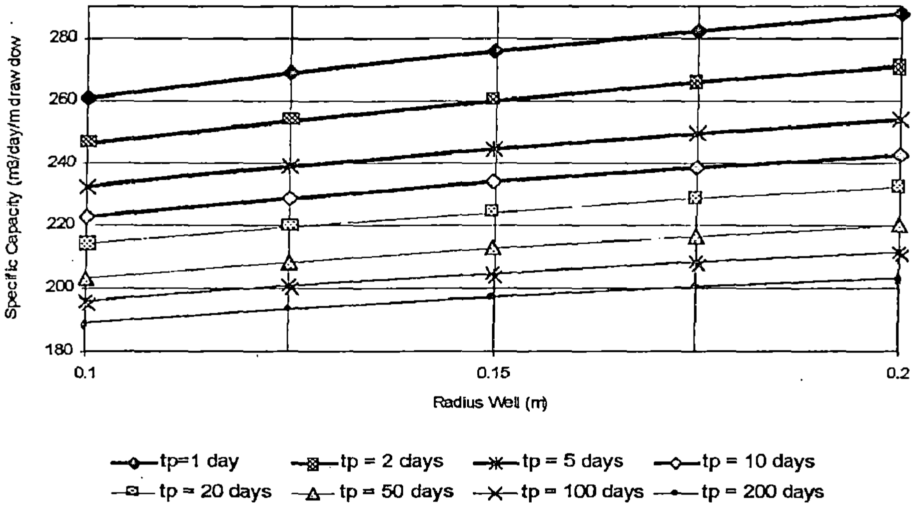

Fig. 3.6 Relationship of Specific Capacity with Radius of a Multiaquifer Well Tapping Two Aquifers

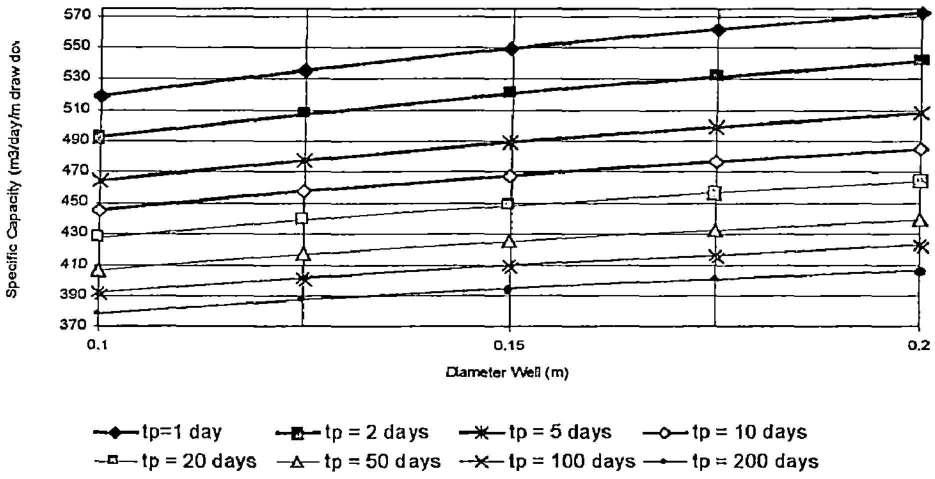

Fig. 3.7 Relationship of Specific Capacity with Radius of a Multiaquifer Well Tapping Three Aquifers

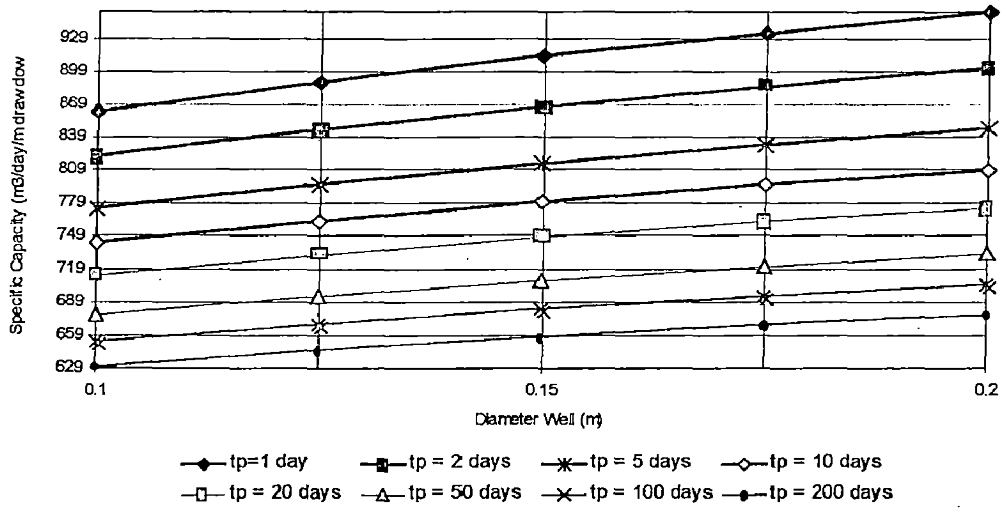

Fig. 3.8 Relationship of Specific Capacity with Radius of a Multiaquifer Well Tapping Four Aquifers

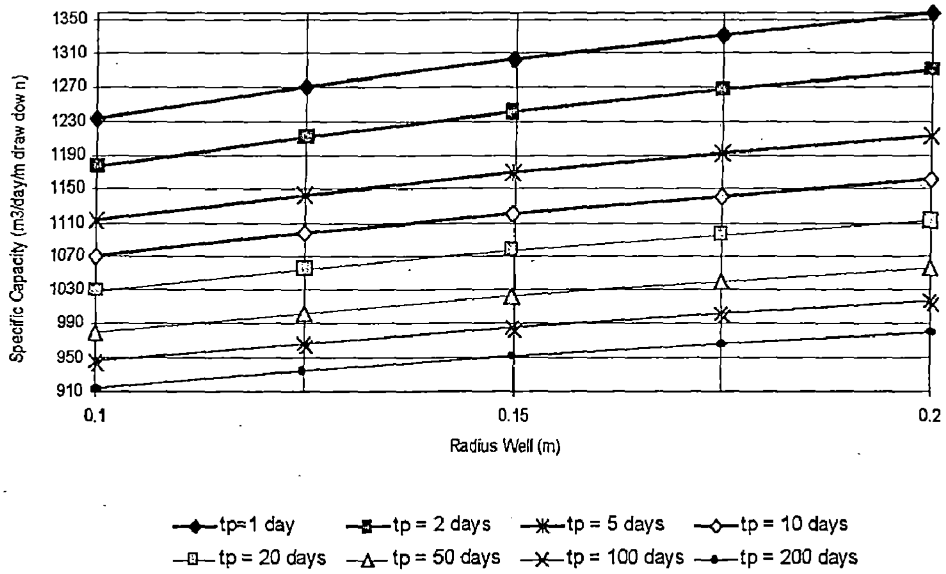

Fig. 3.9 Relationship of Specific Capacity with Radius of a Multiaquifer Well Tapping Five Aquifers

The variations of specific capacity with time during pumping for different well radius are shown in figs. 3.10 through 3.14. It is seen that specific capacity decreases rapidly in the beginning of pumping and if pumping continues for a long time the specific capacity tends to decrease monotonically.

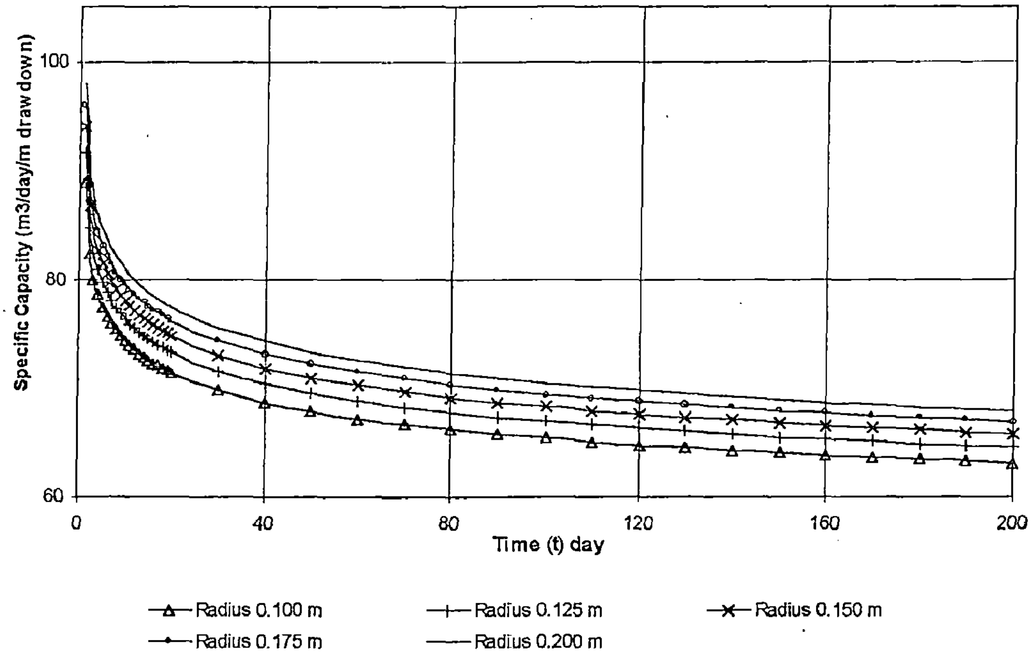

Fig. 3.10 Relationship of Specific Capacity with Pumping Period in a One Aquifer System

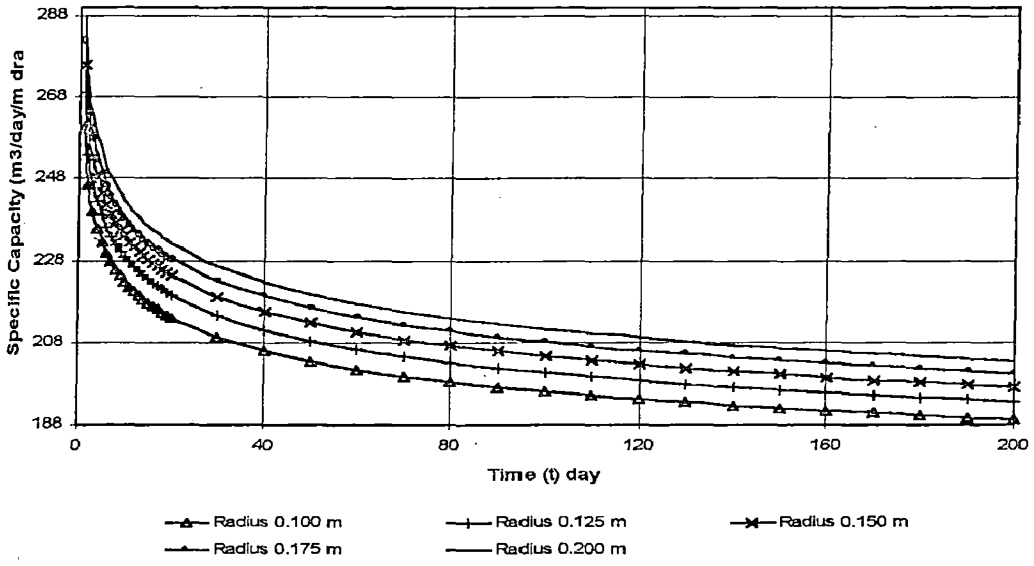

Fig. 3.11 Relationship of Specific Capacity with Pumping Period in a Two Aquifer System

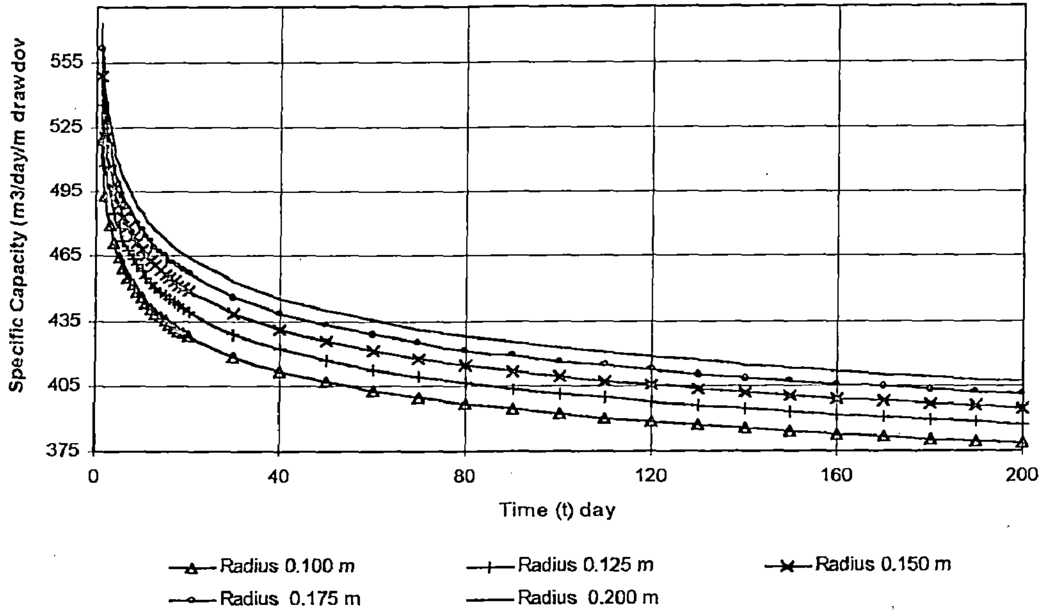

Fig. 3.12 Relationship Specific Capacity with Pumping Period in a Three Aquifer System

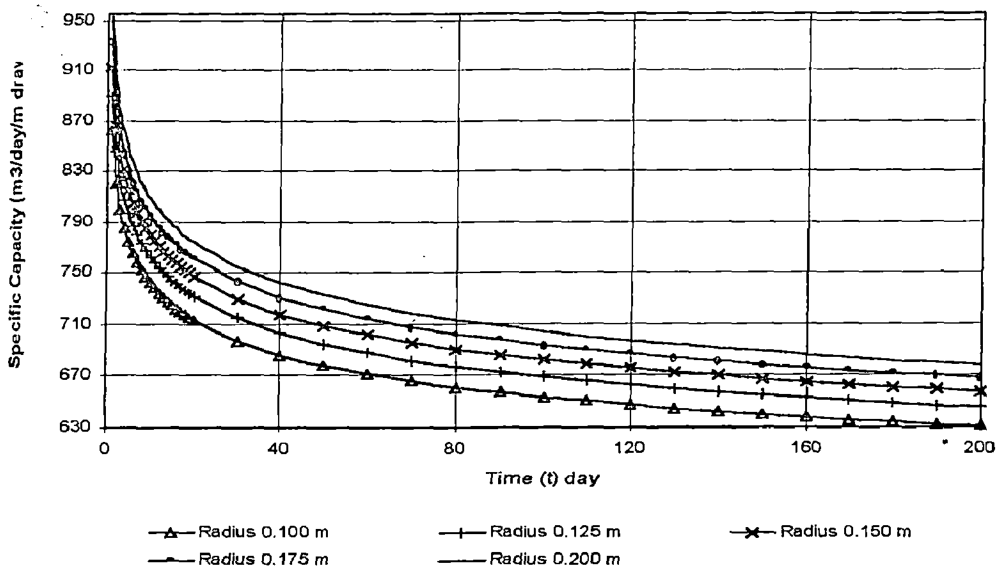

Fig. 3.13 Relationship of Specific Capacity with Pumping Period in a Four Aquifer System

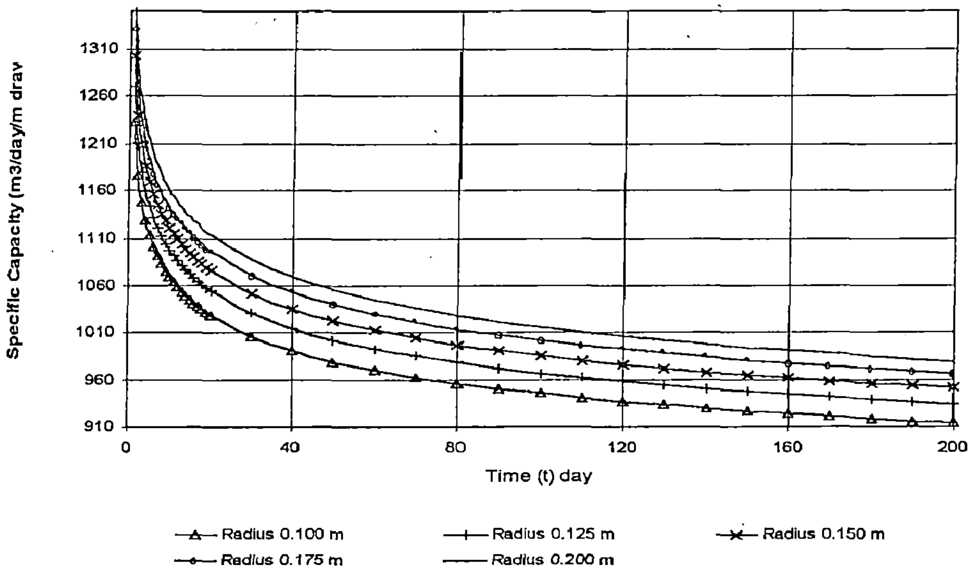

Fig. 3.14 Relationship of Specific Capacity with Pumping Period in a Five Aquifer System

Numerical values of the specific capacity during pumping for different multiaquifer wells are presented in Tables 3.9 through 3.11.

Table 3.9 Specific Capacity of a Well For Different Radius Well

	SPECIFIC CAPACITY IN ONE AQUIFER (m3/day/m drawdown)					SPECIFIC CAPACITY IN TWO AQUIFERS (m3/day/m drawdown)				
	RADIUS WELL (m)					RADIUS WELL (m)				
n	0.1	0.125	0.15	0.175	0.2	0.1	0.125	0.15	0.175	0.2
1	89.068	91.773	94.112	96.189	98.066	260.921	269.035	276.053	282.284	287.915
2	82.394	84.861	86.989	88.874	90.574	246.415	253.808	260.185	265.833	270.928
3	80.087	82.426	84.441	86.223	87.829	239.926	246.935	252.973	258.313	263.125
4	78.599	80.852	82.792	84.506	86.049	235.57	242.325	248.138	253.275	257.9
5	77.493	79.684	81.568	83.232	84.729	232.308	238.875	244.522	249.51	253.997
6	76.617	78.758	80.599	82.223	83.684	229.712	236.132	241.649	246.52	250.9
7	75.894	77.994	79.799	81.391	82.823	227.565	233.864	239.275	244.049	248.341
8	75.28	77.346	79.12	80.686	82.092	225.738	231.935	237.256	241.95	246.168
9	74.747	76.784	78.532	80.074	81.46	224.152	230.261	235.505	240.129	244.283
10	74.277	76.288	78.014	79.536	80.902	222.752	228.784	233.961	238.523	242.622
11	73.857	75.846	77.552	79.055	80.405	221.501	227.465	232.581	237.09	241.14
12	73.479	75.446	77.134	78.622	79.957	220.372	226.274	231.336	235.797	239.802
13	73.134	75.083	76.755	78.227	79.549	219.343	225.19	230.203	234.62	238.585
14	72.818	74.75	76.407	77.866	79.176	218.4	224.195	229.164	233.54	237.469
15	72.526	74.443	76.086	77.533	78.831	217.528	223.277	228.205	232.545	236.439
16	72.255	74.158	75.788	77.224	78.512	216.72	222.426	227.316	231.621	235.484
17	72.003	73.892	75.511	76.935	78.214	215.966	221.632	226.486	230.76	234.595
18	71.767	73.643	75.251	76.666	77.935	215.26	220.888	225.71	229.954	233.762
19	71.545	73.41	75.007	76.413	77.674	214.596	220.19	224.981	229.197	232.98
20	71.336	73.189	74.777	76.174	77.427	213.971	219.531	224.293	228.484	232.243
30	69.725	71.495	73.01	74.341	75.534	209.152	214.461	219.004	222.998	226.577
40	68.627	70.341	71.806	73.094	74.247	205.863	211.005	215.401	219.264	222.723
50	67.799	69.472	70.901	72.156	73.279	203.383	208.401	212.688	216.453	219.823
60	67.138	68.777	70.178	71.407	72.507	201.401	206.32	210.521	214.209	217.51
70	66.588	68.201	69.578	70.786	71.867	199.755	204.593	208.724	212.348	215.591
80	66.12	67.71	69.067	70.257	71.322	198.351	203.121	207.191	210.763	213.957
90	65.712	67.282	68.622	69.797	70.848	197.129	201.84	205.858	209.383	212.536
100	65.352	66.905	68.229	69.391	70.429	196.049	200.707	204.68	208.165	211.28
110	65.029	66.566	67.878	69.027	70.055	195.082	199.693	203.626	207.075	210.158
120	64.738	66.261	67.56	68.698	69.716	194.207	198.777	202.674	206.089	209.143
130	64.471	65.982	67.27	68.399	69.408	193.409	197.941	201.805	205.191	208.218
140	64.227	65.726	67.004	68.124	69.125	192.677	197.174	201.007	204.367	207.369
150	64.001	65.49	66.758	67.87	68.863	191.999	196.465	200.271	203.605	206.585
160	63.791	65.27	66.53	67.634	68.62	191.37	195.806	199.586	202.898	205.857
170	63.596	65.065	66.317	67.414	68.394	190.783	195.192	198.948	202.238	205.177
180	63.412	64.873	66.118	67.208	68.182	190.233	194.615	198.349	201.62	204.541
190	63.239	64.692	65.93	67.014	67.982	189.715	194.074	197.786	201.038	203.943
200	63.077	64.522	65.753	66.831	67.794	189.227	193.562	197.256	200.49	203.378

Table 3.10 Specific Capacity of a Well For Different Radius Well

n	SPECIFIC CAPACITY IN THREE AQUIFERS (m3/day/m drawdown)					SPECIFIC CAPACITY IN FOUR AQUIFERS (m3/day/m drawdown)				
	RADIUS WELL (m)					RADIUS WELL (m)				
	0.1	0.125	0.15	0.175	0.2	0.1	0.125	0.15	0.175	0.2
1	518.7	534.928	548.965	561.425	572.688	862.405	889.452	912.848	933.615	952.385
2	492.515	507.293	520.044	531.335	541.519	820.661	845.288	866.534	885.349	902.32
3	479.693	493.706	505.778	516.455	526.075	799.382	822.734	842.852	860.645	876.677
4	471.029	484.535	496.159	506.43	515.678	784.975	807.482	826.853	843.972	859.384
5	464.53	477.662	488.955	498.928	507.902	774.161	796.045	814.865	831.486	846.442
6	459.356	472.193	483.226	492.965	501.725	765.548	786.941	805.329	821.56	836.158
7	455.072	467.668	478.489	488.036	496.62	758.416	779.407	797.441	813.352	827.658
8	451.427	463.819	474.461	483.846	492.282	752.345	772.998	790.733	806.375	820.434
9	448.26	460.477	470.964	480.211	488.52	747.072	767.432	784.91	800.321	814.168
10	445.466	457.529	467.88	477.005	485.203	742.417	762.521	779.774	794.982	808.643
11	442.968	454.894	465.126	474.143	482.241	738.257	758.133	775.186	790.213	803.71
12	440.712	452.516	462.64	471.56	479.569	734.499	754.171	771.044	785.91	799.259
13	438.658	450.35	460.376	469.208	477.137	731.077	750.563	767.273	781.993	795.208
14	436.772	448.363	458.3	467.052	474.908	727.936	747.254	763.815	778.401	791.494
15	435.032	446.529	456.385	465.063	472.851	725.037	744.199	760.624	775.087	788.068
16	433.417	444.828	454.607	463.217	470.944	722.345	741.364	757.662	772.012	784.89
17	431.91	443.241	452.95	461.497	469.166	719.836	738.72	754.901	769.146	781.927
18	430.499	441.755	451.399	459.887	467.502	717.485	736.245	752.317	766.464	779.155
19	429.173	440.359	449.941	458.374	465.939	715.276	733.919	749.889	763.943	776.55
20	427.923	439.043	448.567	456.948	464.465	713.193	731.726	747.599	761.567	774.096
30	418.292	428.911	437.996	445.983	453.141	697.145	714.843	729.985	743.296	755.226
40	411.718	422.002	430.794	438.518	445.436	686.191	703.33	717.983	730.857	742.388
50	406.76	416.795	425.369	432.898	439.639	677.928	694.653	708.943	721.492	732.727
60	402.797	412.635	421.037	428.412	435.013	671.324	687.721	701.724	714.016	725.018
70	399.506	409.182	417.443	424.692	431.178	665.84	681.967	695.734	707.816	718.626
80	396.699	406.237	414.379	421.521	427.909	661.162	677.06	690.628	702.531	713.18
90	394.255	403.675	411.713	418.763	425.068	657.089	672.79	686.186	697.935	708.443
100	392.095	401.411	409.357	416.326	422.557	653.489	669.016	682.26	693.875	704.26
110	390.161	399.384	407.25	414.146	420.312	650.266	665.638	678.748	690.242	700.518
120	388.411	397.551	405.345	412.176	418.283	647.351	662.584	675.572	686.958	697.136
130	386.816	395.88	403.608	410.38	416.433	644.692	659.799	672.677	683.965	694.054
140	385.351	394.346	402.013	408.731	414.736	642.25	657.241	670.019	681.217	691.224
150	383.997	392.928	400.539	407.208	413.168	639.993	654.878	667.564	678.679	688.611
160	382.739	391.61	399.17	405.794	411.711	637.897	652.683	665.283	676.321	686.184
170	381.564	390.381	397.893	404.474	410.353	635.939	650.634	663.154	674.122	683.92
180	380.464	389.229	396.696	403.237	409.08	634.105	648.714	661.16	672.061	681.799
190	379.428	388.146	395.571	402.074	407.883	632.38	646.908	659.284	670.123	679.805
200	378.451	387.123	394.509	400.978	406.755	630.751	645.205	657.515	668.295	677.923

Table 3.11 Specific Capacity of a Well For Different Radius Well

n	SPECIFIC CAPACITY IN FIVE AQUIFERS (m3/day/m drawdown)				
	RADIUS WELL (m)				
	0.1	0.125	0.15	0.175	0.2
1	1233.594	1270.692	1302.714	1331.085	1356.686
2	1177.226	1211.117	1240.298	1266.095	1289.329
3	1147.93	1180.129	1207.816	1232.263	1254.257
4	1128.047	1159.122	1185.818	1209.371	1230.546
5	1113.104	1143.347	1169.311	1192.204	1212.775
6	1101.189	1130.778	1156.166	1178.541	1198.638
7	1091.316	1120.368	1145.284	1167.234	1186.943
8	1082.907	1111.506	1136.023	1157.615	1176.997
9	1075.598	1103.806	1127.98	1149.263	1168.362
10	1069.143	1097.008	1120.881	1141.895	1160.747
11	1063.371	1090.932	1114.537	1135.31	1153.943
12	1058.157	1085.443	1108.809	1129.366	1147.802
13	1053.405	1080.443	1103.591	1123.953	1142.21
14	1049.044	1075.855	1098.804	1118.987	1137.082
15	1045.017	1071.619	1094.385	1114.404	1132.349
16	1041.277	1067.686	1090.283	1110.151	1127.958
17	1037.789	1064.019	1086.458	1106.185	1123.864
18	1034.522	1060.584	1082.877	1102.472	1120.031
19	1031.45	1057.355	1079.511	1098.983	1116.43
20	1028.553	1054.311	1076.337	1095.694	1113.035
30	1006.215	1030.85	1051.895	1070.371	1086.912
40	990.949	1014.831	1035.218	1053.107	1069.112
50	979.424	1002.745	1022.644	1040.096	1055.704
60	970.205	993.083	1012.595	1029.702	1044.997
70	962.546	985.059	1004.253	1021.076	1036.113
80	956.008	978.212	997.137	1013.72	1028.538
90	950.316	972.252	990.944	1007.319	1021.949
100	945.28	966.982	985.469	1001.662	1016.126
110	940.771	962.263	980.569	996.599	1010.916
120	936.693	957.996	976.137	992.021	1006.206
130	932.971	954.104	972.096	987.847	1001.912
140	929.553	950.528	968.384	984.014	997.969
150	926.393	947.224	964.954	980.473	994.326
160	923.456	944.153	961.768	977.183	990.942
170	920.714	941.287	958.793	974.112	987.784
180	918.144	938.601	956.006	971.235	984.826
190	915.726	936.074	953.385	968.529	982.044
200	913.444	933.689	950.911	965.976	979.419

3.4.3 EFFECT WELL LOSS PARAMETER ON SPECIFIC CAPACITY

3.4.3.1 The case of a well tapping a single aquifer and having storage.

Let, $Q_{A1}(n)$, $Q_W(n)$ be contributions from the aquifer and well storage respectively during time step n. At any time the algebraic sum of the abstraction from the aquifer and well storage will be equal to the pumping rate. Hence,

$$Q_{A1}(n) + Q_W(n) = Q_p(n) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.18)}$$

The drawdown at the well face at the end of time step n in the aquifer is given by :

$$S_{A1}(n) = \sum_{\gamma=1}^{n} Q_{A1}(\gamma).\delta_1(r_w, n-\gamma+1) + C\,Q_{A1}^2(n) \ldots. \quad \text{(3.19)}$$

where;

$$\delta_1(r_w, m) = \frac{1}{4\pi T_1}\left[E_1\left(\frac{r_w^2}{4\beta_1 m}\right) - E_1\left(\frac{r_w^2}{4\beta_1(m-1)}\right)\right],$$

$\beta_1 = \frac{T_1}{\phi_1}$ = hydraulic diffusivity of the aquifer.

C = well loss parameter.

The drawdown at the well due to abstraction from well storage at the end of time step n is given by :

$$S_w(n) = \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n} Q_w(\gamma) \qquad \ldots\ldots\ldots\ldots \text{(3.20)}$$

According to the assumption that at any time drawdown in the aquifer at the well face is equal to that in the well, $S_{A1}(n)=S_W(n)$. Hence, from equation (3.19) and (3.20) :

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(r_w, n-\gamma+1) + CQ_{A1}^{2}(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_w(\gamma) \quad \ldots(3.21)$$

or

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(r_W, n-\gamma+1) + CQ_{A1}^{2}(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} \left[Q_p(\gamma) - Q_{A1}(\gamma)\right]$$

or

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(r_w, n-\gamma+1) + CQ_{A1}^{2}(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_P(\gamma)$$

$$-\frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_{A1}(\gamma) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.22)$$

$$Q_{A1}(n)\,.\,\delta_1(1) + \frac{1}{\pi r_C^2}Q_{A1}(n) + CQ_{A1}^{2}(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_p(\gamma)$$

$$-\frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)) - \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\,.\,\delta_1(r_w, n-\gamma+1) \quad \ldots\ldots(3.23)$$

$$CQ_{A1}^{2}(n) + Q_{A1}(n)\,.\,\delta_1(1) + \frac{1}{\pi r_C^2}Q_{A1}(n) - \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_p(\gamma)$$

$$+\frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\,.\,\delta_1(r_w, n-\gamma+1) = 0 \quad \ldots\ldots\ldots(3.24)$$

This is a quadratic equation in $Q_{A1}(n)$ and the above equation is in the form.

$$aQ^2_{A1}(n) + bQ_{A1}(n) + c = 0$$

and $Q_{A1}(n)$ is given by:

$$Q_{A1} = (-b + \sqrt{b^2 - 4ac})/(2a)$$

Where;

$a = C$,

$b = \delta_1(1) + \dfrac{1}{\pi r_c^2}$, and

$$c = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) - \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_p(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) \cdot \delta_1(r_w, n-\gamma+1)$$

$Q_{A1}(n)$ can be solved in succession starting from n=1. Knowing $Q_{A1}(n)$, $Q_W(n)$ can be found using equation (3.18).

3.4.3.2 The case of a Multiaquifer well, Tapping Two Aquifers : Specific Capacity of a multiaquifer well considering well loss in one of the aquifers and well storage is computed as described below.

Let, $Q_{A1}(n)$, $Q_{A2}(n)$, and $Q_W(n)$ be contributions from aquifer 1, 2, and well storage respectively at time step n. At any time the algebraic sum of the abstractions from aquifer 1, 2, and well storage is equal to the pumping rate. Hence,

$$Q_{A1}(n) + Q_{A2}(n) + Q_W(n) = Q_p(n) \qquad \text{..............(3.25)}$$

Let there be clogging only in aquifer 1 and no clogging in aquifer 2. Hence, there will be entry loss in aquifer 1.

The drawdown at the well face at the end of time step n in the aquifer 1 is given by :

$$S_{A1}(n) = \sum_{\gamma=1}^{n} Q_{A1}(\gamma).\delta_1(r_w, n-\gamma+1) + C\,Q_{A1}^2(n) \quad \text{.... (3.26)}$$

where;

$$\delta_1(r_w, m) = \frac{1}{4\pi T_1}\left[E_1\left(\frac{r_w^2}{4\beta_1 m}\right) - E_1\left(\frac{r_w^2}{4\beta_1(m-1)}\right)\right],$$

$\beta_1 = \frac{T_1}{\phi_1} =$ hydraulic diffusivity of the aquifer 1

$E_1(X) =$ well function

$C =$ well loss parameter.

The drawdown at the well face at the end of time step n in the aquifer 2 is given by :

$$S_{A2}(n) = \sum_{\gamma=1}^{n} Q_{A2}(\gamma)\,.\,\delta_2(r_w, n-\gamma+1) \qquad \ldots\ldots\ldots\ldots\ (3.27)$$

where;

$$\delta_2(r_w, m) = \frac{1}{4\pi T_2}\left[E_1\left(\frac{r_w^2}{4\beta_2 m}\right) - E_1\left(\frac{r_w^2}{4\beta_2(m-1)}\right)\right],$$

$\beta_2 = \frac{T_2}{\phi_2}$ = hydraulic diffusivity of the aquifer 2

$E_1(X)$ = well function

The drawdown at the well due to abstraction from well storage at the end of time step n is given by :

$$S_w(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_w(\gamma) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.28)$$

According to the assumption that at any time drawdown in the aquifer 1,2 at the well face is equal to that in the well, $S_{A1}(n) = S_{A2}(n) = S_W(n)$.

Hence,

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\,.\,\delta_1(r_w, n-\gamma+1) + CQ_{A1}^2(n) = \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_w(\gamma) \ \ldots\ldots\ (3.29)$$

$$\sum_{\gamma=1}^{n} Q_{A2}(\gamma)\,.\,\delta_2(r_w, n-\gamma+1) = \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n} Q_w(\gamma) \ \ldots\ldots\ldots\ldots\ldots\ldots\ (3.30)$$

Applying equation (3.25) in equation (3.29)

$$\sum_{\gamma=1}^{n} Q_{A1}(\gamma)\cdot\delta_1(r_w, n-\gamma+1) + CQ_{A1}^{2}(n) = \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n}\Big[Q_p(\gamma) - Q_{A1}(\gamma) - Q_{A2}($$

or,

$$CQ_{A1}^{2}(n) + Q_{A1}(n)\cdot\delta_1(1) + \frac{1}{\pi r_C^2}Q_{A1}(n) + \frac{1}{\pi r_C^2}Q_{A2}(n)$$

$$-\frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n} Q_p(\gamma) + \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \frac{1}{\pi r_C^2}\sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)$$

$$+\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma)\cdot\delta_1(r_w, n-\gamma+1) = 0 \qquad \ldots\ldots\ldots\ldots\ldots(3.31)$$

Applying equation (3.25) in equation (3.30)

$$\sum_{\gamma=1}^{n} Q_{A2}(\gamma)\cdot\delta_2(r_w, n-\gamma+1) = \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n}\Big[Q_p(\gamma) - Q_{A1}(\gamma) - Q_{A2}(\gamma)\Big]$$

or,

$$Q_{A2}(n)\cdot\delta_2(1) + \frac{1}{\pi r_c^2}Q_{A2}(n) + \frac{1}{\pi r_c^2}Q_{A1}(n) + \sum_{\gamma=1}^{n-1} Q_{A2}(n)\cdot\delta_2(r_w, n-\gamma +$$

$$-\frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n} Q_p(\gamma) + \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \frac{1}{\pi r_c^2}\sum_{\gamma=1}^{n-1} Q_{A2}(\gamma) = 0$$

or,

$$Q_{A2}(n) = \frac{-Q_{A1}(n)}{1+\pi r_c^2\delta_2(1)} - \frac{1}{1+\pi r_c^2\delta_2(1)}\Big[\pi r_c^2\sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\cdot\delta_2(r_w, n-\gamma+1)$$

$$- \sum_{\gamma=1}^{n} Q_{P}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)] \qquad \text{.........} (3.32)$$

Substituting equation (3.31) in (3.32)

$$\pi r_c^2 C Q_{A1}^{2}(n) + \pi r_c^2 Q_{A1}(n) . \delta_1(1) + Q_{A1}(n) - \frac{Q_{A1}(n)}{1 + \pi r_c^2 \delta_2(1)}$$

$$- \frac{1}{1 + \pi r_C^2 \delta_2(1)} [\pi r_C^2 \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma) . \delta_2(r_w, n - \gamma + 1)$$

$$- \sum_{\gamma=1}^{n} Q_{P}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)]$$

$$- \sum_{\gamma=1}^{n} Q_{P}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) . \delta_1(r_w, n - \gamma + 1) . \pi r_C^2 = 0$$

or,

$$\pi r_C^2 C Q_{A1}^{2}(n) + \left[1 + \pi r_C^2 . \delta_1(1) - \frac{1}{1 + \pi r_C^2 \delta_2(1)} \right] Q_{A1}(n)$$

$$+ [\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) . \delta_1(r_w, n - \gamma + 1) . \pi r_C^2 - \sum_{\gamma=1}^{n} Q_{P}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)$$

$$- \frac{1}{1 + \pi r_C^2 \delta_2(1)} \{\pi r_C^2 \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma) . \delta_2(r_w, n - \gamma + 1) - \sum_{\gamma=1}^{n} Q_{P}(\gamma)$$

$$+ \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\}] = 0 \qquad \text{.................} (3.33)$$

This is a quadratic equation in $Q_{A1}(n)$ and the above equation is in the form.

$$aQ^2_{A1}(n) + bQ_{A1}(n) + c = 0$$

and $Q_{A1}(n)$ is given by:

$$Q_{A1} = (-b + \sqrt{b^2 - 4ac})/(2a)$$

Where;

$$a = \pi r_C^2 C \ ,$$

$$b = \left[1 + \pi r_C^2 . \delta_1(1) - \frac{1}{1 + \pi r_C^2 \delta_2(1)}\right] \ , \quad \text{and}$$

$$c = [\sum_{\gamma=1}^{n-1} Q_{A1}(\gamma).\delta_1(r_w, n - \gamma + 1).\pi r_C^2 - \sum_{\gamma=1}^{n} Q_P(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma$$

$$- \frac{1}{1 + \pi r_C^2 \delta_2(1)} \{\pi r_C^2 \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma) . \delta_2(r_w, n - \gamma + 1) - \sum_{\gamma=1}^{n} Q_P(\gamma)$$

$$+ \sum_{\gamma=1}^{n-1} Q_{A1}(\gamma) + \sum_{\gamma=1}^{n-1} Q_{A2}(\gamma)\}]$$

$Q_{A1}(n)$ can be solved in succession starting from n=1. Thus, the value $Q_{A2}(n)$ and $Q_W(n)$ can be found with equation (3.32) and (3.25) respectively.

3.4.3.3. Results

- **The case of a Well Tapping a Single Aquifer and Having Storage**

The analyses of specific capacities with well loss parameter are carried out for a well tapping a single aquifer. Well storage effect has been considered in the analyses. The data given in table 3.12 are used.

Table 3.12 The Data

No.	**Case**	**Aquifer**	**Transmissivity (m2/day)**	**Coefficient Of Storage**
1.	**Case I** Qp = 100 m3/day Rw = 0.1 m Rc = 2.0 m	1	100	0.1
		2	200	0.01
2.	**Case II** Qp = 700 m3/day Rw = 0.1 m Rc = 0.1 m	1	700	0.01
		2	500	0.02

The analyses are carried out for pumping rate Qp(n), radius of well(rw), radius of well storage (rc) and different conditions of well (well loss parameter).

The well loss parameter C is taken according to condition of well as suggested by Walton. Walton has recommended the ranges of well loss coefficient C which are given below:

Table 3.13 Relationship between Coefficient of C and Well Condition

Condition	Condition Criteria	C (min^2/m^5)
1	Properly designed and developed	< 0.5
2	Mild deterioration or clogging	0.5 - 1.0
3	Severe deterioration or clogging	1.0 - 4.0
4	Difficult to restore well to original capacity	> 4.0

Source: W.C. Walton, "Selected Analytical Methods for Well and Aquifers Evaluation," Illinois State Water Survey Bulletin NO. 49.1962.

In this analysis, the following values are chosen for different condition of the well.

- Condition 1 : 0.01 min^2/m^5 or 4.82253 x 10^{-9} day^2/m^5
- Condition 2 : 0.9 min^2/m^5 or 4.340 x 10^{-7} day^2/m^5
- Condition 4 : 5.0 min^2/m^5 or 2.411 x 10^{-6} day^2/m^5

The analyses are worked out for different conditions of well and pumping period. Pumping periods chosen are 1 day, 5 days, 10 days, 15 day, 20 day, 50 days, 100 days, 200 days and 365 days.

- Case I

Case I pertains to hardrock region in which the aquifer has low transmissivity and the pumping rate is low. In hardrock region, the well possesses considerable storage.

The specific capacities and drawdowns are presented in table 3.14 and 3.15 for different conditions of well.

The variations of specific capacity with respect to time for different conditions of well are shown in Figure 3.15. The specific capacity is largest for condition 1 and its decreases as well condition deteriorates to conditions

2, and 4. As seen in figure 3.16, the drawdown in the well for condition 4 is more than those in the well with condition 2, and 1. It is a fact that the specific capacity would increase if the well do not have any clogging/deterioration. The drawdown in the well would increase if the well has been clogged/ deteriorated. For different well condition there is no significant difference in specific capacities as the pumping rate is low and well storage contribution is significant.

- Case II

For case II, the specific capacities and drawdowns are presented in table 3.16 and 3.17 for different conditions of well. Case II presents a well in an alluvial area.

The variations of specific capacity with respect to time for different conditions of well are shown in Figure 3.17. The specific capacity is largest for condition 1 and it~~s~~ decreases as well condition deteriorates to conditions 2, and 4. In figure 3.18, the drawdown in the well for condition 4 is more than those in the well with condition 2 and 1.

Since the pumping rate is large, and these is insignificant well storage, the specific capacities decreases considerably as the well condition deteriorates.

Table 3.14 Specific Capacities for Different Well Conditions at Various Time in Case I

CASE I

GIVEN DATA :

Qp= 100 m3/day , Rw=0.1 m, Rc=2.0 m , T1=100 m2/day

Storativity = 0.1

t (day)	Specific Capacity (m3/day/m drawdown) Condition of Well		
	Condition 1	Condition 2	Condition 4
1	114.545	114.149	112.37
5	90.614	90.266	88.695
10	86.106	85.79	84.364
15	83.721	83.422	82.071
20	82.119	81.831	80.531
50	77.436	77.18	76.02
100	74.25	74.014	72.947
200	71.322	71.105	70.119
365	68.964	68.761	67.839

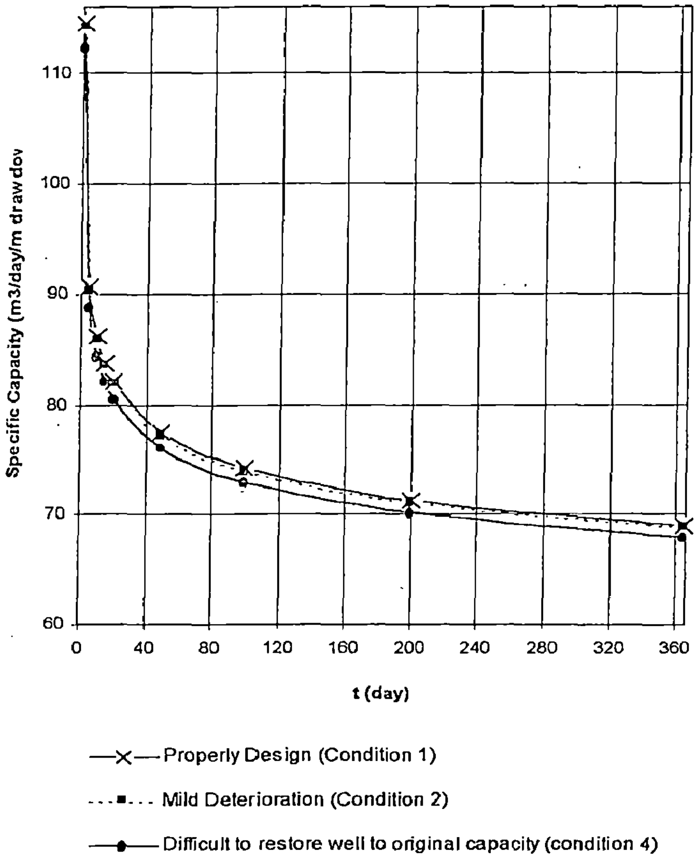

Figure 3.15 Variation of Specific Capacity For Different Well Conditions with Time (Case I)

Table 3.15 Drawdown for Different Well Conditions At Various Time (Case I)

t (day)	Drawdown (m)		
	Condition of Well		
	Condition 1	Condition 2	Condition 4
1	0.873	0.876	0.89
5	1.104	1.108	1.127
10	1.161	1.166	1.185
15	1.194	1.199	1.218
20	1.218	1.222	1.242
50	1.291	1.296	1.315
100	1.347	1.351	1.371
200	1.402	1.406	1.426
365	1.45	1.454	1.474

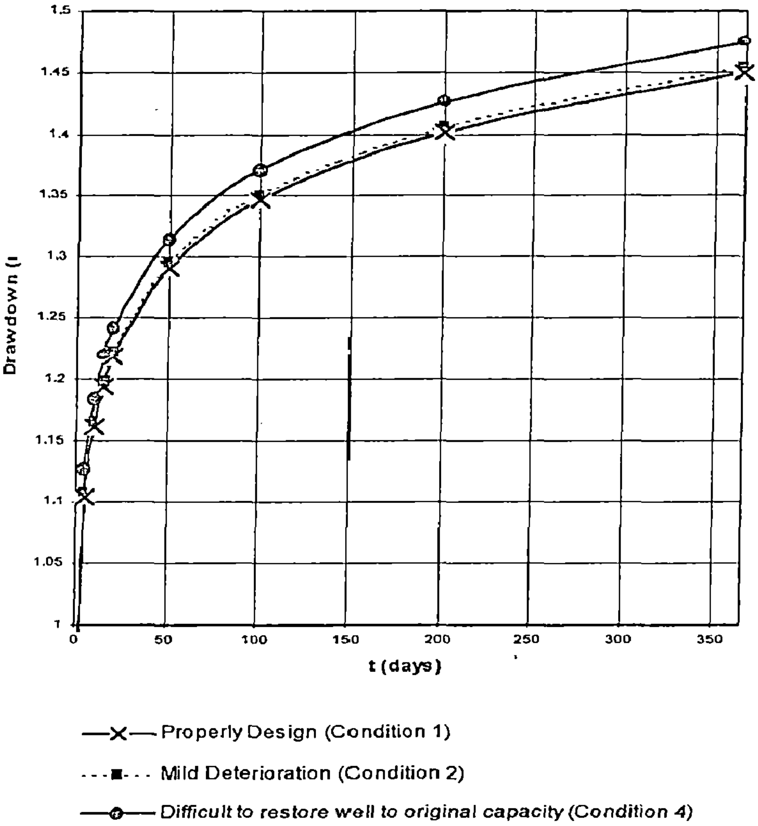

Figure 3.16 Variation of Drawdown with Time for Different Well Conditions (Case I)

Table 3.16 Specific Capacities for Different Well Conditions at Various Time in Case II

CASE II

GIVEN DATA :

Qp= 700 m3/day , Rw=0.1 m, Rc=0.1 m , T1=700 m2/day

Storativity = 0.01

t (day)	Specific Capacity (m3/day/m drawdown)		
	Condition of Well		
	Condition 1	Condition 2	Condition 4
1	529.932	457.164	280.043
5	483.067	421.847	266.352
10	465.353	408.275	260.877
15	455.581	400.733	257.777
20	448.892	395.549	255.622
50	428.84	379.897	248.992
100	414.822	368.855	244.201
200	401.692	358.437	239.59
365	390.952	349.861	235.728

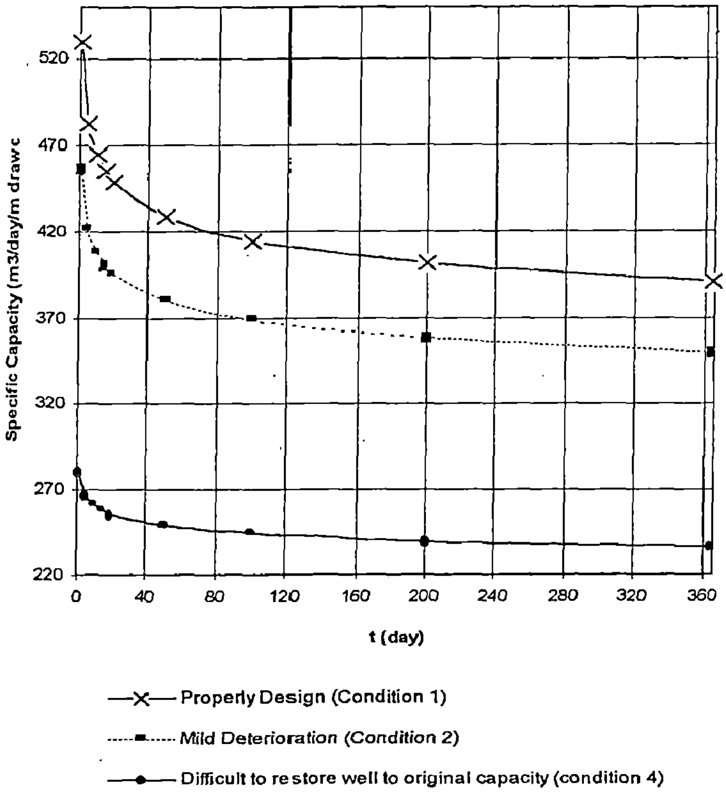

Figure 3.17 Variation of Specific Capacity with Time For Different Well Conditions (Case II)

Table 3.17 Drawdown for Different Well Conditions At Various Time (Case II)

t (day)	Drawdown (m)		
	Condition of Well		
	Condition 1	Condition 2	Condition 4
1	1.321	1.531	2.5
5	1.449	1.659	2.628
10	1.504	1.715	2.683
15	1.537	1.747	2.716
20	1.559	1.77	2.738
50	1.632	1.843	2.811
100	1.687	1.898	2.866
200	1.743	1.953	2.922
365	1.791	2.001	2.97

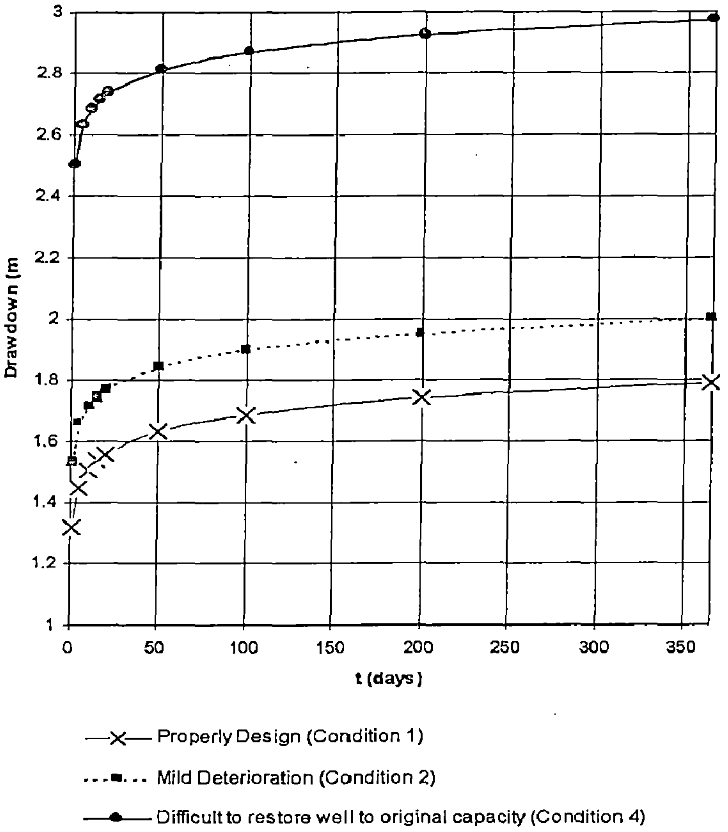

Figure 3.18 Variation of Drawdown with Time for Different Well Conditions (Case II)

☐ The Case of a Multiaquifer Well Tapping Two Aquifer.

The specific capacity is presented for the following set data :

Qp = 100 m3/day, Rw = 0.1 m , Rc = 2.0 m
T1 = 100 m2/day T2 = 200 m2/day
Storativity $\Phi 1 = 0.1$, and $\Phi 2 = 0.01$

Table 3.18 Specific Capacities of a Multiaquifer Well for Different Well Conditions at Various Time

t (day)	Specific Capacity (m3/day/m drawdown) Condition of Well		
	Condition 1	Condition 2	Condition 4
1	278.624	278.461	277.721
5	239.024	238.892	238.294
10	228.711	228.593	228.053
15	223.127	223.015	222.505
20	219.34	219.232	218.742
50	208.124	208.029	207.595
100	200.394	200.307	199.909
200	193.226	193.146	192.78
365	187.413	187.338	186.997

The variation of specific capacity with time are shown in Fig. 3.19

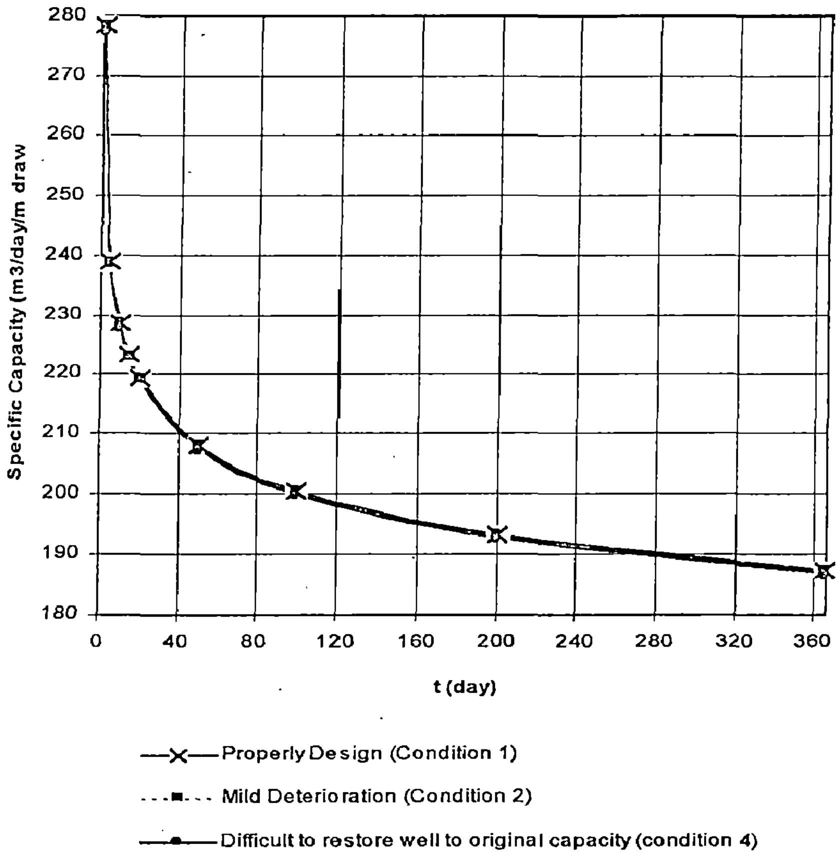

Figure 3.19 **Variation of Specific Capacity Of a Multiaquifer Well with Time For Different Well Conditions**

From the figure 3.19, it is seen that for the multiaquifer well and pumping rate assumed, the different well condition considered do not have any significant effect. This is due to the fact that the well has been assumed to have storage and the contribution of the aquifer through the clogged screen is quite small. Hence, because of the well screen which has not been deteriorated, the specific capacity is unaffected. The drawdown for different condition are presented in Figure 3.20.

The specific capacity for higher pumping rate in a multiaquifer well tapping aquifer of high transmissivity is presented in Figure 3.21. The specific capacity for different condition are also presented in Table 3.20.

For higher pumping rate, the well conditions influence the specific capacities considerably.

Table 3.19 Drawdown for Different Well Conditions At Various Time

t (day)	Drawdown (m)		
	Condition of Well		
	Condition 1	Condition 2	Condition 4
1	0.359	0.359	0.36
5	0.418	0.418	[illegible]
10	0.437	0.437	0.438
15	0.448	0.448	0.449
20	0.456	0.456	0.457
50	0.48	0.481	0.482
100	0.499	0.499	0.5
200	0.518	0.518	0.519
365	0.534	0.534	0.535

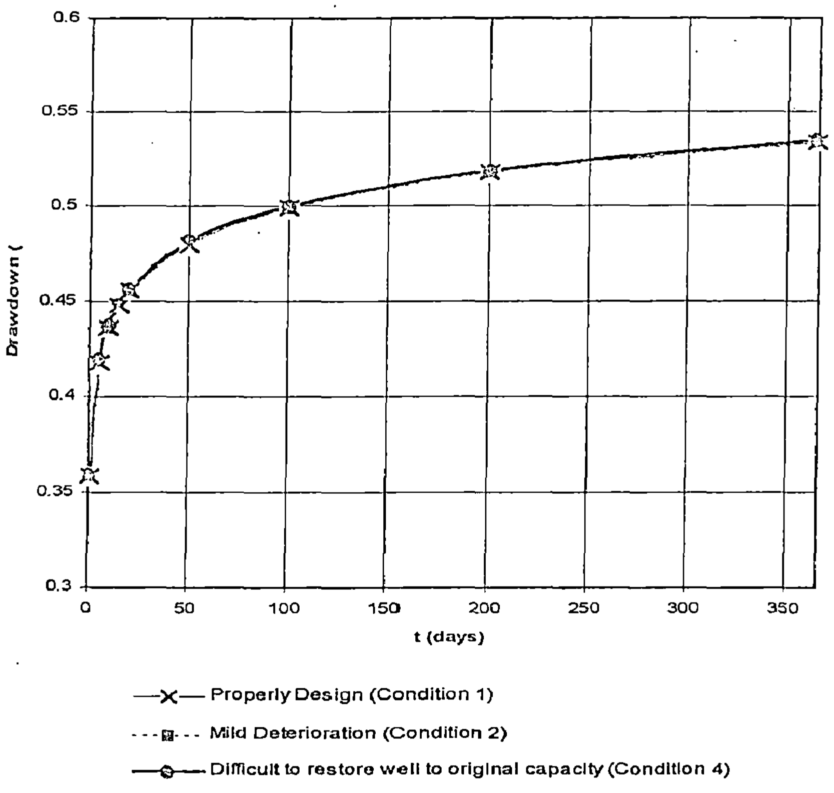

Figure 3.20 Variation of Drawdown for Different Well Conditions at Various Time

Table 3.20 Specific Capacities for Different Well Conditions at Various Time For High Pumping Rate

GIVEN DATA :

Qp= 700 m3/day , Rw=0.1 m, Rc=0.1 m , T1=700 m2/day, T2=500m2/day

Storativity 1 = 0.01 , Storativity 2 = 0.02

t (day)	Specific Capacity (m3/day/m drawdown) Condition of Well		
	Condition 1	Condition 2	Condition 4
1	934.643	892.164	775.818
5	849.764	814.009	712.653
10	817.793	784.456	688.678
15	800.184	768.149	675.423
20	788.143	756.986	666.338
50	752.099	723.512	639.032
100	726.952	700.103	619.876
200	703.432	678.169	601.876
365	684.22	660.221	587.111

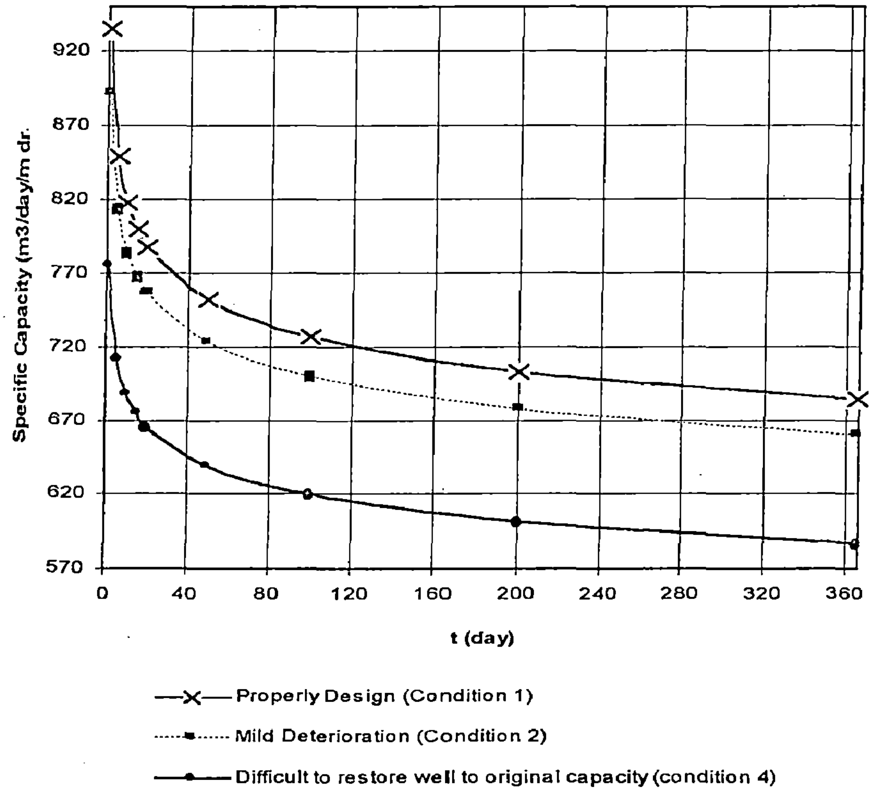

Figure 3.21 Variation of Specific Capacity For Different Well Conditions at Various Time

Table 3.21 Drawdown for Different Well Condition at Various Time For Higher Pumping Rate

t (day)	Drawdown (m)		
	Condition of Well		
	Condition 1	Condition 2	Condition 4
1	0.749	0.785	0.902
5	0.824	0.86	0.982
10	0.856	0.892	1.016
15	0.875	0.911	1.036
20	0.888	0.925	1.051
50	0.931	0.968	1.095
100	0.963	1	1.129
200	0.995	1.032	1.163
365	1.023	1.06	1.192

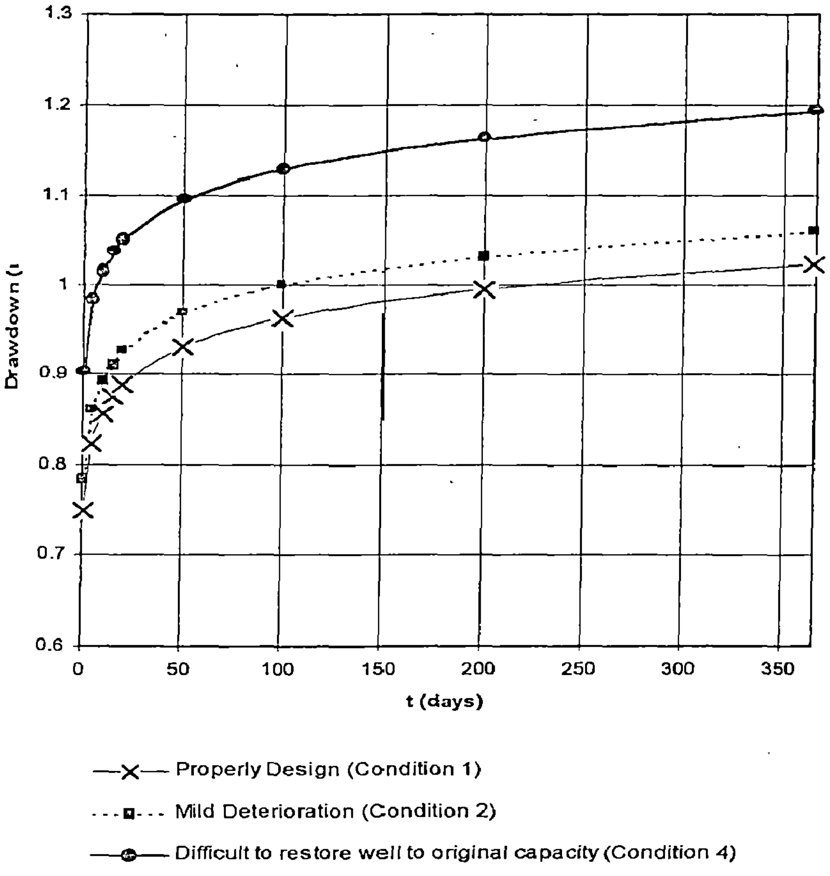

Figure 3.22 Variation of Drawdown for Different Well Conditions at Various Time

□ Selection of an Aquifer Considering Energy Requirement.

The calculation of energy consumption is important for deciding construction of a well in a multiaquifer system tapping one of the layers only or to go for constructing a multiaquifer well.

The computation of energy consumption for different well conditions also gives direction whether to go for development of deteriorated well.

The rate of energy consumption during nth day is given by:

$$E_r = \frac{Qp(n).\ \gamma_w.g.[G+s(n)]}{\eta} \qquad \text{Joule/sec}$$

in which,

s(n) = drawdown during nth day

Qp(n) = Pumping rate in m^3/sec

γ_w = 1000 kg/m3

g = 9.81 m/sec2

η = Efficiency of pump motor (taken 0.75)

or,

$$E_r = \frac{Qp(n)\ 9.81.[G+s(n)]}{\eta x 3.6x10^3} \qquad \text{Kwh}$$

Result are presented for a well in a hard rock region or in an alluvial ground water basin.

In table 3.22 and 3.23, the results are presented for a well tapping a low transmissivity aquifer. It could be seen if either of the aquifers are tapped the energy consumption will be more compared to that if both are tapped by a multiaquifer well. More energy is consumed if the well deteriorates.

The comparison has been made in Fig. 3.23 and Fig. 3.24 in respect of energy consumption.

Table 3.22. **Energy Requirement For Lifting The Water With No Clogging Well Condition**

GIVEN DATA :

QP = 100 M3/DAY	Φ1 = 0.1	RW = 0.1 M
T1 = 100 M2/DAY	Φ2 = 0.01	RC = 2.0 M
T2 = 200 M2/DAY		

t (day)	NO CLOGGING		
	WELL IN		
	FIRST AQUIFER	SECOND AQUIFER	MULTIAQUIFER
1	1.769	1.657	1.582
5	9.262	8.479	8.019
10	18.734	17.061	16.106
15	28.281	25.68	24.218
20	37.877	34.324	32.347
50	96.028	86.475	81.312
100	194.067	173.955	163.298
200	392.148	349.914	327.939
365	722.021	641.767	600.615

Table 3.23. Energy Requirement For Lifting The Water With Clogging Well Condition

t (day)	WITH CLOGGING		
	WELL IN		
	FIRST AQUIFER	SECOND AQUIFER	MULTIAQUIFER *
1	1.775	1.664	1.583
5	9.305	8.522	8.021
10	18.821	17.148	16.11
15	28.412	25.811	24.225
20	38.051	34.499	32.356
50	96.465	86.913	81.335
100	194.942	174.83	163.342
200	393.898	351.664	328.026
365	725.214	644.961	600.773

Note *) : clogging only in first aquifer

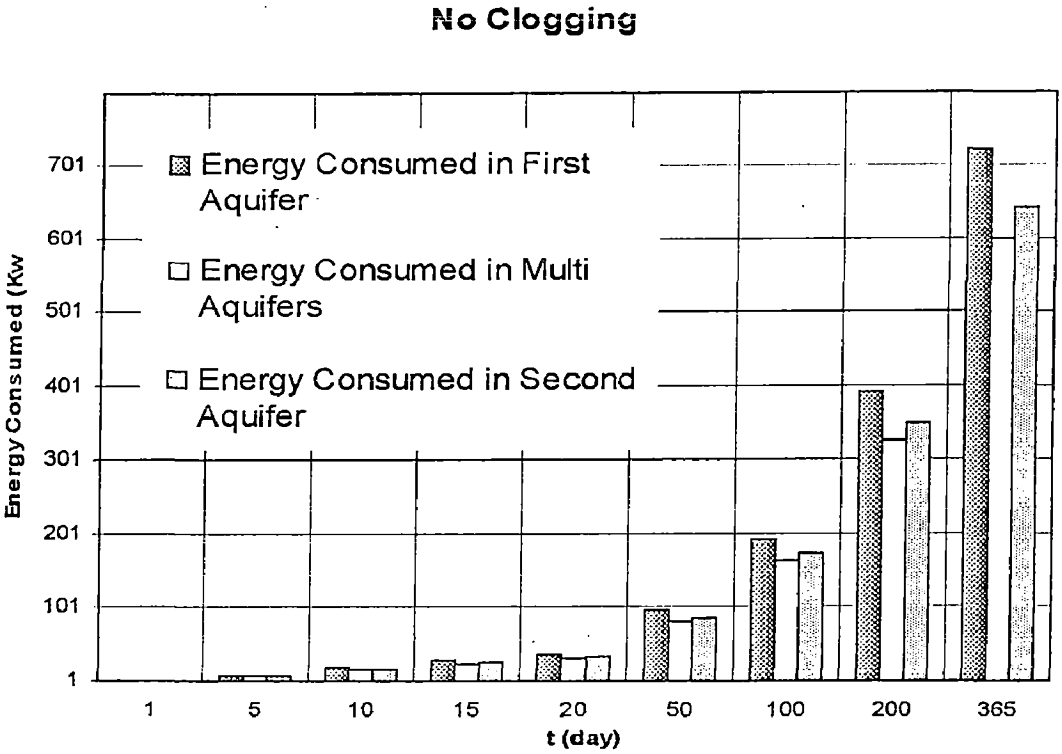

Fig. 3.23. Energy Requirement For Lifting The Water With No Clogging Well Condition

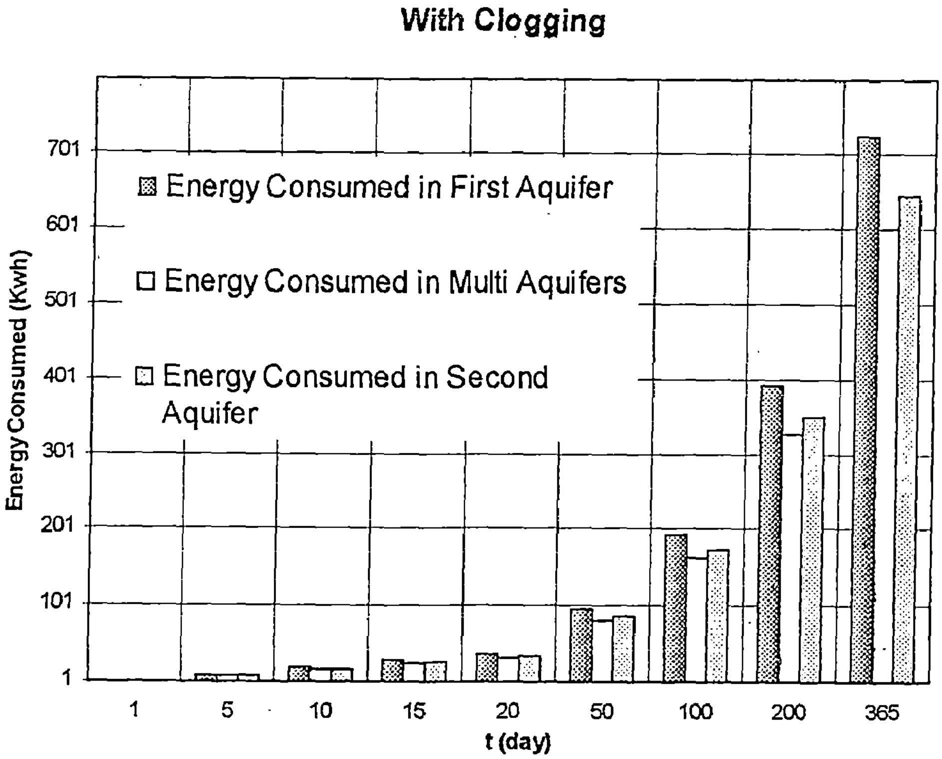

Fig. 3.24. Energy Requirement For Lifting The Water With Clogging Well Condition

CHAPTER IV

COST ANALYSIS OF A WELL IN A MULTI-AQUIFER SYSTEM

4.1 GENERAL

The cost analysis of a well in a multi-aquifer system has been carried out considering fixed cost and recurring cost (see Chapter II).

The fixed cost consist :

1. Cost of pump
2. Cost of construction (drilling/boring),and
3. Cost of miscellaneous equipment.

The recurring cost consist of.

1. Cost of energy and
2. Cost of operation and maintenance.

In this study, the cost estimate is made for supplying a water demand of 432 m^3/day (5 lps) using a well with capacity 432 m^3/day or 864 m^3/day, with annual running hours of 8760 and 4380 depending on capacity of the well.

4.2. UNIT COST OF PUMPED WATER

The total cost of pumped water. Which is equal to the annual capital cost plus the annual recurring cost can be computed using the following formula :

A. Annual Capital Recovery Cost (Fixed Cost)

The annual capital recovery cost, A, is given by 2):

$$A = C \times \frac{(1+i)^n \times i}{(1+i)^n - 1} \qquad \text{.................} \quad (4.1)$$

Where;

A = Annual Capital Recovery Cost in Rs

C = Invested Capital Cost in Rs

I = Rate of interest in percent (%)

n = life time of project.

B. Annual Recurring Cost

The energy cost of pumping water depends on:

i) position of water table below ground surface, and

ii) drawdown in the well due to pumping

The drawdown at time n reckoned from the beginning of the pumping is given by :

$$S(n) = \sum_{\gamma=1}^{n} Q(\gamma) \cdot \delta(n - \gamma + 1) \qquad \text{.................} \quad (4.2)$$

where;

$$\delta(m) = \frac{1}{4\pi T}\left[E_1\left(\frac{r_w^2}{4\beta m}\right) - E_1\left(\frac{r_w^2}{4\beta(m-1)}\right)\right]$$

$$\beta = \frac{T}{\phi},$$

T = Transmissivity, and

ϕ = Coefficient of storage.

So, the annual energy cost will be :

$$E = \frac{C_1\ 9.8\ Qp\,(t)}{\eta .86400}\left(\sum_{n=1}^{N}\left(G+S(n)\right)\right) \qquad \text{.................. (4.3)}$$

where ;

C1 = Cost of energy per Kwh
Qp = Pumping rate in m^3/day
η = Efficiency of pump motor
G = Depth to water table or piezometric surface
s(n) = Drawdown.

The operation and maintenance costs are generally computed as a percentage of the investment cost i.e around:

$$O = \frac{K}{100} xC \qquad \text{.................. (4.4)}$$

$$M = \frac{K}{100} xC \qquad \text{.................. (4.5)}$$

where;

C = Invested capital cost
O = Operation
M = Maintenance
K = a Constant

The total annual cost obtained by summing of all annual cost divided by the number of unit of ground water produced gives the cost for unit volume of water (ie. Rs/m^3)

Thus,

$$\text{Unit Cost} = \frac{A + E + O + M}{Va}$$

Where ;

Va = Volume of water pumped per years
Qp = Discharge in m3/hours
Va = Qp x ta
ta = Total annual pumping hours.

The electric pump which is available in market is to be used as the lifting device.

4.3 DATA AND ASSUMPTION

The following assumptions have been made in the cost calculation;

- Consider a ground water basin consisting of five aquifers separated by aquicludes, see figure 4.1.
- Piezometric surfaces in all the aquifers are same.
- Life time of pumps/tube well is 50 years
- Pump life is taken as 500,000 running hours
- The depth water table is taken to be at 4 meter below ground surface
- Interest rate is 15 %
- Energy charges have been assumed to be Rs. 2.8/Kwh.

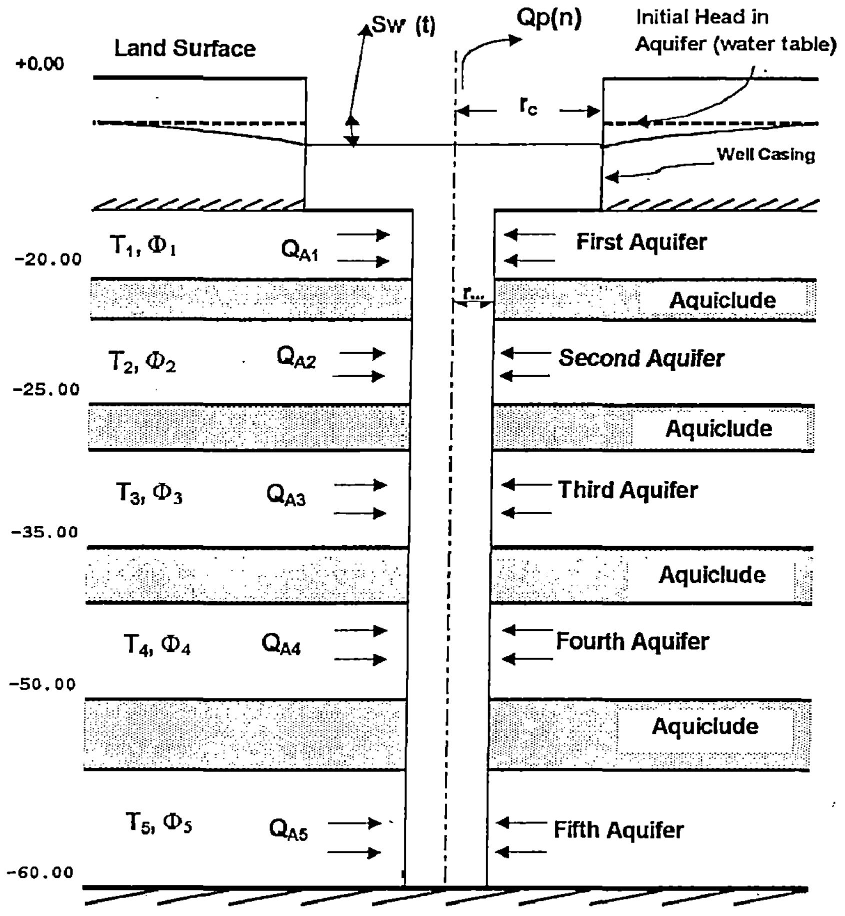

Figure 4.1 Depth of the Aquifers

The total cost of water supply through well can be divided into following fixed cost and running cost.

4.3.1 The fixed Cost

The fixed cost of Well in this study only consists of:

- Cost of pumpset
- Cost of boring/drilling
- Cost of miscellaneous equipment

The various cost components are explained below.

a. The price of pumpset

The cost of pump and appurtenances may vary between Rs. 7,500 - Rs. 20,000. It is dependent on the horse power of the pump as well as on the capacity of pump and height through which water is to be lifted.

The costs of pumps has been taken around Rs. 12,500 and Rs. 15,000 for pump with capacity 5 lps and 10 lps respectively. They can lift water from a depth of 60 m from ground surface.

b. The cost of boring/drilling

The cost of boring depends on the depth and diameter of well. For a well with diameter of 0.2 m, the cost of excavation is Rs. 150 per meter depth of excavation. For a well with 0.25 m diameter the cost is Rs. 200/m

c. Miscellaneous equipment

Besides, the cost of pumpset and boring, the miscellaneous cost equipment are taken around Rs 5,000 to 8,500.

The cost of boring/drilling and miscellaneous equipment for different depth and diameter of well are presented in table 4.1.

After summing the all fixed cost, the annual recovery capital cost is calculated making use equation (4.1)

Table 4.1 Cost of Boring/drilling and Miscellaneous Equipment

No.	Aquifers	Depth (m)	Diameter of Well (m)	Cost of Boring (Rs)	Cost of Miscellaneous (Rs)
1.	I	20	0.2	3000	5000
			0.25	4000	5000
2.	II	25	0.2	3750	5500
			0.25	5000	5500
3.	III	35	0.2	5250	6000
			0.25	7000	6000
4.	IV	50	0.2	7500	8000
			0.25	1000	8000
5.	V	60	0.2	9000	8500
			0.25	12000	8500

4.3.1 The Recurring Cost

In the study, the following recurring costs are considered;

- Cost of Energy
- Operation and
- Maintenance.

The calculation of annual cost of energy has been made using equation (4.3), for constant pumping rate of 432 m^3/day (5 lps) and 864 m3/day (10 lps). Energy charge has been taken as 2.8/Kwh; initial water table is assumed to be at 4 m below ground surface. The drawdown is calculated making use of equation (4.2).

The Operation and maintenance costs per years are usually taken as 2 % of the invested cost.

The energy cost is given in table 4.2

Table 4.2 Energy Cost

- **For Well Dia.=0.2 m, Qp=432 m3/day (1 day operation)**

No.	Aquifers	Depth (m)	Energy of Cost (Rs. Kwh)
1.	I	20	17716.720
2.	II	25	10178.930
3.	III	35	8294.461
4.	IV	50	7540.671
5.	V	60	7163.776

- **For Well Dia.=0.25 m, Qp=432 m3/day (1 day operation)**

No.	Aquifers	Depth (m)	Energy of Cost (Rs. Kwh)
1.	I	20	17470.860
2.	II	25	10096.980
3.	III	35	8253.478
4.	IV	50	7516.085
5.	V	60	7147.385

- For Dia.of Well=0.2 m,Qp=864 m3/day (0.5 day operation)

No.	Aquifers	Depth (m)	Energy of Cost (Rs. Kwh)
1.	I	20	29023.450
2.	II	25	13430.110
3.	III	35	9667.520
4.	IV	50	8406.969
5.	V	60	7689.375

- For Dia.of Well=0.25 m, Qp=864 m3/day (0.5 day operation)

No.	Aquifers	Depth (m)	Energy of Cost (Rs. Kwh)
1.	I	20	28531.740
2.	II	25	13274.070
3.	III	35	9591.525
4.	IV	50	8360.158
5.	V	60	7658.168

4.4 RESULT AND DISCUSSION

According to the above data and assumption, the total cost of pumping is calculated, in which electric engine is used for lifting the water.

The step wise calculation and results are presented in the table 4.3 for different diameter of well and well capacity:

TABLE 4.3 THE CALCULATION OF FIXED COST AND RECURRING COST

COST ANALYSIS OF WELL IN MULTI-AQUIFER (diameter 0.200 m, Qp = 432 m3/day)							
FOR AQUIFER 1 (First Aquifer)				FOR AQUIFER I AND II (Until Second Aquifer)			
I	Fixed Cost			I	Fixed Cost		
	Cost of Pump		125000		Cost of Pump		125000
	Cost Boring per m depth				Cost Boring per m depth		
	- radius of well 0.100 m (dia. 0.2 m) and 20 m deep is @	150	3000		- radius of well 0.100 m (dia. 0.2 m) and 25 m deep is @	150	3750
	Cost Miscelenious (other equipment)		5000		Cost Miscelenious (other equipment)		5500
		TOTAL 1	133000			TOTAL 1	134250
	Annual Capital Recovery Cost (A) or ACR Calculate with :				Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	19949		A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	20136.5
	Where;				Where;		
	C = Capital Cost				C = Capital Cost		
	i = interest rate (taken 15 %)				i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)				N = Life time of project (taken 50 years)		
II	Recurring Cost			II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon				The Calculation Annual Energy Cost is basedon		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))				Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))		
	where;				where;		
	C1 = cost of energy per kwh = Rp. 2.8,-				C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour				ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day				Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75				eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m				G = Depth of water table = 4 m		
	s(t) = drawdown				s(t) = drawdown		
		Annual Cost of Energy	17716.72			Annual Cost of Energy	10178.93
	Cost of Operation and Maintenance ;				Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost				Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 133000)		26600		- Operation (0.2 x 134250)		26850
	- Maintenance (0.2 x 133000)		26600		- Maintenance (0.2 x 134250)		26850
		Total 2	70916.72			Total 2	63878.93
III	Total Cost	NPV + TOTAL 2	90865.72	III	Total Cost	NPV + TOTAL 2	84015.43

CONTINUED TABLE 4.3

FOR AQUIFER I,II, and III (until Third Aquifer)				
I	**Fixed Cost**			
	Cost of Pump			*125000*
	Cost Boring per m depth			
	- radius of well 0.100 m and 35 m deep is 8		150	*5250*
	Cost Miscelenious			*6000*
		TOTAL 1		*136250*
	Annual Capital Recovery Cost (A) or ACR Calculate with :			
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR		20436.5
	Where;			
	C = Capital Cost			
	i = interest rate (taken 15 %)			
	N = Life time of project (taken 50 years)			
II	**Recurring Cost**			
	The Calculation Annual Energy Cost is basedon			
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))			
	where;			
	C1 = cost of energy per kwh = Rp. 2.8,-			
	ta = total annual pumping hour			
	Q = well capacity in m3/day = 432 m3/day			
	eff = efficiency of pumping = 0.75			
	G = Depth of water table = 4 m			
	s(t) = drawdown			
		Annual Cost of Energy		*8294.461*
	Cost of Operation and Maintenance ;			
	Cost of Operation and maintenace taking 2% Of capital cost			
	- Operation (0.2 x 136250)			*27250*
	- Maintenance (0.2 x 136250)			*27250*
		Total 2		62794.461
III	Total Cost	ACR + TOTAL 2		83230.961

FOR AQUIFER I,II,III and IV (until Fourth Aquifer)				
I	**Fixed Cost**			
	Cost of Pump			*125000*
	Cost Boring per m depth			
	- radius of well 0.100 m and 50 m deep is 8		150	*7500*
	Cost Miscelenious			*8000*
		TOTAL 1		*140500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :			
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR		21074
	Where;			
	C = Capital Cost			
	i = interest rate (taken 15 %)			
	N = Life time of project (taken 50 years)			
II	**Recurring Cost**			
	The Calculation Annual Energy Cost is basedon			
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))			
	where;			
	C1 = cost of energy per kwh = Rp. 2.8,-			
	ta = total annual pumping hour			
	Q = well capacity in m3/day = 432 m3/day			
	eff = efficiency of pumping = 0.75			
	G = Depth of water table = 4 m			
	s(t) = drawdown			
		Annual Cost of Energy		*7540.671*
	Cost of Operation and Maintenance ;			
	Cost of Operation and maintenece taking 2% Of capital cost			
	- Operation (0.2 x 140500)			*28100*
	- Maintenance (0.2 x 140500)			*28100*
		Total 2		63740.671
III	Total Cost	ACR + TOTAL 2		84814.671

CONTINUED TABLE 4.3

FOR AQUIFER I, II, III, IV and V (Until Fifth Aquifer)			
I	**Fixed Cost**		
	Cost of Pump ;		125000
	Cost Boring per m depth		
	- radius of well 0.100 m and 60 m deep is @	150	9000
	Cost Miscelinious		8500
	TOTAL 1		142500
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1 +i)^N x i/ (1 + i)^N - 1) ACR		21374
	Where; C = Capital Cost i = interest rate (taken 15 %) N = Life time of project (taken 50 years)		
II	**Recurring Cost**		
	The Calculation Annual Energy Cost is based on		
	Cp = C1 x (9.8 x Qp (t) x ta/Eff x 86400) x (G + s(t))		
	where; C1 = cost of energy per kwh = Rp. 2.8,- ta = total annual pumping hour Q = well capacity in m3/day = 432 m3/day eff = efficiency of pumping = 0.75 G = Depth of water table = 4 m s(t) = drawdown		
	Annual Cost of Energy		7163.776
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.1 x 142500)		28500
	- Maintenance (0.1 x 142500)		28500
	Total 2		64163.776
III	**Total Cost** ACR + TOTAL 2		85537.776

CONTINUED TABLE 4.3

COST ANALYSIS OF WELL IN MULTI-AQUIFER (diameter 0.250 m, Qp = 432 m3/day)

FOR AQUIFER 1 (First Aquifer)			
I	**Fixed Cost**		
	Cost of Pum..		*125000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 20 m deep i	200	*4000*
	Cost Miscelenious (other equipment)		*5000*
	TOTAL 1		*134000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^N \times i / (1+i)^N - 1)$ ACR		20099
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	$Cp = C1 \times (9.8 \times Qp(t) \times ta/(Eff \times 86400)) \times (G + S(t))$		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
	Annual Cost of Energy		17470.86
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% Of capital cost		
	- Operation (0.2 x 133000)		*26800*
	- Maintenance (0.2 x 133000)		*26800*
	Total 2		71070.86
III	Total Cost ACR + TOTAL 2		91169.86

FOR AQUIFER I AND II (Until Second Aquifer)			
I	**Fixed Cost**		
	Cost of Pump:		*125000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 25 m deep is @	200	*5000*
	Cost Miscelenious (other equipment)		*5500*
	TOTAL 1		*135500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^N \times i / (1+i)^N - 1)$ ACR		20324
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	$Cp = C1 \times (9.8 \times Qp(t) \times ta/(Eff \times 86400)) \times (G + S(t))$		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
	Annual Cost of Energy		10096.98
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% Of capital cost		
	- Operation (0.2 x 134250)		*27100*
	- Maintenance (0.2 x 134250)		*27100*
	Total 2		64296.98
III	Total Cost ACR + TOTAL 2		84620.98

	FOR AQUIFER I,II, and III (until Third Aquifer)		
I	Fixed Cost		
	Cost of Pump		*125000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia.0.250 m) and 35 m deep i	200	*7000*
	Cost Miscelenious		*6000*
	TOTAL 1		*138000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^{N} \times i / (1+i)^{N} - 1)$ ACR		20699
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
	Annual Cost of Energy		8253.484
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 136250)		*27600*
	- Maintenance (0.2 x 136250)		*27600*
	Total 2		63453.484
III	Total Cost ACR + TOTAL 2		84152.484

	FOR AQUIFER I,II,III and IV (until Fourth Aquifer)		
I	Fixed Cost		
	Cost of Pump		*125000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.250 m) and 50 m deep is	200	*10000*
	Cost Miscelenious		*8000*
	TOTAL 1		*143000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^{N} \times i / (1+i)^{N} - 1)$ ACR		21449
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
	Annual Cost of Energy		7516.085
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 140500)		*28600*
	- Maintenance (0.2 x 140500)		*28600*
	Total 2		64716.085
III	Total Cost ACR + TOTAL 2		86165.085

CONTINUED TABLE 4.3

	FOR AQUIFER I,II, III, IV and V (Until Fifth Aquifer)		
I	**Fixed Cost**		
	Cost of Pump		
			125000
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.250 m) and 60 m deep	200	*12000*
	Cost Miscelinious		
			8500
	TOTAL 1		*145500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1 +i)^N x i/ (1 + i)^N - 1) ACR		21824
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	**Recurring Cost**		
	The Calculation Annual Energy Cost is based on		
	Cp = C1 x (9.8 x Qp (t) x ta/Eff x 86400) x (G + s(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
	Annual Cost of Energy		7147.385
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.1 x 145500)		*29100*
	- Maintenance (0.1 x 145500)		*29100*
	Total 2		65347.385
III	Total Cost ACR + TOTAL 2		87171.385

CONTINUED TABLE 4.3

COST ANALYSIS OF WELL IN MULTI-AQUIFER (diameter 0.200 m, Qp = 864 m3/day)

FOR AQUIFER 1 (First Aquifer)

I	Fixed Cost		
	Cost of Pump		*150000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 20 m deep i	150	*3000*
	Cost Miscelenious (other equipment)		*5000*
		TOTAL 1	*158000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	23699
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is base on		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
		Annual Cost of Energy	28531.74
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 158000)		*31600*
	- Maintenance (0.2 x 158000)		*31600*
		Total 2	91731.74
III	Total Cost	ACR + TOTAL 2	115430.74

FOR AQUIFER I AND II (Until Second Aquifer)

I	Fixed Cost		
	Cost of Pump		*150000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 25 m deep is	150	*3750*
	Cost Miscelenious (other equipment)		*5500*
		TOTAL 1	*159250*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	23886.5
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is base on		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
		Annual Cost of Energy	13274.07
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 159250)		*31850*
	- Maintenance (0.2 x 159250)		*31850*
		Total 2	76974.07
III	Total Cost	ACR + TOTAL 2	100860.57

CONTINUED TABLE 4.3

FOR AQUIFER I,II, and III (until Third Aquifer)			
I	**Fixed Cost**		
	Cost of Pump		*150000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia.0.25 m) and 35 m deep is	150	*5250*
	Cost Miscelinious		*6000*
		TOTAL 1	*161250*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	24186.5
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	**Recurring Cost**		
	The Calculation Annual Energy Cost is based on		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
		Annual Cost of Energy	9591.525
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 163000)		*32250*
	- Maintenance (0.2 x 163000)		*32250*
		Total 2	74091.525
III	**Total Cost**	ACR + TOTAL 2	98278.025

FOR AQUIFER I,II,III and IV (until Fourth Aquifer)			
I	**Fixed Cost**		
	Cost of Pump		*150000*
	Cost Boring per m depth		
	- radius of well 0.125 m (0.25 m) and 50 m deep is @	150	*7500*
	Cost Miscelinious		*8000*
		TOTAL 1	*165500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR	24824
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	**Recurring Cost**		
	The Calculation Annual Energy Cost is based on		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + s(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
		Annual Cost of Energy	8360.158
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 168000)		*33100*
	- Maintenance (0.2 x 168000)		*33100*
		Total 2	74560.158
III	**Total Cost**	ACR+ TOTAL 2	99384.158

CONTINUED TABLE 4.3

FOR AQUIFER I, II, III, IV and V (Until Fifth Aquifer)			
I	**Fixed Cost**		
	Cost of Pump		*150000*
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 60 m deep i	150	*9000*
	Cost Miscelinious		*8500*
	TOTAL 1		*167500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^N \times i / (1+i)^N - 1)$ — ACR		25124
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	**Recurring Cost**		
	The Calculation Annual Energy Cost is based on		
	$Cp = C1 \times (9.8 \times Qp\ (t) \times ta/Eff \times 86400) \times (G + s(t))$		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	s(t) = drawdown		
		Annual Cost of Energy	7658.168
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 167500)		*33500*
	- Maintenance (0.2 x 167500)		*33500*
	Total 2		74658.168
III	**Total Cost** — ACR + TOTAL 2		99782.168

CONTINUED TABLE 4.3

COST ANALYSIS OF WELL IN MULTI-AQUIFER (diameter 0.250 m, Qp = 864 m3/day)

FOR AQUIFER 1 (First Aquifer)			
I	Fixed Cost		
	Cost of Pump		150000
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 20 m deep is @	200	4000
	Cost Miscelenious (other equipment)		5000
		TOTAL 1	159000
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^N \times i/(1+i)^N - 1)$	ACR	23849
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
		Annual Cost of Energy	28531.74
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 159000)		31800
	- Maintenance (0.2 x 159000)		31800
		Total 2	92131.74
III	Total Cost	ACR + TOTAL 2	115980.74

FOR AQUIFER I AND II (Until Second Aquifer)			
I	Fixed Cost		
	Cost of Pump		150000
	Cost Boring per m depth		
	- radius of well 0.125 m (dia. 0.25 m) and 25 m deep is @	200	5000
	Cost Miscelenious (other equipment)		5500
		TOTAL 1	160500
	Annual Capital Recovery Cost (A) or ACR Calculate with :		
	$A = C \times ((1+i)^N \times i/(1+i)^N - 1)$	ACR	24074
	Where;		
	C = Capital Cost		
	i = interest rate (taken 15 %)		
	N = Life time of project (taken 50 years)		
II	Recurring Cost		
	The Calculation Annual Energy Cost is basedon		
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))		
	where;		
	C1 = cost of energy per kwh = Rp. 2.8,-		
	ta = total annual pumping hour		
	Q = well capacity in m3/day = 432 m3/day		
	eff = efficiency of pumping = 0.75		
	G = Depth of water table = 4 m		
	S(t) = drawdown		
		Annual Cost of Energy	13274.07
	Cost of Operation and Maintenance ;		
	Cost of Operation and maintenace taking 2% of capital cost		
	- Operation (0.2 x 160500)		32100
	- Maintenance (0.2 x 160500)		32100
		Total 2	77474.07
III	Total Cost	ACR + TOTAL 2	101548.07

CONTINUED TABLE 4.3

FOR AQUIFER I,II, and III (until Third Aquifer)				
I	Fixed Cost			
	Cost of Pump			*150000*
	Cost Boring per m depth			
	- radius of well 0.125 m (dia.0.25 m) and 35 m deep is @		200	*7000*
	Cost Miscelinious			*6000*
		TOTAL 1		*163000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :			
	$A = C x ((1+i)^N x i/(1+i)^N - 1)$	ACR		24449
	Where;			
	C = Capital Cost			
	i = interest rate (taken 15 %)			
	N = Life time of project (taken 50 years)			
II	Recurring Cost			
	The Calculation Annual Energy Cost is based on			
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))			
	where;			
	C1 = cost of energy per kwh = Rp. 2.8,-			
	ta = total annual pumping hour			
	Q = well capacity in m3/day = 432 m3/day			
	eff = efficiency of pumping = 0.75			
	G = Depth of water table = 4 m			
	S(t) = drawdown			
		Annual Cost of Energy		9591.525
	Cost of Operation and Maintenance ;			
	Cost of Operation and maintenace taking 2% Of capital cost			
	- Operation (0.2 x 163000)			*32600*
	- Maintenance (0.2 x 163000)			*32600*
		Total 2		74791.525
III	Total Cost	ACR + TOTAL 2		99240.525

FOR AQUIFER I,II,III and IV (until Fourth Aquifer)				
I	Fixed Cost			
	Cost of Pump.			*150000*
	Cost Boring per m depth			
	- radius of well 0.125 m (0.25 m) and 50 m deep is @		200	*10000*
	Cost Miscelinious			*8000*
		TOTAL 1		*168000*
	Annual Capital Recovery Cost (A) or ACR Calculate with :			
	$A = C x ((1+i)^N x i/(1+i)^N - 1)$	ACR		25199
	Where;			
	C = Capital Cost			
	i = interest rate (taken 15 %)			
	N = Life time of project (taken 50 years)			
II	Recurring Cost			
	The Calculation Annual Energy Cost is based on			
	Cp = C1 x (9.8 x Qp (t) x ta/(Eff x 86400)) x (G + S(t))			
	where;			
	C1 = cost of energy per kwh = Rp. 2.8,-			
	ta = total annual pumping hour			
	Q = well capacity in m3/day = 432 m3/day			
	eff = efficiency of pumping = 0.75			
	G = Depth of water table = 4 m			
	S(t) = drawdown			
		Annual Cost of Energy		8360.158
	Cost of Operation and Maintenance ;			
	Cost of Operation and maintenace taking 2% Of capital cost			
	- Operation (0.2 x 168000)			*33600*
	- Maintenance (0.2 x 168000)			*33600*
		Total 2		75560.158
III	Total Cost	ACR + TOTAL 2		100759.158

CONTINUED TABLE [illegible]

FOR AQUIFER I,II, III, IV and V (Until [illegible]				
I	**Fixed Cost**			
	Cost of Pump			*150000*
	Cost Boring per m depth			
	- radius of well 0.125 m (dia. 0.25 m) and 60 ~~m deep is 6~~		200	*12000*
	Cost Miscelinious			*8500*
		TOTAL 1		*170500*
	Annual Capital Recovery Cost (A) or ACR Calculate with :			
	A = C x ((1+i)^N x i/ (1 + i)^N - 1)	ACR		25574
	Where;			
	C = Capital Cost			
	i = interest rate (taken 15 %)			
	N = Life time of project (taken 50 years)			
II	**Recurring Cost**			
	The Calculation Annual Energy Cost is based on			
	Cp = C1 x (9.8 x Qp (t) x ta/Eff x 86400) x (G + s(t))			
	where;			
	C1 = cost of energy per kwh = Rp. 2.8,-			
	ta = total annual pumping hour			
	Q = well capacity in m3/day = 432 m3/day			
	eff = efficiency of pumping = 0.75			
	G = Depth of water table = 4 m			
	s(t) = drawdown			
		Annual Cost of Energy		7658.168
	Cost of Operation and Maintenance ;			
	Cost of Operation and maintenace taking 2% of capital cost			
	- Operation (0.2 x 170500)			*34100*
	- Maintenance (0.2 x 170500)			*34100*
		Total 2		75858.168
III	**Total Cost**	~~ACR +~~ TOTAL 2		101432.17

The cost of a well calculated for different well diameter, pump capacity and duration of pumping are presented in the table 4.3.and also are plotted in figures 4.2 through 4.5.

- The variation of total cost with number of aquifers tapped by a multiaquifer well exhibits that a multiaquifer well is always profitable. The total cost decreases very sharply when the well taps both the 1st and the 2rd aquifer. Only tapping the upper aquifer is not economical. The cost reaches minimum when the multiaquifer well taps the third aquifer. From the nature of the graph, it is seen that, the reduction in cost of energy is nearly balanced by the extra cost of excavation. Therefore, there is no much difference between the costs corresponding to a well either tapping two aquifers or tapping three aquifers. In any case it is not necessary to go beyond the third aquifer, for the multiaquifer system considered in the present study.

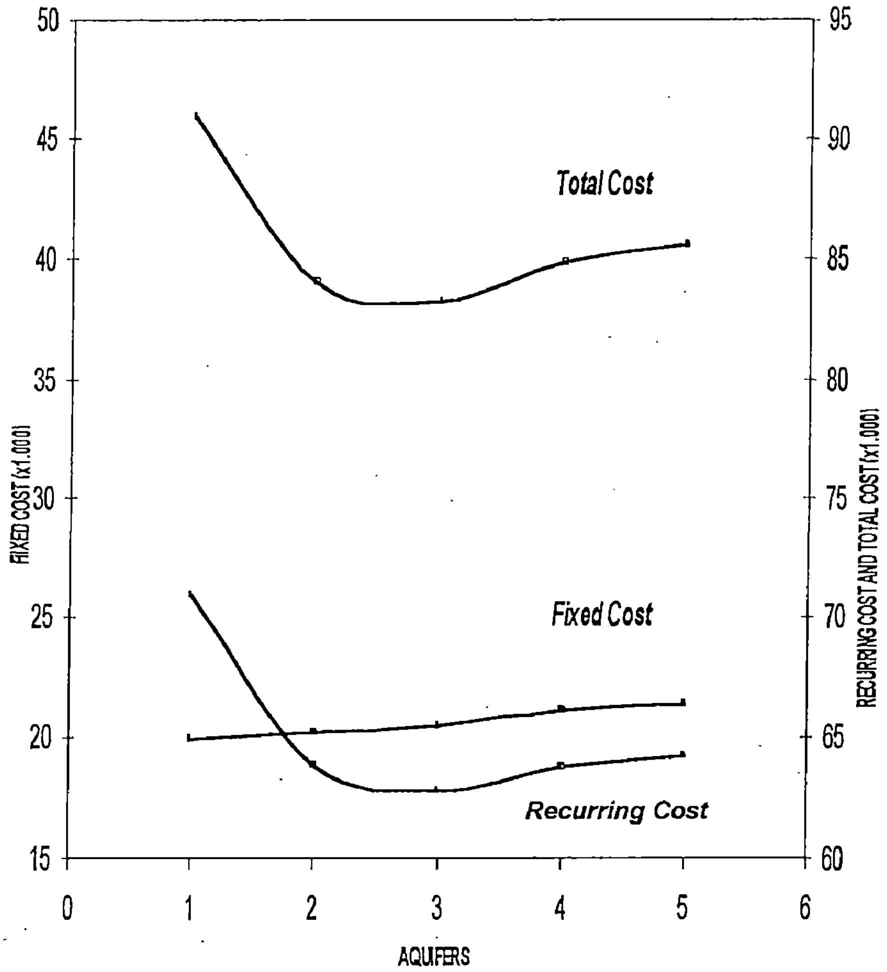

Figure 4.2 Cost Analysis of a Well in a Multiaquifer System
Qp = 432 m3/day, Diameter of Well=0.2 m,
Well operates daily

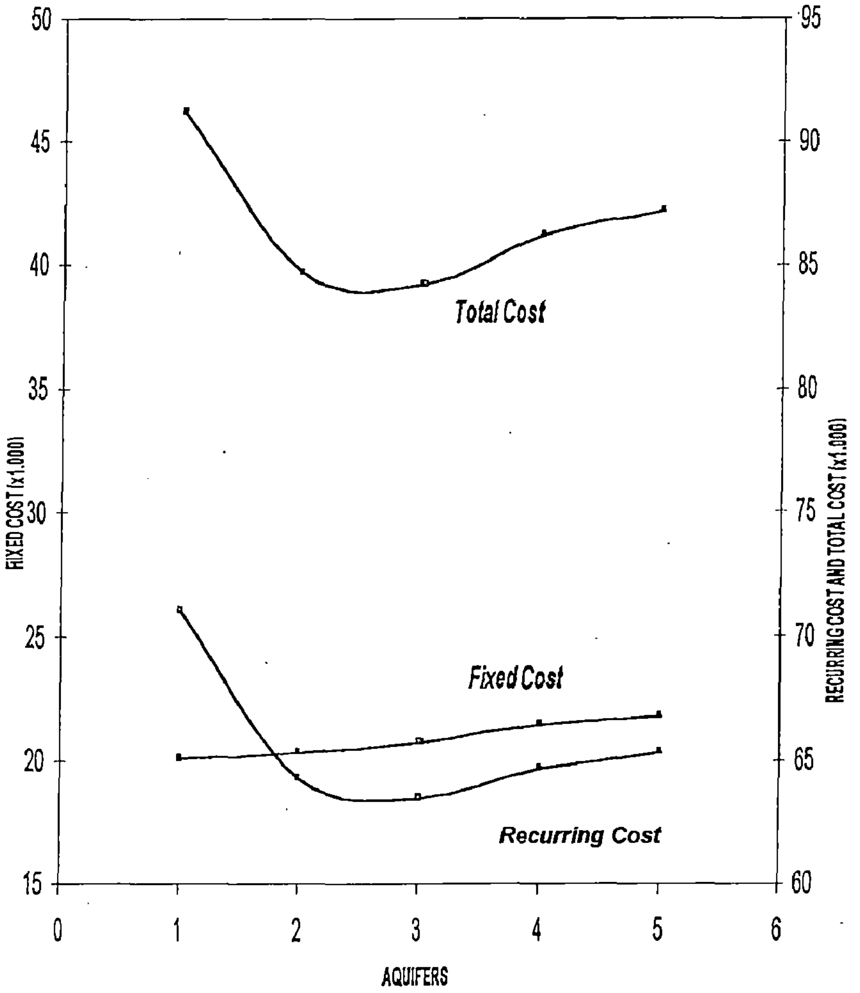

Figure 4.3 Cost Analysis of a Well in a Multiaquifer System
Qp = 432 m3/day, Diameter of Well=0.25 m,
Well operates daily

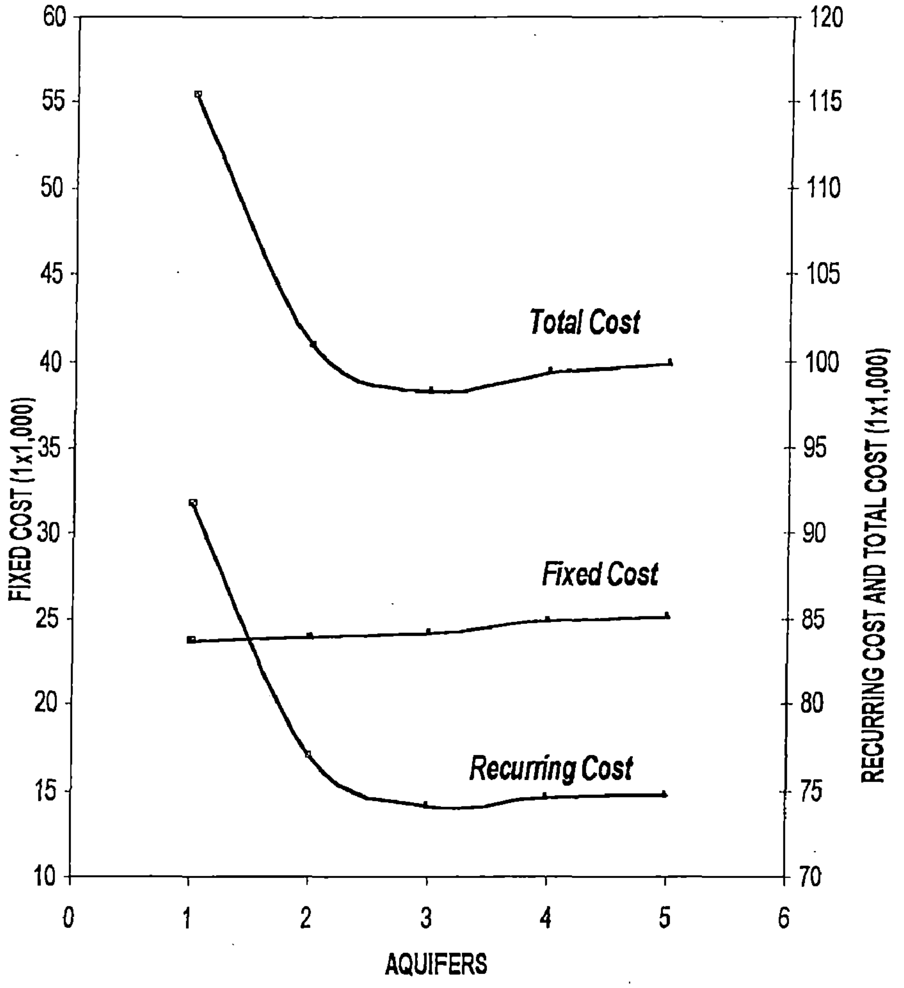

Figure 4.4 Cost Analysis of a Well in a Multiaquifer System
Qp = 864 m3/day, Diameter of Well=0.20 m,
Well operates 0.5 day

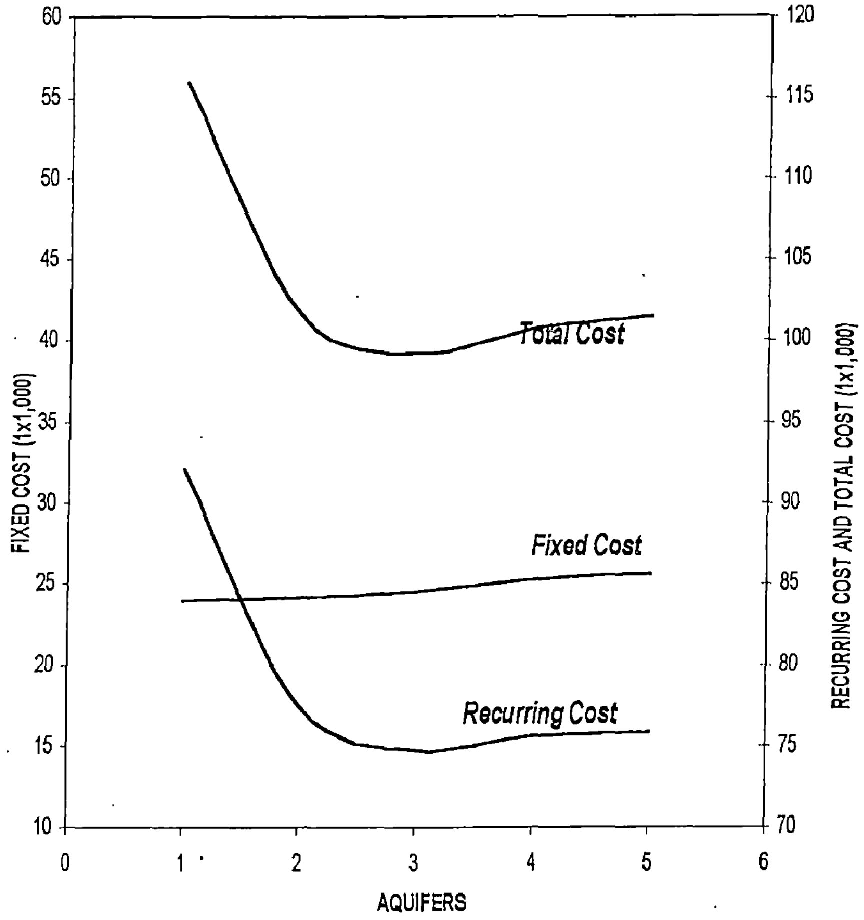

Figure 4.5 Cost Analysis of a Well in a Multiaquifer System
Qp = 864 m3/day, Diameter of Well=0.25 m,
Well operates 0.5 day

- The variation of total cost with numbers of aquifers tapped for different diameter of well and capacity of pump is presented in Fig. 4.6. It is seen that well with a smaller diameter and low capacity is economical. For larger diameter, because of cost of excavation, the cost is higher. The most economical well is that which tapped the uppers three aquifers, pumps continuously and has minimum required diameter.

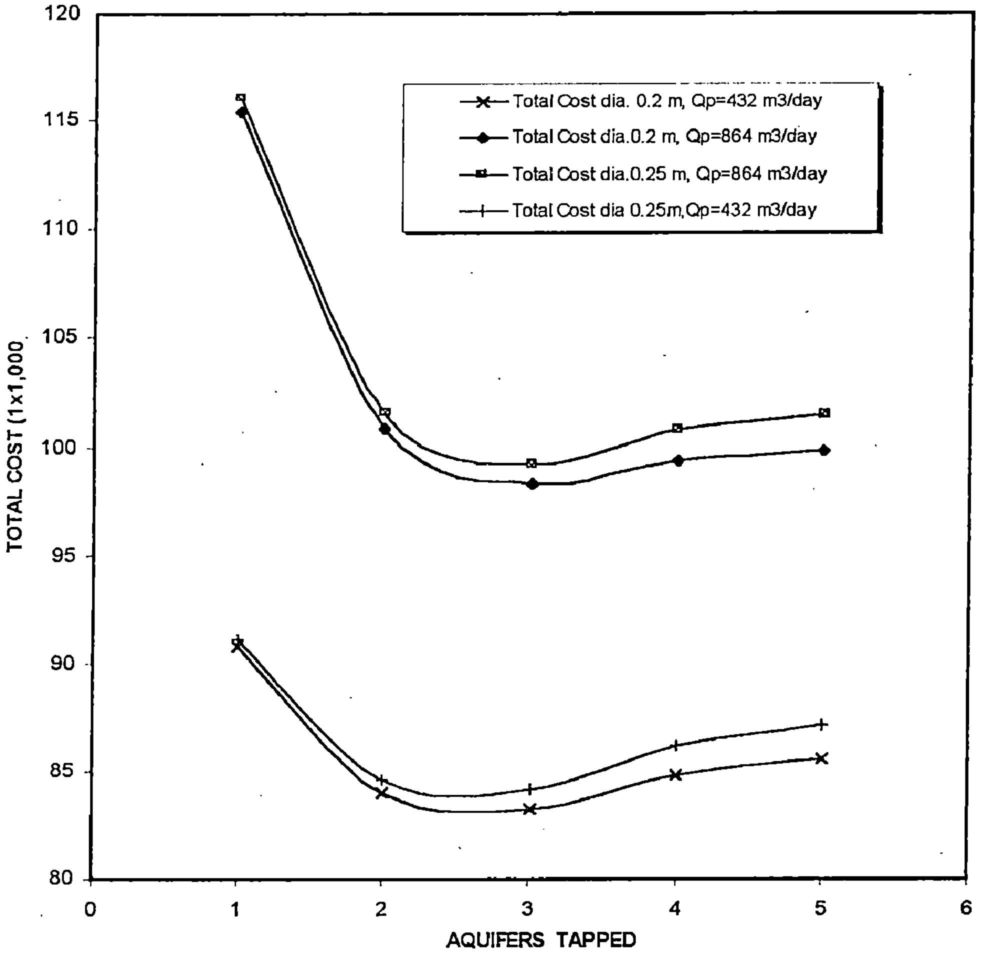

Figure 4.6 Total Cost of a Well For Different Capacity Of Pumps, Diameter of Well and Pumping Operation

- For easy estimate of the cost of a well, a relationship between the depth of aquifer and the cost of a well is found. The relationship between the cost of well and the depth of aquifer in a five aquifers system is obtained with the following equation:

◆ For Qp = 432m3/day,
well diameter = 0.2 m, the equation is

$$U = -0.0052d^3 + 0.7009d^2 - 29.882d + 931.05$$

where;
U = Cost (Rs/1000 m3) of well
d = Depth of aquifer (m)

◆ For Qp = 864 m3/day,
well diameter = 0.2 m, the equation is

$$U = -0.0103d^3 + 1.3961d^2 - 60.441d + 1455.8$$

- The relationships between cost of a well and depth of aquifer are presented in the figures 4.7 and 4.8 for Qp = 432 m3/day, well diameter=0.2 m and Qp = 864 m3/day, and well diameter=0.2 m, respectively.

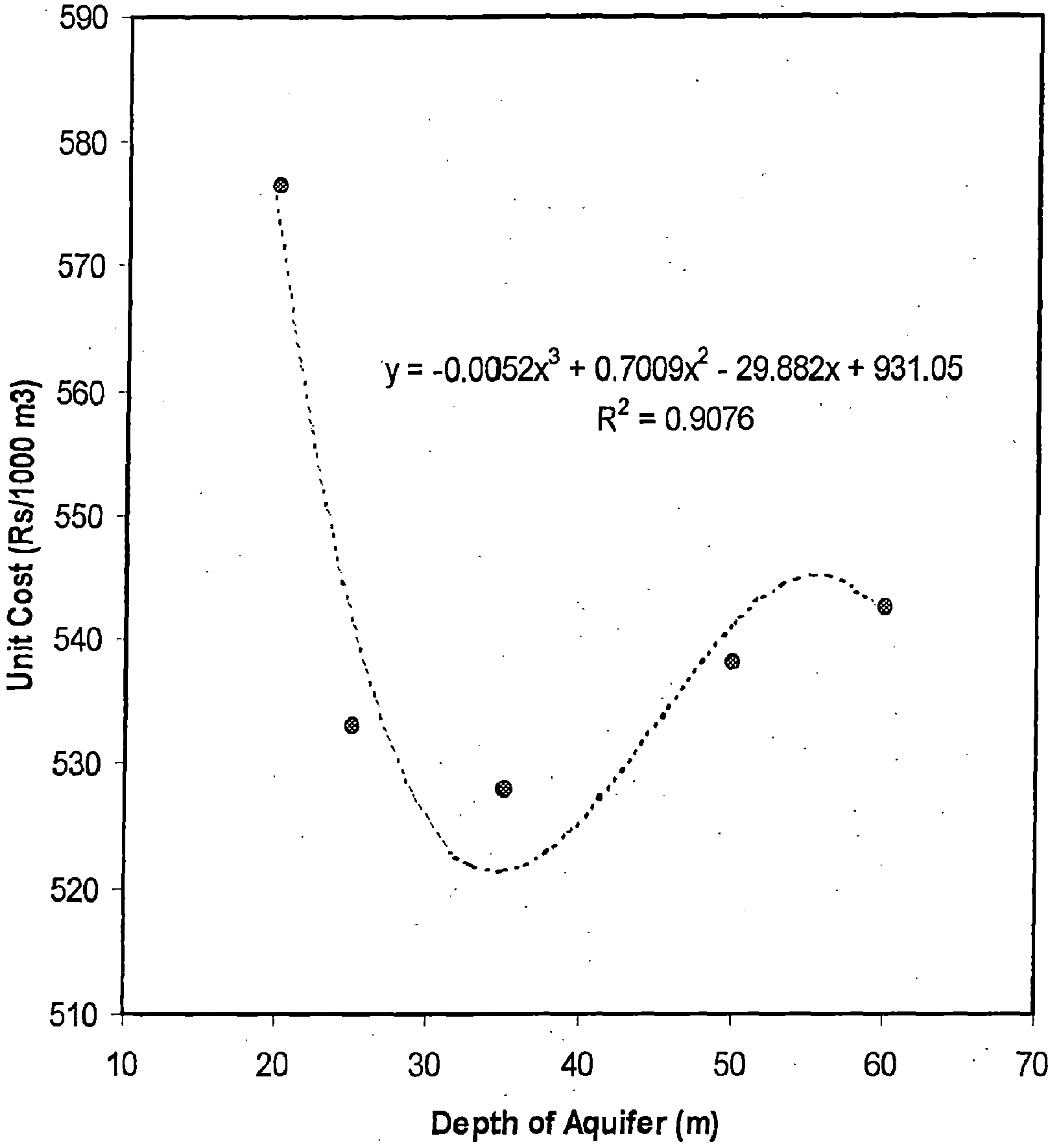

Figure 4.7 Relationship Between Cost of a Well and Depth of Aquifer for Qp=432 m3/day, and well Dia. 0.2 m

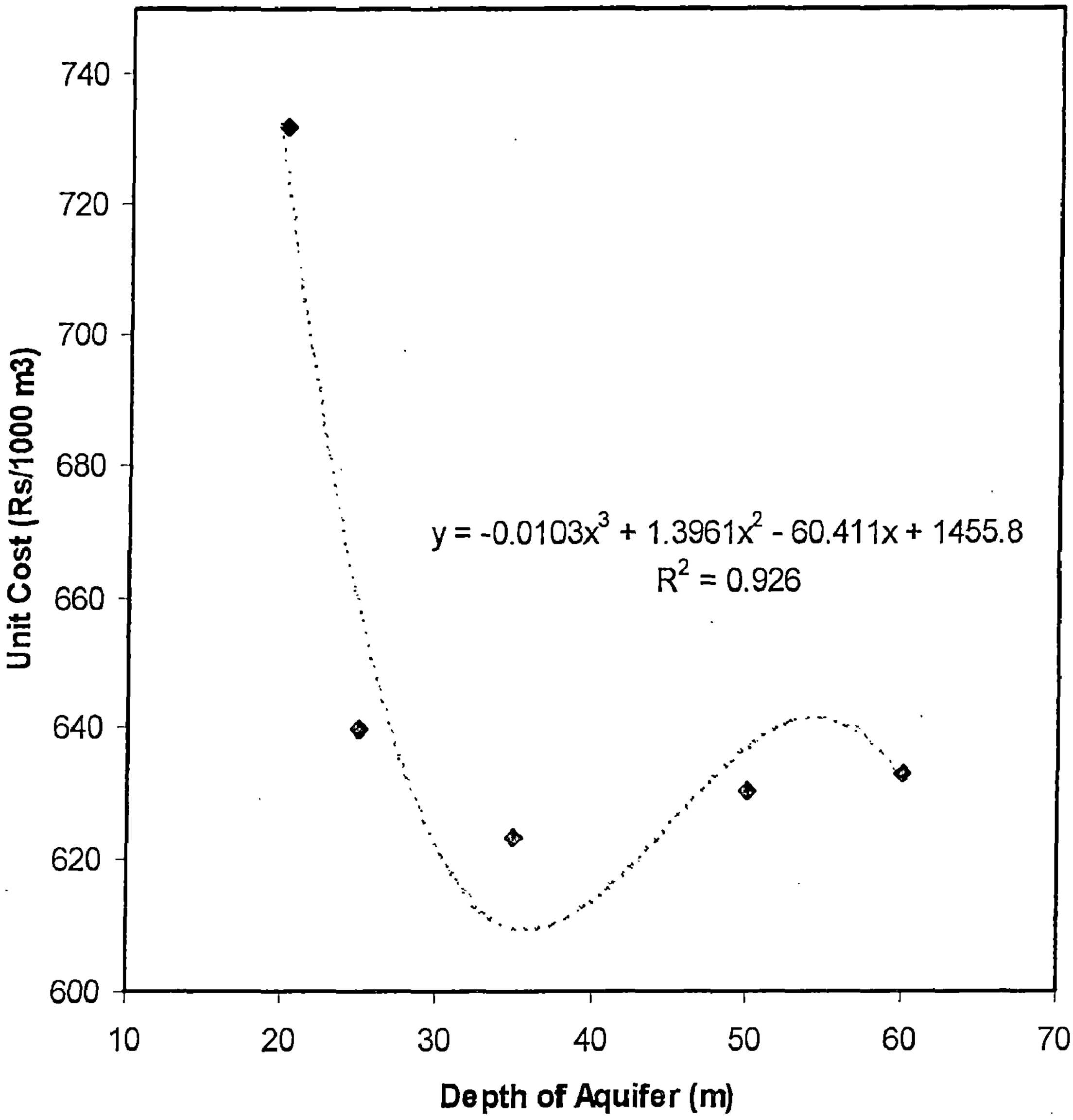

Figure 4.8 Relationship Between Cost of a Well and Depth of Aquifer for Qp=864 m3/day, and well Dia. 0.2 m

- From Figs. 4.7 and 4.8, it is seen that the aquifer should be tapped up to a depth of 35 m from ground surface.

CHAPTER V

CONCLUSIONS

Based on the study, the following conclusions are drawn:

- The specific capacity of a well increases with transmissivity of the aquifer.
- Well storage counter acts the well deterioration.
- Well loss is vulnerable to high pumping rate and a multiaquifer well should be preferred to reduce well loss.
- In a multi aquifer well, ~~these~~ there is scope to find a multi aquifer well which would provide water at considerable minimum cost in comparison to a well tapping the top aquifer only.
- Tapping very deeper aquifer is not economical because of higher cost of excavation.

The methodology based on discrete Kernel approach is very useful to account for variable pumping rate and analysing flow to a multi aquifer system. The discrete Kernel approach is also very useful for analysing unsteady flow to a multi aquifer well accounting well deterioration.

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APPENDIXES

- ☐ APPENDIX-A
PROGRAM OF SPECIFIC CAPACITY

- ☐ APPENDIX-B
PROGRAM OF SPECIFIC CAPACITY
FOR WELL LOSS UNDER CONSIDERATION

APPENDIX - A

PROGRAM OF SPECIFIC CAPACITY

FOR SINGLE AQUIFER

```
      DIMENSION TEISF1(365),THISK1(365),A(4,4),UU(365),QP(365),
     1 QA1(365),DRAWHP(365),DRAWA1(365),QW(365),SPCAPT(365),
     1 ECOST(365),SUMEC(365)
      OPEN (UNIT=1,FILE='Sam61.DAT',STATUS='OLD')
      OPEN (UNIT=2,FILE='Sam91.OUT',STATUS='NEW')
      READ(1,*)RW,RC,TRANS1,STOR1,PRATE
      PAI=3.14159265
      G=4.
      C=2.8
      DO 100 I=1,365
         QP(I)=PRATE
 100  CONTINUE

C    GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

      DO 200 NTIME=1,365
         TIME=NTIME
         U=RW**2*STOR1/(4.*TIME*TRANS1)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF1(NTIME)=EXFN

 200  CONTINUE
      THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
      DO 250 INDEX=2,365
      THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
 250  CONTINUE
      WRITE(2,251)
 251  FORMAT(2X,'   THEIS  FUNCTION   AND   DISCRETE KERNEL')
      WRITE(2,252)
 252  FORMAT(2X,'=====================================================')
      WRITE(2,253)
 253  FORMAT(2X,' THEIS FUNCTION  ',2X,' DISCRETE KERNEL')
      WRITE(2,254)
 254  FORMAT(2X,'  N  ',' TEISF1  ',' THISK1 ')
      DO 256 N=1,365
 256  WRITE(2,255)N,TEISF1(N),THISK1(N)
 255  FORMAT(I5,2E10.3)
```

```
C     COMPUTATION OF QUANTITY OF FLOW AND SPECIFIC CAPACITY OF WELL
      IN MULTIAQUIFER SYSTEM WITH MATRIX 2X2

C     MATRIX
      A(1,1)=THISK1(1)
      A(1,2)=-1./(PAI*RC*RC)
      A(2,1)=1.
      A(2,2)=1.
      M=2
      CALL MATIN(A,M)
      QA1(1)=A(1,1)*0.+A(1,2)*QP(1)
      QW(1)=A(2,1)*0.+A(2,2)*QP(1)
      DO 300 N=2,365
      SUM1=0.
      SUM2=0.
      DO 400 NGAMA=1,(N-1)
      SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
      SUM2=SUM2+QW(NGAMA)/(PAI*RC*RC)
  400 CONTINUE
      QA1(N)=A(1,1)*(SUM2-SUM1)+A(1,2)*QP(N)
      QW(N)=A(2,1)*(SUM2-SUM1)+A(2,2)*QP(N)
  300 CONTINUE
      DO 301 N=1,365
      SUMP=0
      SUMA1=0
      DO 302 NGAMA=1,N
      SUMP=SUMP+QW(NGAMA)/(PAI*RC*RC)
      SUMA1=SUMA1+QA1(NGAMA)*THISK1(N-NGAMA+1)
  302 CONTINUE
      DRAWHP(N)=SUMP
      DRAWA1(N)=SUMA1
      SPCAPT(N)=QP(N)/SUMA1
  301 CONTINUE
C     CALCULATION ENERGY CONSUMED
      DO 303 N=1,365
      ECOST(N)=(C*9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
      UMEC=0
      DO 304 NGAMA=1,N
      UMEC=UMEC+ECOST(NGAMA)
  304 CONTINUE
      SUMEC(N)=UMEC
  303 CONTINUE
      WRITE(2,306)
  306 FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'SPCAPT')
  307 FORMAT(I5,3F10.3)
      DO 308 N=1,365
  308 WRITE(2,307)N,DRAWHP(N),DRAWA1(N),SPCAPT(N)
      WRITE(2,310)
  310 FORMAT(2X,'--------------------------------------------------')
      WRITE(2,401)
  401 FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
      WRITE(2,402)
  402 FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
      WRITE(2,403)
  403 FORMAT(2X,'--------------------------------------------------')
      WRITE(2,404)
  404 FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,'QW ',5X,'ECOST',
```

```
      1  14X,'SUMEC')
   406   FORMAT(I5,4F10.3,F13.3)
         DO 410 N=1,365
   410   WRITE(2,406)N,QP(N),QA1(N),QW(N),ECOST(N),SUMEC(N)
         WRITE(2,405)
   405   FORMAT(2X,'-----------------------------------------------')
         WRITE(2,411)
   411   FORMAT(2X,'-----------------------------------------------')
         STOP
         END

C        SUBROUTINE EXI
         SUBROUTINE EXI(U,EXFN)
         X=U
             IF(X-1.0)10,10,20
10       EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1       +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
         RETURN
20           CONTINUE
             IF(X- 80.)50,40,40
50           CONTINUE
         EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1   +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
     2   +3.9584969))/(X*EXP(X))
             RETURN
40       EXFN=0.
         RETURN
             END

      SUBROUTINE MATIN (AAA,MMM)
      DIMENSION AAA(4,4),B(4),C(4)
        NN=MMM-1
        AAA(1,1)=1./AAA(1,1)
        DO 8 M=1,NN
        K=M+1
        DO 3 I=1,M
        B(I)=0.0
        DO 3 J=1,M
3       B(I)=B(I)+AAA(I,J)*AAA(J,K)
        D=0.0
        DO 4 I=1,M
4       D=D+AAA(K,I)*B(I)
        D=-D+AAA(K,K)
        AAA(K,K)=1./D
        DO 5 I=1,M
5       AAA(I,K)=-B(I)*AAA(K,K)
        DO 6 J=1,M
        C(J)=0.0
        DO 6 I=1,M
6       C(J)=C(J)+AAA(K,I)*AAA(I,J)
      DO 7 J=1,M
7       AAA(K,J)=-C(J)*AAA(K,K)
        DO 8 I=1,M
        DO 8 J=1,M
8       AAA(I,J)=AAA(I,J)-B(I)*AAA(K,J)
        RETURN
        END
```

MULTIAQUIFER TAPPING TWO AQUIFER

```
       DIMENSION TEISF1(365),TEISF2(365),THISK1(365),
     1 THISK2(365)
       DIMENSION A(4,4),UU(365),QP(365),QA1(365),DRAWHP(365),
     1 DRAWA1(365),DRAWA2(365),QA2(365),QW(365),SPCAPT(365),
     1 ECOST(365),SUMEC(365)
       OPEN (UNIT=1,FILE='Sam62.DAT',STATUS='OLD')
       OPEN (UNIT=2,FILE='Sam92.OUT',STATUS='NEW')
       READ(1,*)RW,RC,TRANS1,TRANS2,STOR1,STOR2,PRATE
       PAI=3.14159265
       G=4.
       C=2.8
       DO 100 I=1,365
          QP(I)=PRATE
  100  CONTINUE

C    GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

       DO 200 NTIME=1,365
          TIME=NTIME
          U=RW**2*STOR1/(4.*TIME*TRANS1)
          UU(NTIME)=U
          CALL EXI(U,EXFN)
          TEISF1(NTIME)=EXFN
          U=RW**2*STOR2/(4.*TIME*TRANS2)
          UU(NTIME)=U
          CALL EXI(U,EXFN)
          TEISF2(NTIME)=EXFN

  200  CONTINUE
       THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
       THISK2(1)=TEISF2(1)/(4.*PAI*TRANS2)
       DO 250 INDEX=2,365
       THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
       THISK2(INDEX)=(TEISF2(INDEX)-TEISF2(INDEX-1))/(4.*PAI*TRANS2)
  250  CONTINUE
       WRITE(2,251)
  251  FORMAT(2X,'    THEIS  FUNCTION   AND   DISCRETE KERNEL')
       WRITE(2,252)
  252  FORMAT(2X,'=========================================')
       WRITE(2,253)
  253  FORMAT(2X,'   THEIS FUNCTION    ',3X,' DISCRETE KERNEL')
       WRITE(2,254)
  254  FORMAT(2X,'  N  ','  TEISF1  ','  TEISF2  ', ' THISK1  ',
     1 ' THISK2  ')
       DO 256 N=1,365
  256  WRITE(2,255)N,TEISF1(N),TEISF2(N),THISK1(N),THISK2(N)
  255  FORMAT(I5,4E10.3)


C      COMPUTATION OF QUANTITY OF FLOW AND SPECIFIC CAPACITY OF WELL
C      IN  MULTIAQUIFER SYSTEM WITH MATRIX 3X3

C      MATRIX
       A(1,1)=THISK1(1)
```

```
      A(1,2)=-THISK2(1)
      A(1,3)=0.
      A(2,1)=THISK1(1)
      A(2,2)=0.
      A(2,3)=-1./(PAI*RC*RC)
      A(3,1)=1.
      A(3,2)=1.
      A(3,3)=1.
      M=3
      CALL MATIN(A,M)
      QA1(1)=A(1,1)*0.+A(1,2)*0.+A(1,3)*QP(1)
      QA2(1)=A(2,1)*0.+A(2,2)*0.+A(2,3)*QP(1)
      QW(1)=A(3,1)*0.+A(3,2)*0.+A(3,3)*QP(1)
      DO 300 N=2,365
      SUM1=0
      SUM2=0
      SUM3=0
      DO 400 NGAMA=1,(N-1)
      SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
      SUM2=SUM2+QA2(NGAMA)*THISK2(N-NGAMA+1)
      SUM3=SUM3+QW(NGAMA)/(PAI*RC*RC)
400   CONTINUE
      QA1(N)=A(1,1)*(SUM2-SUM1)+A(1,2)*(SUM3-SUM1)+A(1,3)*QP(N)
      QA2(N)=A(2,1)*(SUM2-SUM1)+A(2,2)*(SUM3-SUM1)+A(2,3)*QP(N)
      QW(N)=A(3,1)*(SUM2-SUM1)+A(3,2)*(SUM3-SUM1)+A(3,3)*QP(N)
300   CONTINUE
      DO 301 N=1,365
      SUMP=0
      SUMA1=0
      SUMA2=0
      DO 302 NGAMA=1,N
      SUMP=SUMP+QW(NGAMA)/(PAI*RC*RC)
      SUMA1=SUMA1+QA1(NGAMA)*THISK1(N-NGAMA+1)
      SUMA2=SUMA2+QA2(NGAMA)*THISK2(N-NGAMA+1)
302   CONTINUE
      DRAWHP(N)=SUMP
      DRAWA1(N)=SUMA1
      DRAWA2(N)=SUMA2
      SPCAPT(N)=QP(N)/SUMA1
301   CONTINUE
C     CALCULATION ENERGY CONSUMED
      DO 303 N=1,365
      ECOST(N)=(C*9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
      UMEC=0
      DO 304 NGAMA=1,N
      UMEC=UMEC+ECOST(NGAMA)
304   CONTINUE
      SUMEC(N)=UMEC
303   CONTINUE
      WRITE(2,306)
306   FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'DRAWA2',
     1 5X,'SPCAPT')
307   FORMAT(I5,3F10.3,F12.3)
      DO 308 N=1,365
308   WRITE(2,307)N,DRAWHP(N),DRAWA1(N),DRAWA2(N),SPCAPT(N)
      WRITE(2,310)
310   FORMAT(2X,'-----------------------------------------------')
```

```
      WRITE(2,401)
401   FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
      WRITE(2,402)
402   FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
      WRITE(2,403)
403   FORMAT(2X,'---------------------------------------------------')
      WRITE(2,404)
404   FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,' QA2 ',5X,'QW ',
     1 7X,'ECOST',14X,'SUMEC')
406   FORMAT(I5,5F10.3,F14.3)
      DO 410 N=1,365
410   WRITE(2,406)N,QP(N),QA1(N),QA2(N),QW(N),ECOST(N),SUMEC(N)
      WRITE(2,405)
405   FORMAT(2X,'-----------------------------------------------')
      WRITE(2,411)
411   FORMAT(2X,'-----------------------------------------------')
      STOP
    END

C      SUBROUTINE EXI
       SUBROUTINE EXI(U,EXFN)
       X=U
           IF(X-1.0)10,10,20
10     EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1     +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
       RETURN
20         CONTINUE
           IF(X- 80.)50,40,40
50         CONTINUE
       EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1 +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
     2 +3.9584969))/(X*EXP(X))
           RETURN
40     EXFN=0.
       RETURN
           END

     SUBROUTINE MATIN (AAA,MMM)
     DIMENSION AAA(4,4),B(4),C(4)
       NN=MMM-1
       AAA(1,1)=1./AAA(1,1)
       DO 8 M=1,NN
       K=M+1
       DO 3 I=1,M
       B(I)=0.0
       DO 3 J=1,M
3      B(I)=B(I)+AAA(I,J)*AAA(J,K)
       D=0.0
       DO 4 I=1,M
4      D=D+AAA(K,I)*B(I)
       D=-D+AAA(K,K)
       AAA(K,K)=1./D
       DO 5 I=1,M
5      AAA(I,K)=-B(I)*AAA(K,K)
       DO 6 J=1,M
       C(J)=0.0
       DO 6 I=1,M
```

```
6        C(J)=C(J)+AAA(K,I)*AAA(I,J)
         DO 7 J=1,M
7        AAA(K,J)=-C(J)*AAA(K,K)
         DO 8 I=1,M
         DO 8 J=1,M
8        AAA(I,J)=AAA(I,J)-B(I)*AAA(K,J)
         RETURN
         END
```

MULTIAQUIFER TAPPING THREE AQUIFER

```
         DIMENSION TEISF1(365),TEISF2(365),TEISF3(365),THISK1(365),
     1   THISK2(365),THISK3(365)
         DIMENSION A(4,4),UU(365),QP(365),QA1(365),DRAWHP(365),
     1   DRAWA1(365),DRAWA2(365),DRAWA3(365),QA2(365),QA3(365),
     1   QW(365),SPCAPT(365),ECOST(365),SUMEC(365)
         OPEN (UNIT=1,FILE='SAM63.DAT',STATUS='OLD')
         OPEN (UNIT=2,FILE='SAM93.OUT',STATUS='NEW')
         READ(1,*)RW,RC,TRANS1,TRANS2,TRANS3,STOR1,STOR2,STOR3,PRATE,
         PAI=3.14159265
         G=4.
         C=2.8
         DO 100 I=1,365
            QP(I)=PRATE
  100    CONTINUE

C     GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

         DO 200 NTIME=1,365
            TIME=NTIME
            U=RW**2*STOR1/(4.*TIME*TRANS1)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF1(NTIME)=EXFN
            U=RW**2*STOR2/(4.*TIME*TRANS2)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF2(NTIME)=EXFN
            U=RW**2*STOR3/(4.*TIME*TRANS3)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF3(NTIME)=EXFN

  200    CONTINUE
         THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
         THISK2(1)=TEISF2(1)/(4.*PAI*TRANS2)
         THISK3(1)=TEISF3(1)/(4.*PAI*TRANS3)
         DO 250 INDEX=2,365
         THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
         THISK2(INDEX)=(TEISF2(INDEX)-TEISF2(INDEX-1))/(4.*PAI*TRANS2)
         THISK3(INDEX)=(TEISF3(INDEX)-TEISF3(INDEX-1))/(4.*PAI*TRANS3)
  250    CONTINUE
         WRITE(2,251)
  251    FORMAT(2X,'        THEIS      FUNCTION       AND       DISCRETE
     1   KERNEL')
```

```
          WRITE(2,252)
    252
 FORMAT(2X,'=================================================
      1   ==============')
          WRITE(2,253)
   253    FORMAT(2X,'      THEIS FUNCTION             '5X,'     DISCRETE
      1   KERNEL')
          WRITE(2,254)
   254    FORMAT(2X,'  N  ','  TEISF1  ','  TEISF2  ','  TEISF3'  , '
      1   THISK1  ',' THISK2  ',' THISK3 ')
          DO 256 N=1,365
   256    WRITE(2,255)N,TEISF1(N),TEISF2(N),TEISF3(N),THISK1(N),
      1   THISK2(N),THISK3(N)
   255    FORMAT(I5,6E10.3)


 C        COMPUTATION OF QUANTITY FLOW AND SPECIFIC CAPACITY OF WELL IN
 C        MULTIAQUIFER SYSTEM WITH MATRIX 4X4

 C        MATRIX
          A(1,1)=THISK1(1)
          A(1,2)=-THISK2(1)
          A(1,3)=0.
          A(1,4)=0.
          A(2,1)=THISK1(1)
          A(2,2)=0.
          A(2,3)=-THISK3(1)
          A(2,4)=0.
          A(3,1)=THISK1(1)
          A(3,2)=0.
          A(3,3)=0.
          A(3,4)=-1./(PAI*RC*RC)
          A(4,1)=1.
          A(4,2)=1.
          A(4,3)=1.
          A(4,4)=1.
          M=4
          CALL MATIN(A,M)
          QA1(1)=A(1,1)*0.+A(1,2)*0.+A(1,3)*0.+A(1,4)*QP(1)
          QA2(1)=A(2,1)*0.+A(2,2)*0.+A(2,3)*0.+A(2,4)*QP(1)
          QA3(1)=A(3,1)*0.+A(3,2)*0.+A(3,3)*0.+A(3,4)*QP(1)
          QW(1)=A(4,1)*0.+A(4,2)*0.+A(4,3)*0.+A(4,4)*QP(1)
          DO 300 N=2,365
          SUM1=0
          SUM2=0
          SUM3=0
          SUM4=0
          DO 400 NGAMA=1,(N-1)
          SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
          SUM2=SUM2+QA2(NGAMA)*THISK2(N-NGAMA+1)
          SUM3=SUM3+QA3(NGAMA)*THISK3(N-NGAMA+1)
          SUM4=SUM4+QW(NGAMA)/(PAI*RC*RC)
   400    CONTINUE
          QA1(N)=A(1,1)*(SUM2-SUM1)+A(1,2)*(SUM3-SUM1)+A(1,3)*(SUM4-SUM1)
      1   +A(1,4)*QP(N)
          QA2(N)=A(2,1)*(SUM2-SUM1)+A(2,2)*(SUM3-SUM1)+A(2,3)*(SUM4-SUM1)
      1   +A(2,4)*QP(N)
```

```
      QA3(N)=A(3,1)*(SUM2-SUM1)+A(3,2)*(SUM3-SUM1)+A(3,3)*(SUM4-SUM1)
     1 +A(3,4)*QP(N)
      QW(N)=A(4,1)*(SUM2-SUM1)+A(4,2)*(SUM3-SUM1)
     1 +A(4,3)*(SUM4-SUM1)+A(4,4)*QP(N)
  300 CONTINUE
      DO 301 N=1,365
      SUMP=0
      SUMA1=0
      SUMA2=0
      SUMA3=0
      DO 302 NGAMA=1,N
      SUMP=SUMP+QW(NGAMA)/(PAI*RC*RC)
      SUMA1=SUMA1+QA1(NGAMA)*THISK1(N-NGAMA+1)
      SUMA2=SUMA2+QA2(NGAMA)*THISK2(N-NGAMA+1)
      SUMA3=SUMA3+QA3(NGAMA)*THISK3(N-NGAMA+1)
  302 CONTINUE
      DRAWHP(N)=SUMP
      DRAWA1(N)=SUMA1
      DRAWA2(N)=SUMA2
      DRAWA3(N)=SUMA3
      SPCAPT(N)=QP(N)/SUMA1
  301 CONTINUE
C     CALCULATION ENERGY CONSUMED
      DO 303 N=1,365
      ECOST(N)=(C*9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
      UMEC=0
      DO 304 NGAMA=1,N
      UMEC=UMEC+ECOST(NGAMA)
  304 CONTINUE
      SUMEC(N)=UMEC
  303 CONTINUE
      WRITE(2,306)
  306 FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'DRAWA2',5X,'DRAWA3',
     1 5X,'SPCAPT')
  307 FORMAT(I5,5F10.3)
      DO 308 N=1,365
  308 WRITE(2,307)N,DRAWHP(N),DRAWA1(N),DRAWA2(N),DRAWA3(N),SPCAPT(N)
      WRITE(2,310)
  310 FORMAT(2X,'---------------------------------------------------------')
      WRITE(2,401)
  401 FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
      WRITE(2,402)
  402 FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
      WRITE(2,403)
  403 FORMAT(2X,'---------------------------------------------------------')
      WRITE(2,404)
  404 FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,' QA2 ',5X,' QA3 ',5X,'
     1 QW ',7X,'ECOST',12X,'SUMEC')
  406 FORMAT(I5,6F10.3,F14.3)
      DO 410 N=1,365
  410 WRITE(2,406)N,QP(N),QA1(N),QA2(N),QA3(N),QW(N),ECOST(N),
     1 SUMEC(N)
      WRITE(2,405)
  405 FORMAT(2X,'----------------------------------------------------
--

     1 ----------')
      WRITE(2,411)
```

```
   411    FORMAT(2X,'-----------------------------------------------------
--
       1  ----------')
          STOP
        END

 C        SUBROUTINE EXI
          SUBROUTINE EXI(U,EXFN)
          X=U
              IF(X-1.0)10,10,20
 10       EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
      1       +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
          RETURN
 20           CONTINUE
              IF(X- 80.)50,40,40
 50           CONTINUE
          EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
      1   +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
      2   +3.9584969))/(X*EXP(X))
              RETURN
 40       EXFN=0.
          RETURN
              END

        SUBROUTINE MATIN (AAA,MMM)
        DIMENSION AAA(4,4),B(4),C(4)
          NN=MMM-1
          AAA(1,1)=1./AAA(1,1)
          DO 8 M=1,NN
          K=M+1
          DO 3 I=1,M
          B(I)=0.0
          DO 3 J=1,M
 3        B(I)=B(I)+AAA(I,J)*AAA(J,K)
          D=0.0
          DO 4 I=1,M
 4        D=D+AAA(K,I)*B(I)
          D=-D+AAA(K,K)
          AAA(K,K)=1./D
          DO 5 I=1,M
 5        AAA(I,K)=-B(I)*AAA(K,K)
          DO 6 J=1,M
          C(J)=0.0
          DO 6 I=1,M
 6        C(J)=C(J)+AAA(K,I)*AAA(I,J)
        DO 7 J=1,M
 7        AAA(K,J)=-C(J)*AAA(K,K)
          DO 8 I=1,M
          DO 8 J=1,M
 8        AAA(I,J)=AAA(I,J)-B(I)*AAA(K,J)
          RETURN
          END
```

MULTIAQUIFER TAPPING FOUR AQUIFER

```
      DIMENSION TEISF1(365),TEISF2(365),TEISF3(365),TEISF4(365),
     1   THISK1(365),THISK2(365),THISK3(365),THISK4(365),
     2   A(5,5),UU(365),QP(365),QA1(365),DRAWHP(365),
     3   DRAWA1(365),DRAWA2(365),DRAWA3(365),DRAWA4(365),QA2(365),
     4   QA3(365),QA4(365),QW(365),SPCAPT(365),ECOST(365),SUMEC(365)
         OPEN (UNIT=1,FILE='SAM64.DAT',STATUS='OLD')
         OPEN (UNIT=2,FILE='SAM94.OUT',STATUS='NEW')
         READ(1,*)RW,RC,TRANS1,TRANS2,TRANS3,TRANS4,STOR1,STOR2,STOR3,
     1   STOR4,PRATE,
      PAI=3.14159265
         G=4.
         C=2.8
         DO 100 I=1,365
            QP(I)=PRATE
 100     CONTINUE

C     GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

         DO 200 NTIME=1,365
            TIME=NTIME
            U=RW**2*STOR1/(4.*TIME*TRANS1)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF1(NTIME)=EXFN
            U=RW**2*STOR2/(4.*TIME*TRANS2)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF2(NTIME)=EXFN
            U=RW**2*STOR3/(4.*TIME*TRANS3)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF3(NTIME)=EXFN
            U=RW**2*STOR4/(4.*TIME*TRANS4)
            UU(NTIME)=U
            CALL EXI(U,EXFN)
            TEISF4(NTIME)=EXFN

 200     CONTINUE
         THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
         THISK2(1)=TEISF2(1)/(4.*PAI*TRANS2)
         THISK3(1)=TEISF3(1)/(4.*PAI*TRANS3)
         THISK4(1)=TEISF4(1)/(4.*PAI*TRANS4)
         DO 250 INDEX=2,365
         THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
         THISK2(INDEX)=(TEISF2(INDEX)-TEISF2(INDEX-1))/(4.*PAI*TRANS2)
         THISK3(INDEX)=(TEISF3(INDEX)-TEISF3(INDEX-1))/(4.*PAI*TRANS3)
         THISK4(INDEX)=(TEISF4(INDEX)-TEISF4(INDEX-1))/(4.*PAI*TRANS4)
 250     CONTINUE
         WRITE(2,251)
 251     FORMAT(2X,'        THEIS     FUNCTION      AND      DISCRETE
     1   KERNEL')
         WRITE(2,252)
 252
FORMAT(2X,'==============================================
```

```
    1   ==============')
        WRITE(2,253)
  253   FORMAT(2X,'       THEIS FUNCTION              '5X,'    DISCRETE
    1   KERNEL')
        WRITE(2,254)
  254   FORMAT(2X,'  N   ','  TEISF1   ','  TEISF2   ','  TEISF3'  , '
    1   TEISF4 ','THISK1   ',' THISK2   ',' THISK3 ',' THISK4   ')
        DO 256 N=1,365
  256   WRITE(2,255)N,TEISF1(N),TEISF2(N),TEISF3(N),TEISF4(N),
    1   THISK1(N),THISK2(N),THISK3(N),THISK4(N)
  255   FORMAT(I5,8E10.3)


C       COMPUTATION OF QUANTITY OF FLOW AND SPECIFIC CAPACITY OF WELL
C       IN MULTIAQUIFER SYSTEM WITH MATRIX 4X4

C       MATRIX
        A(1,1)=THISK1(1)
        A(1,2)=-THISK2(1)
        A(1,3)=0.
        A(1,4)=0.
        A(1,5)=0.
        A(2,1)=THISK1(1)
        A(2,2)=0.
        A(2,3)=-THISK3(1)
        A(2,4)=0.
        A(2,5)=0.
        A(3,1)=THISK1(1)
        A(3,2)=0.
        A(3,3)=0.
        A(3,4)=-THISK4(1)
        A(3,5)=0.
        A(4,1)=THISK1(1)
        A(4,2)=0.
        A(4,3)=0.
        A(4,4)=0.
        A(4,5)=-1./(PAI*RC*RC)
        A(5,1)=1.
        A(5,2)=1.
        A(5,3)=1.
        A(5,4)=1.
        A(5,5)=1.
        M=5
        CALL MATIN(A,M)
        QA1(1)=A(1,1)*0+A(1,2)*0+A(1,3)*0+A(1,4)*0+A(1,5)*QP(1)
        QA2(1)=A(2,1)*0+A(2,2)*0+A(2,3)*0+A(2,4)*0+A(2,5)*QP(1)
        QA3(1)=A(3,1)*0+A(3,2)*0+A(3,3)*0+A(3,4)*0+A(3,5)*QP(1)
        QA4(1)=A(4,1)*0+A(4,2)*0+A(4,3)*0+A(4,4)*0+A(4,5)*QP(1)
        QW(1)=A(5,1)*0+A(5,2)*0+A(5,3)*0+A(5,4)*0+A(5,5)*QP(1)
        DO 300 N=2,365
        SUM1=0
        SUM2=0
        SUM3=0
        SUM4=0
        SUM5=0
        DO 400 NGAMA=1,(N-1)
        SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
```

```
        SUM2=SUM2+QA2(NGAMA)*THISK2(N-NGAMA+1)
        SUM3=SUM3+QA3(NGAMA)*THISK3(N-NGAMA+1)
        SUM4=SUM4+QA4(NGAMA)*THISK4(N-NGAMA+1)
        SUM5=SUM5+QW(NGAMA)/(PAI*RC*RC)
  400   CONTINUE
        QA1(N)=A(1,1)*(SUM2-SUM1)+A(1,2)*(SUM3-SUM1)+A(1,3)*(SUM4-SUM1)
     1  +A(1,4)*(SUM5-SUM1)+A(1,5)*QP(N)
        QA2(N)=A(2,1)*(SUM2-SUM1)+A(2,2)*(SUM3-SUM1)+A(2,3)*(SUM4-SUM1)
     1  +A(2,4)*(SUM5-SUM1)+A(2,5)*QP(N)
        QA3(N)=A(3,1)*(SUM2-SUM1)+A(3,2)*(SUM3-SUM1)+A(3,3)*(SUM4-SUM1)
     1  +A(3,4)*(SUM5-SUM1)+A(3,5)*QP(N)
        QA4(N)=A(4,1)*(SUM2-SUM1)+A(4,2)*(SUM3-SUM1)+A(4,3)*(SUM4-SUM1)
     1  +A(4,4)*(SUM5-SUM1)+A(4,5)*QP(N)
        QW(N)=A(5,1)*(SUM2-SUM1)+A(5,2)*(SUM3-SUM1)
     1  +A(5,3)*(SUM4-SUM1)+A(5,4)*(SUM5-SUM1)+A(5,5)*QP(N)
  300   CONTINUE
        DO 301 N=1,365
        SUMP=0
        SUMA1=0
        SUMA2=0
        SUMA3=0
        SUMA4=0
        DO 302 NGAMA=1,N
        SUMP=SUMP+QW(NGAMA)/(PAI*RC*RC)
        SUMA1=SUMA1+QA1(NGAMA)*THISK1(N-NGAMA+1)
        SUMA2=SUMA2+QA2(NGAMA)*THISK2(N-NGAMA+1)
        SUMA3=SUMA3+QA3(NGAMA)*THISK3(N-NGAMA+1)
        SUMA4=SUMA4+QA4(NGAMA)*THISK4(N-NGAMA+1)
  302   CONTINUE
        DRAWHP(N)=SUMP
        DRAWA1(N)=SUMA1
        DRAWA2(N)=SUMA2
        DRAWA3(N)=SUMA3
        DRAWA4(N)=SUMA4
        SPCAPT(N)=QP(N)/SUMA1
  301   CONTINUE
C       CALCULATION ENERGY CONSUMED
        DO 303 N=1,365
        ECOST(N)=(C*9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
        UMEC=0
        DO 304 NGAMA=1,N
        UMEC=UMEC+ECOST(NGAMA)
  304   CONTINUE
        SUMEC(N)=UMEC
  303   CONTINUE
        WRITE(2,306)
  306   FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'DRAWA2',5X,'DRAWA3',
     1  5X,'DRAWA4',5X,'SPCAPT')
  307   FORMAT(I5,6F10.3)
        DO 308 N=1,365
  308   WRITE(2,307)N,DRAWHP(N),DRAWA1(N),DRAWA2(N),DRAWA3(N),
     1  DRAWA4(N),SPCAPT(N)
        WRITE(2,310)
  310   FORMAT(2X,'----------------------------------------------')
        WRITE(2,401)
  401   FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
        WRITE(2,402)
```

```
  402   FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
        WRITE(2,403)
  403   FORMAT(2X,'----------------------------------------------------')
        WRITE(2,404)
  404   FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,' QA2 ',5X,' QA3 ',5X,'
     1  QA4 ',5X,'QW ',7X,'ECOST',7X,'SUMEC')
  406   FORMAT(I5,7F10.3,F13.3)
        DO 410 N=1,365
  410   WRITE(2,406)N,QP(N),QA1(N),QA2(N),QA3(N),QA4(N),QW(N),ECOST(N),
     1  SUMEC(N)
        WRITE(2,405)
  405   FORMAT(2X,'-----------------------------------------------------
--
     1  ----------')
        WRITE(2,411)
  411   FORMAT(2X,'-----------------------------------------------------
--
     1  ----------')
        STOP
       END

C       SUBROUTINE EXI
        SUBROUTINE EXI(U,EXFN)
        X=U
            IF(X-1.0)10,10,20
10      EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1      +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
        RETURN
20          CONTINUE
            IF(X- 80.)50,40,40
50          CONTINUE
        EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1  +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
     2  +3.9584969))/(X*EXP(X))
            RETURN
40      EXFN=0.
        RETURN
            END

      SUBROUTINE MATIN (AAA,MMM)
        DIMENSION AAA(5,5),B(5),C(5)
        NN=MMM-1
        AAA(1,1)=1./AAA(1,1)
        DO 8 M=1,NN
        K=M+1
        DO 3 I=1,M
        B(I)=0.0
        DO 3 J=1,M
3       B(I)=B(I)+AAA(I,J)*AAA(J,K)
        D=0.0
        DO 4 I=1,M
4       D=D+AAA(K,I)*B(I)
        D=-D+AAA(K,K)
        AAA(K,K)=1./D
        DO 5 I=1,M
5       AAA(I,K)=-B(I)*AAA(K,K)
        DO 6 J=1,M
```

```
        C(J)=0.0
        DO 6 I=1,M
 6      C(J)=C(J)+AAA(K,I)*AAA(I,J)
      DO 7 J=1,M
 7      AAA(K,J)=-C(J)*AAA(K,K)
        DO 8 I=1,M
        DO 8 J=1,M
 8      AAA(I,J)=AAA(I,J)-B(I)*AAA(K,J)
        RETURN
        END
```

MULTIAQUIFER TAPPING FIVE AQUIFER

```
      DIMENSION TEISF1(365),TEISF2(365),TEISF3(365),TEISF4(365),
     1 TEISF5(365),THISK1(365),THISK2(365),THISK3(365),THISK4(365),
     2 THISK5(365),A(6,6),UU(365),QP(365),DRAWHP(365),DRAWA5(365),
     3 DRAWA1(365),DRAWA2(365),DRAWA3(365),DRAWA4(365),QA1(365),
     4 QA2(365),QA3(365),QA4(365),QA5(365),QW(365),SPCAPT(365),
     5 ECOST(365),SUMEC(365)
      OPEN (UNIT=1,FILE='SAM65.DAT',STATUS='OLD')
      OPEN (UNIT=2,FILE='SAM95.OUT',STATUS='NEW')
      READ(1,*)RW,RC,TRANS1,TRANS2,TRANS3,TRANS4,TRANS5,STOR1,
     1 STOR2,STOR3,STOR4,STOR5,PRATE,
    PAI=3.14159265
      G=4.
      C=2.8
      DO 100 I=1,365
         QP(I)=PRATE
  100 CONTINUE

C     GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

      DO 200 NTIME=1,365
         TIME=NTIME
         U=RW**2*STOR1/(4.*TIME*TRANS1)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF1(NTIME)=EXFN
         U=RW**2*STOR2/(4.*TIME*TRANS2)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF2(NTIME)=EXFN
         U=RW**2*STOR3/(4.*TIME*TRANS3)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF3(NTIME)=EXFN
         U=RW**2*STOR4/(4.*TIME*TRANS4)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF4(NTIME)=EXFN
         U=RW**2*STOR5/(4.*TIME*TRANS5)
         UU(NTIME)=U
         CALL EXI(U,EXFN)
         TEISF5(NTIME)=EXFN
```

```
  200  CONTINUE
       THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
       THISK2(1)=TEISF2(1)/(4.*PAI*TRANS2)
       THISK3(1)=TEISF3(1)/(4.*PAI*TRANS3)
       THISK4(1)=TEISF4(1)/(4.*PAI*TRANS4)
       THISK5(1)=TEISF5(1)/(4.*PAI*TRANS5)
       DO 250 INDEX=2,365
       THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
       THISK2(INDEX)=(TEISF2(INDEX)-TEISF2(INDEX-1))/(4.*PAI*TRANS2)
       THISK3(INDEX)=(TEISF3(INDEX)-TEISF3(INDEX-1))/(4.*PAI*TRANS3)
       THISK4(INDEX)=(TEISF4(INDEX)-TEISF4(INDEX-1))/(4.*PAI*TRANS4)
       THISK5(INDEX)=(TEISF5(INDEX)-TEISF5(INDEX-1))/(4.*PAI*TRANS5)
  250  CONTINUE
       WRITE(2,251)
  251  FORMAT(2X,'        THEIS     FUNCTION       AND      DISCRETE
     1 KERNEL')
       WRITE(2,252)
  252
FORMAT(2X,'======================================================
     1 ===============')
       WRITE(2,253)
  253  FORMAT(2X,'       THEIS FUNCTION             '5X,'    DISCRETE
     1 KERNEL')
       WRITE(2,254)
  254  FORMAT(2X,'  N   ','  TEISF1   ','  TEISF2  ','  TEISF3'  , '
     1 TEISF4 ',' TEISF5 ','THISK1   ',' THISK2  ',' THISK3 ',
     2 ' THISK4   ','THISK5')
       DO 256 N=1,365
  256  WRITE(2,255)N,TEISF1(N),TEISF2(N),TEISF3(N),TEISF4(N),
     1 TEISF5(N),THISK1(N),THISK2(N),THISK3(N),THISK4(N),THISK5(N)
  255  FORMAT(I5,10E10.3)


C      COMPUTATION OF QUANTITY FLOW AND SPECIFIC CAPACITY OF WELL IN
C      MULTIAQUIFER SYSTEM WITH MATRIX 4X4

C      MATRIX
       A(1,1)=THISK1(1)
       A(1,2)=-THISK2(1)
       A(1,3)=0.
       A(1,4)=0.
       A(1,5)=0.
       A(1,6)=0.
       A(2,1)=THISK1(1)
       A(2,2)=0.
       A(2,3)=-THISK3(1)
       A(2,4)=0.
       A(2,5)=0.
       A(2,6)=0.
       A(3,1)=THISK1(1)
       A(3,2)=0.
       A(3,3)=0.
       A(3,4)=-THISK4(1)
       A(3,5)=0.
       A(3,6)=0.
       A(4,1)=THISK1(1)
       A(4,2)=0.
```

```
      A(4,3)=0.
      A(4,4)=0
      A(4,5)=-THISK5(1)
      A(4,6)=0.
      A(5,1)=THISK1(1)
      A(5,2)=0.
      A(5,3)=0.
      A(5,4)=0.
      A(5,5)=0.
      A(5,6)=-1./(PAI*RC*RC)
      A(6,1)=1.
      A(6,2)=1.
      A(6,3)=1.
      A(6,4)=1.
      A(6,5)=1.
      A(6,6)=1.
      M=6
      CALL MATIN(A,M)
      QA1(1)=A(1,1)*0.+A(1,2)*0.+A(1,3)*0.+A(1,4)*0.
     1 +A(1,5)*0.+A(1,6)*QP(1)
      QA2(1)=A(2,1)*0.+A(2,2)*0.+A(2,3)*0.+A(2,4)*0.
     1 +A(2,5)*0.+A(2,6)*QP(1)
      QA3(1)=A(3,1)*0.+A(3,2)*0.+A(3,3)*0.+A(3,4)*0.
     1 +A(3,5)*0.+A(3,6)*QP(1)
      QA4(1)=A(4,1)*0.+A(4,2)*0.+A(4,3)*0.+A(4,4)*0.
     1 +A(4,5)*0.+A(4,6)*QP(1)
      QA5(1)=A(5,1)*0.+A(5,2)*0.+A(5,3)*0.+A(5,4)*0.
     1 +A(5,5)*0.+A(5,6)*QP(1)
      QW(1)=A(6,1)*0.+A(6,2)*0.+A(6,3)*0.+A(6,4)*0.
     1 +A(6,5)*0.+A(6,6)*QP(1)
      DO 300 N=2,365
      SUM1=0
      SUM2=0
      SUM3=0
      SUM4=0
      SUM5=0
      SUM6=0
      DO 400 NGAMA=1,(N-1)
      SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
      SUM2=SUM2+QA2(NGAMA)*THISK2(N-NGAMA+1)
      SUM3=SUM3+QA3(NGAMA)*THISK3(N-NGAMA+1)
      SUM4=SUM4+QA4(NGAMA)*THISK4(N-NGAMA+1)
      SUM5=SUM5+QA5(NGAMA)*THISK5(N-NGAMA+1)
      SUM6=SUM6+QW(NGAMA)/(PAI*RC*RC)
400   CONTINUE
      QA1(N)=A(1,1)*(SUM2-SUM1)+A(1,2)*(SUM3-SUM1)+A(1,3)*(SUM4-SUM1)
     1 +A(1,4)*(SUM5-SUM1)+A(1,5)*(SUM6-SUM1)+A(1,6)*QP(N)
      QA2(N)=A(2,1)*(SUM2-SUM1)+A(2,2)*(SUM3-SUM1)+A(2,3)*(SUM4-SUM1)
     1 +A(2,4)*(SUM5-SUM1)+A(2,5)*(SUM6-SUM1)+A(2,6)*QP(N)
      QA3(N)=A(3,1)*(SUM2-SUM1)+A(3,2)*(SUM3-SUM1)+A(3,3)*(SUM4-SUM1)
     1 +A(3,4)*(SUM5-SUM1)+A(3,5)*(SUM6-SUM1)+A(3,6)*QP(N)
      QA4(N)=A(4,1)*(SUM2-SUM1)+A(4,2)*(SUM3-SUM1)+A(4,3)*(SUM4-SUM1)
     1 +A(4,4)*(SUM5-SUM1)+A(4,5)*(SUM6-SUM1)+A(4,6)*QP(N)
      QA5(N)=A(5,1)*(SUM2-SUM1)+A(5,2)*(SUM3-SUM1)+A(5,3)*(SUM4-SUM1)
     1 +A(5,4)*(SUM5-SUM1)+A(5,5)*(SUM6-SUM1)+A(5,6)*QP(N)
      QW(N)=A(6,1)*(SUM2-SUM1)+A(6,2)*(SUM3-SUM1)
     1 +A(6,3)*(SUM4-SUM1)+A(6,4)*(SUM5-SUM1)+A(6,5)*(SUM6-SUM1)
```

```
    2  +A(6,6)*QP(N)
  300  CONTINUE
       DO 301 N=1,365
       SUMP=0
       SUMA1=0
       SUMA2=0
       SUMA3=0
       SUMA4=0
       SUMA5=0
       DO 302 NGAMA=1,N
       SUMP=SUMP+QW(NGAMA)/(PAI*RC*RC)
       SUMA1=SUMA1+QA1(NGAMA)*THISK1(N-NGAMA+1)
       SUMA2=SUMA2+QA2(NGAMA)*THISK2(N-NGAMA+1)
       SUMA3=SUMA3+QA3(NGAMA)*THISK3(N-NGAMA+1)
       SUMA4=SUMA4+QA4(NGAMA)*THISK4(N-NGAMA+1)
       SUMA5=SUMA5+QA5(NGAMA)*THISK5(N-NGAMA+1)
  302  CONTINUE
       DRAWHP(N)=SUMP
       DRAWA1(N)=SUMA1
       DRAWA2(N)=SUMA2
       DRAWA3(N)=SUMA3
       DRAWA4(N)=SUMA4
       DRAWA5(N)=SUMA5
       SPCAPT(N)=QP(N)/SUMA1
  301  CONTINUE
C      CALCULATION ENERGY CONSUMED
       DO 303 N=1,365
       ECOST(N)=(C*9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
       UMEC=0
       DO 304 NGAMA=1,N
       UMEC=UMEC+ECOST(NGAMA)
  304  CONTINUE
       SUMEC(N)=UMEC
  303  CONTINUE
       WRITE(2,306)
  306  FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'DRAWA2',5X,'DRAWA3',
    1  5X,'DRAWA4',5X,'DRAWA5',5X,'SPCAPT')
  307  FORMAT(I5,7F11.5)
       DO 308 N=1,365
  308  WRITE(2,307)N,DRAWHP(N),DRAWA1(N),DRAWA2(N),DRAWA3(N),
    1  DRAWA4(N),DRAWA5(N),SPCAPT(N)
       WRITE(2,310)
  310  FORMAT(2X,'-------------------------------------------------------')
       WRITE(2,401)
  401  FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
       WRITE(2,402)
  402  FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
       WRITE(2,403)
  403  FORMAT(2X,'-------------------------------------------------------')
       WRITE(2,404)
  404  FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,' QA2 ',5X,' QA3 ',5X,'
    1  QA4 ',5X,'QA5',5X, 'QW ',7X,'ECOST',7X,'SUMEC')
  406  FORMAT(I5,8F10.3,F13.3)
       DO 410 N=1,365
  410  WRITE(2,406)N,QP(N),QA1(N),QA2(N),QA3(N),QA4(N),QA5(N),
    1  QW(N),ECOST(N),SUMEC(N)
       WRITE(2,405)
```

```
  405   FORMAT(2X,'---------------------------------------------------
--
     1  ----------')
        WRITE(2,411)
  411   FORMAT(2X,'---------------------------------------------------
--
     1  ----------')
        STOP
      END

C       SUBROUTINE EXI
        SUBROUTINE EXI(U,EXFN)
        X=U
            IF(X-1.0)10,10,20
10      EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1      +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
        RETURN
20          CONTINUE
            IF(X- 80.)50,40,40
50          CONTINUE
        EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1  +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*
     2  +3.9584969))/(X*EXP(X))
            RETURN
40      EXFN=0.
        RETURN
            END

      SUBROUTINE MATIN (AAA,MMM)
        DIMENSION AAA(6,6),B(6),C(6)
        NN=MMM-1
        AAA(1,1)=1./AAA(1,1)
        DO 8 M=1,NN
        K=M+1
        DO 3 I=1,M
        B(I)=0.0
        DO 3 J=1,M
3       B(I)=B(I)+AAA(I,J)*AAA(J,K)
        D=0.0
        DO 4 I=1,M
4       D=D+AAA(K,I)*B(I)
        D=-D+AAA(K,K)
        AAA(K,K)=1./D
        DO 5 I=1,M
5       AAA(I,K)=-B(I)*AAA(K,K)
        DO 6 J=1,M
        C(J)=0.0
        DO 6 I=1,M
6       C(J)=C(J)+AAA(K,I)*AAA(I,J)
      DO 7 J=1,M
7       AAA(K,J)=-C(J)*AAA(K,K)
        DO 8 I=1,M
        DO 8 J=1,M
8       AAA(I,J)=AAA(I,J)-B(I)*AAA(K,J)
        RETURN
        END
```

APPENDIX - B

PROGRAM OF SPECIFIC CAPACITY FOR WELL LOSS UNDER COSIDERATION IN SINGLE AQUIFER

```
      DIMENSION TEISF1(365),THISK1(365),UU(365),QP(365),
     1 QA1(365),DRAWHP(365),DRAWA1(365),QW(365),SPCAPT(365),
     1 ECOST(365),SUMEC(365),SPCAP1(365)


      DOUBLE PRECISION TEISF1,THISK1,UU,QP, QA1,DRAWHP,DRAWA1,QW,
     1 SPCAPT, ECOST,SUMEC,SPCAP1,c1,sum,sumt,c2,c3,a,b,sum1,sum2,
     2 sum3,umec
      OPEN (UNIT=1,FILE='ofi.DAT',STATUS='OLD')
      OPEN (UNIT=2,FILE='muh3.OUT',STATUS='new')
      READ(1,*)RW,RC,TRANS1,STOR1,PRATE,NTIME,NPUMP,DELT
      WRITE(2,*)'TRANS1=',TRANS1,'PRATE=',PRATE
      PAI=3.14159265
      G=4.
c     C=2.8
      C1=0.000002411*(1./DELT)**2
      DO 100 I=1,NPUMP
      QP(I)=PRATE
  100 CONTINUE

C    GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

         DO 200 N=1,NTIME
         TIME=N
         U=RW**2*STOR1/(4.*TIME*TRANS1)
         UU(N)=U
         CALL EXI(U,EXFN)
         TEISF1(N)=EXFN
  200    CONTINUE

      THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)

      DO 250 INDEX=2,NTIME
      THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
  250 CONTINUE

      WRITE(2,251)
  251 FORMAT(2X,'   THEIS  FUNCTION   AND   DISCRETE KERNEL')
      WRITE(2,252)
  252 FORMAT(2X,'==========================================')
      WRITE(2,253)
```

```
  253    FORMAT(2X,' THEIS FUNCTION  ',2X,' DISCRETE KERNEL')
         WRITE(2,254)
  254    FORMAT(2X,'  N  ',' TEISF1  ',' THISK1 ')
         DO 256 N=1,NTIME
         WRITE(2,255)N,TEISF1(N),THISK1(N)
 256     CONTINUE
 255    FORMAT(I5,2E10.3)


C        COMPUTATION OF SPECIFIC CAPACITY OF WELL IN
C        MULTIAQUIFER SYSTEM WITH A QUADRATIC EQUATION

C        QUADRATIC EQUATION
         A=C1
         B=THISK1(1)+(1./(PAI*RC*RC))
         C3=-QP(1)/(PAI*RC*RC)
         QA1(1)=(-B+SQRT(B*B-4.*A*C3))/(2.*A)
         QW(1)=QP(1)-(QA1(1))
         RESIDUE=A*QA1(1)**2+B*QA1(1)+C3
         WRITE(2,*)'RESIDUE=',RESIDUE
         DO 300 N=2,NTIME
         SUM1=0
         SUM2=0
         SUM3=0
         DO 400 NGAMA=1,(N-1)
         SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
         SUM2=SUM2+QA1(NGAMA)
  400    CONTINUE
         DO 444 I=1,N
  444    SUM3=SUM3+QP(I)
         C2=SUM1+SUM2/(PAI*RC*RC)-SUM3/(PAI*RC*RC)
         QA1(N)=(-B+SQRT(B*B-4.*A*C2))/(2.*A)
         QW(N)=QP(N)-QA1(N)
         RESIDUE=A*QA1(N)**2+B*QA1(N)+C2
         WRITE(2,*)N,RESIDUE
  300    CONTINUE
         DO 500 N=1,NTIME
         SUM=0
         SUMT=0
         DO 501 NGAMA=1,N
         SUM=SUM+QA1(NGAMA)*THISK1(N-NGAMA+1)
         SUMT=SUMT+QW(NGAMA)
  501    CONTINUE
C        WRITE(2,*)N,SUMT
         DRAWA1(N)=SUM+ C1*QA1(N)**2
         DRAWHP(N)=SUMT/(PAI*RC*RC)
         SPCAP1(N)=QP(N)/DRAWA1(N)
         SPCAPT(N)=QP(N)/DRAWHP(N)
  500    CONTINUE
         WRITE(2,*)'C1=',C1
C        CALCULATION ENERGY CONSUMED
         DO 303 N=1,NPUMP
         ECOST(N)=(9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA1(N)+G)
         UMEC=0
         DO 304 NGAMA=1,N
         UMEC=UMEC+ECOST(NGAMA)
  304    CONTINUE
```

```
      SUMEC(N)=UMEC
303.  CONTINUE
      WRITE(2,306)
306   FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'SPCAPT',5X,'SPCAP1')
307   FORMAT(I5,4F10.3)
      DO 308 N=1,NPUMP
308   WRITE(2,307)N,DRAWHP(N),DRAWA1(N),SPCAPT(N),SPCAP1(N)
      WRITE(2,310)
310   FORMAT(2X,'---------------------------------------------------')
      WRITE(2,401)
401   FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
      WRITE(2,402)
402   FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
      WRITE(2,403)
403   FORMAT(2X,'---------------------------------------------------')
      WRITE(2,404)
404   FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,'QW ',5X,'ECOST',
     1 14X,'SUMEC')
406   FORMAT(I5,4F10.3,F13.3)
      DO 410 N=1,NTIME
410   WRITE(2,406)N,QP(N),QA1(N),QW(N),ECOST(N),SUMEC(N)
      WRITE(2,405)
405   FORMAT(2X,'-----------------------------------------------')
      WRITE(2,411)
411   FORMAT(2X,'-----------------------------------------------')
      STOP
    END

C       SUBROUTINE EXI
        SUBROUTINE EXI(U,EXFN)
        X=U
            IF(X-1.0)10,10,20
10      EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1      +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
        RETURN
20          CONTINUE
            IF(X- 80.)50,40,40
50          CONTINUE
        EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1  +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
     2  +3.9584969))/(X*EXP(X))
            RETURN
40      EXFN=0.
        RETURN
            END
```

PROGRAM OF SPECIFIC CAPACITY FOR WELL LOSS UNDER COSIDERATION IN MULTIAQUIFER TAPPING TWO AQUIFERS

```
      DIMENSION TEISF1(365),TEISF2(365),THISK1(365),
     1 THISK2(365),UU(365),QP(365),QA1(365),DRAWHP(365),
     2 DRAWA1(365),DRAWA2(365),QA2(365),QW(365),SPCAPT(365),
     3 SPCAP1(365),SPCAP2(365),ECOST(365),SUMEC(365)

      DOUBLE PRECISION TEISF1,TEISF2,THISK1,THISK2,UU,QP,QA1,
     1 DRAWHP,DRAWA1,DRAWA2,QA2,QW,SPCAPT,SPCAP1,SPCAP2,ECOST,
     2 SUMEC,c1,sum,sumt,sums,c2,c3,a,b,sum1,sum2,sum3,sum4,
     3 sum5,umec

      OPEN (UNIT=1,FILE='sof.DAT',STATUS='OLD')
      OPEN (UNIT=2,FILE='CUS3.OUT',STATUS='NEW')
      READ(1,*)RW,RC,TRANS1,TRANS2,STOR1,STOR2,PRATE,NTIME,
     1 NPUMP,DELT
      WRITE(2,*)'TRANS1=',TRANS1,'TRANS2=',TRANS2,
     1 'PRATE=',PRATE
      PAI=3.14159265
      G=4.
C     C=2.8
      C1=0.000002411*(1./DELT)**2
      DO 100 I=1,NPUMP
         QP(I)=PRATE
 100  CONTINUE

C    GENERATION OF THEIS FUNCTION & DISCRETE KERNEL

      DO 200 N=1,NTIME
         TIME=N
         U=RW**2*STOR1/(4.*TIME*TRANS1)
         UU(N)=U
         CALL EXI(U,EXFN)
         TEISF1(N)=EXFN
         U=RW**2*STOR2/(4.*TIME*TRANS2)
         UU(N)=U
         CALL EXI(U,EXFN)
         TEISF2(N)=EXFN

 200  CONTINUE
      THISK1(1)=TEISF1(1)/(4.*PAI*TRANS1)
      THISK2(1)=TEISF2(1)/(4.*PAI*TRANS2)

      DO 250 INDEX=2,NTIME
      THISK1(INDEX)=(TEISF1(INDEX)-TEISF1(INDEX-1))/(4.*PAI*TRANS1)
      THISK2(INDEX)=(TEISF2(INDEX)-TEISF2(INDEX-1))/(4.*PAI*TRANS2)
 250  CONTINUE
      WRITE(2,251)
 251  FORMAT(2X,'    THEIS  FUNCTION   AND   DISCRETE KERNEL')
      WRITE(2,252)
```

```
 252    FORMAT(2X,'==================================================')
        WRITE(2,253)
 253    FORMAT(2X,'   THEIS FUNCTION    ',3X,' DISCRETE KERNEL')
        WRITE(2,254)
 254    FORMAT(2X,'  N   ','  TEISF1   ','  TEISF2   ', ' THISK1   ',
     1  ' THISK2   ')
        DO 256 N=1,NTIME
 256    WRITE(2,255)N,TEISF1(N),TEISF2(N),THISK1(N),THISK2(N)
 255    FORMAT(I5,4E10.3)


C       COMPUTATION OF SPECIFIC CAPACITY OF WELL IN
C       MULTIAQUIFER SYSTEM WITH A QUADRATIC EQUATION

C       QUADRATIC EQUATION
        A=PAI*RC*RC*C1
        B=1.+PAI*RC*RC*THISK1(1)-(1./(1.+PAI*RC*RC*THISK2(1)))
        C3=(0.*PAI*RC*RC+0.+0.-QP(1)-(1./(1.+PAI*RC*RC*THISK2(1))
     1  *(PAI*RC*RC*0.-QP(1)+0.+0)))
        QA1(1)=(-B+SQRT(B*B-4.*A*C3))/(2.*A)
        QA2(1)=-QA1(1)/(1.+PAI*RC*RC*THISK2(1))-(1./((1.+PAI*RC*RC
     1  *THISK2(1)))*(PAI*RC*RC*0.-QP(1)+0.+0.))
        QW(1)=QP(1)-(QA1(1)+QA2(1))
        WRITE(2,*)'RESIDUE=',RESIDUE
        DO 300 N=2,NTIME
        SUM1=0
        SUM2=0
        SUM3=0
        SUM4=0
        SUM5=0
        DO 400 NGAMA=1,(N-1)
        SUM1=SUM1+QA1(NGAMA)*THISK1(N-NGAMA+1)
        SUM2=SUM2+QA1(NGAMA)
        SUM3=SUM3+QA2(NGAMA)
        SUM5=SUM5+QA2(NGAMA)*THISK2(N-NGAMA+1)
 400    CONTINUE
        DO 444 I=1,N
 444    SUM4=SUM4+QP(I)
        C2=(SUM1*PAI*RC*RC+SUM2+SUM3-SUM4-(1./(1.+PAI*RC*RC*THISK2(1))
     1  *(PAI*RC*RC*SUM5-SUM4+SUM2+SUM3)))
        QA1(N)=(-B+SQRT(B*B-4.*A*C2))/(2.*A)
        QA2(N)=-QA1(N)/(1.+PAI*RC*RC*THISK2(1))-(1./((1.+PAI*RC*RC
     1  *THISK2(1)))*(PAI*RC*RC*SUM5-SUM4+SUM2+SUM3))
        QW(N)=QP(N)-(QA1(N)+QA2(N))
        RESIDUE=A*QA1(N)**2+B*QA1(N)+C2
        WRITE(2,*)N,RESIDUE
 300    CONTINUE
        DO 500 N=1,NTIME
        SUM=0
        SUMS=0
        SUMT=0
        DO 501 NGAMA=1,N
        SUM=SUM+QA1(NGAMA)*THISK1(N-NGAMA+1)
        SUMS=SUMS+QA2(NGAMA)*THISK2(N-NGAMA+1)
        SUMT=SUMT+QW(NGAMA)*(1./(PAI*RC*RC))
 501    CONTINUE
        DRAWA1(N)=SUM+(C1*QA1(N)**2)
```

```
          DRAWA2(N)=SUMS
          DRAWHP(N)=SUMT
          SPCAP1(N)=QP(N)/(DRAWA1(N))
          SPCAP2(N)=QP(N)/(DRAWA2(N))
          SPCAPT(N)=QP(N)/(DRAWHP(N))
   500    CONTINUE
          WRITE(2,*)'C1=',C1

 C        CALCULATION ENERGY CONSUMED
          DO 303 N=1,NPUMP
          ECOST(N)=(9.8*QP(N)*(24*(N))/(0.75*86400))*(DRAWA2(N)+G)
          UMEC=0
          DO 304 NGAMA=1,N
          UMEC=UMEC+ECOST(NGAMA)
   304    CONTINUE
          SUMEC(N)=UMEC
   303    CONTINUE
          WRITE(2,306)
   306    FORMAT(2X,'N',5X,'DRAWHP',5X,'DRAWA1',5X,'DRAWA2',
     1    5X,'SPCAPT',5X,'SPCAP1',5X,'SPCAP2')
   307    FORMAT(I5,3F10.3,3F12.3)
          DO 308 N=1,NPUMP
   308    WRITE(2,307)N,DRAWHP(N),DRAWA1(N),DRAWA2(N),SPCAPT(N),
     1    SPCAP1(N),SPCAP2(N)
          WRITE(2,310)
   310    FORMAT(2X,'----------------------------------------------------')
          WRITE(2,401)
   401    FORMAT(2X,'COMPUTATION SPECIFIC CAPACITY OF WELL HAVING')
          WRITE(2,402)
   402    FORMAT(2X,'STORAGE IN MULTI AQUIFER SYSTEM')
          WRITE(2,403)
   403    FORMAT(2X,'----------------------------------------------------')
          WRITE(2,404)
   404    FORMAT(2X,'N ',5X,' QP ',5X,'  QA1 ',5X,' QA2 ',5X,'QW ',
     1    7X,'ECOST',14X,'SUMEC')
   406    FORMAT(I5,5F10.3,F14.3)
          DO 410 N=1,NTIME
   410    WRITE(2,406)N,QP(N),QA1(N),QA2(N),QW(N),ECOST(N),SUMEC(N)
          WRITE(2,405)
   405    FORMAT(2X,'------------------------------------------------')
          WRITE(2,411)
   411    FORMAT(2X,'------------------------------------------------')
          STOP
          END

 C        SUBROUTINE EXI
          SUBROUTINE EXI(U,EXFN)
          X=U
              IF(X-1.0)10,10,20
 10       EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1        +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
          RETURN
 20           CONTINUE
              IF(X- 80.)50,40,40
 50           CONTINUE
          EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1    +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
```

```
     2  +3.9584969))/(X*EXP(X))
              RETURN
40          EXFN=0.
            RETURN
            END
```

INPUT-OUTPUT PROGRAM

Data input :

```
- FOR ONE AQUIFER
Rw       Rc       T1       Φ1       PRATE    NTIME    NPUMP     DELT
0.1      2.       100.     0.1      100.     365      365       1.
```

Output :

```
 TRANS1=         100.00    PRATE=         100.00
□
      THEIS   FUNCTION    AND    DISCRETE KERNEL
□
   ============================================
□
   THEIS FUNCTION      DISCRETE KERNEL
□
     N    TEISF1    THISK1
□
     1  .123E+02  .981E-02
□
     5  .139E+02  .178E-03
    10  .146E+02  .838E-04
   356  .182E+02  .224E-05
   365  .182E+02  .218E-05

 C1=   4.8225299309479E-009
  N       DRAWHP       DRAWA1       SPCAPT        SPCAP1
     1       .873         .873     114.545      114.545
     2      1.013        1.013      98.764       98.764
     5      1.104        1.104      90.614       90.614
    10      1.161        1.161      86.106       86.106
    50      1.291        1.291      77.436       77.436
   100      1.347        1.347      74.250       74.250
   200      1.402        1.402      71.322       71.322
   365      1.450        1.450      68.964       68.964


   --------------------------------------------------
□
   COMPUTATION SPECIFIC CAPACITY OF WELL HAVING
□
   STORAGE IN MULTI AQUIFER SYSTEM
□
   --------------------------------------------------
□
  N        QP         QA1         QW         ECOST          SUMEC
    1   100.000     89.029     10.971       1.769          1.769
    2   100.000     98.247      1.753       3.639          5.407
   10   100.000     99.891       .109      18.734        102.245
```

```
 50   100.000     99.980       .020     96.029      2430.443
100   100.000     99.990       .010    194.069      9727.806
200   100.000     99.995       .005    392.152     39121.456
365   100.000     99.997       .003    722.027    131167.170
------------------------------------------------------
------------------------------------------------------
```