CHAPTER V

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CHAPTER -V

EVALUATION OF AQUIFER PARAMETERS THROUGH PUMPING TEST AND DATA ANALYSIS

Aquifer parameters viz. transmissivity $T$ and storage coefficient are necessary to conceptualize groundwater flow regime and assessment of its potential in an area. These parameters are generally arrived through pumping test on bore hole with an observation well Singh and Thang region (1998). A pumping test in one of the most useful mean of determining hydraulic properties of water bearing layers and containing beds. It may yield reliable results which, in general, are representative of a larger area than are single point observations (Krusman and de Ridder, 1970).

With an growing needs of water, water resources are being expected in a big way. hence evaluation of aquifer parameters through pumping test has become imperative. This is turn regains a reliable estimation of hydrogeological parameters pumping test of a well may give a representative estimate of aquifer parameters valid over a large area (Thangrajan and Singh 1998).

A pumping test may serve two main objectives:

Firstly, a pumping test may be performed in order to determine the hydraulic characteristics of aquifers or water bearing layers. Such a test is often called an “aquifer test” because it is aquifer rather than the pump or well, which is tested.

Secondly, a pumping test may provide information about the yield and drawdown of the well. These data can be used for determining the specific capacity or discharge drawdown ratio of the well, for selecting the type of pump, and for estimating the cost of pumping. The specific capacity gives a measure of effectiveness or
productive capacity of the well, such a pumping test is sometimes called a ‘well test’ because it is the well, rather than the aquifer, which is tested.

The analysis of pumping test data involves transformation of field data into calculated value of hydraulic properties of the tested aquifer. On completion of the pumping test, all the collected data on well discharge, drawdown, a recovery in the various observation well and the pumped well with time, pre test water level, trend etc. are processed.

5.1 DESCRIPTION OF METHODS
The non-equilibrium formula introduced by Theis (1935) is widely used for analysis the pumping test data and for determination of the hydraulic properties of an aquifer.

5.1.1 Theis Method of Solution:

Theis studied the transient come of depression around discharging well and developed a mathematical method to determine the transmissivity and storativity from the rate of drawdown (Clebsch, 1994). This methodology allowed the determination of in situ hydraulic properties of aquifers and the prediction of response, such as drawdown with time and distance, of groundwater system of pumping (Back and Human, 1997).

The equation which Theis developed specifically for confined aquifer has the following form.

\[
S = \frac{Q}{4\pi \pi} \int_0^\infty e^{-u} \frac{du}{4} \quad \ldots(1)
\]

or

\[
S = \frac{Q}{4\pi \pi} W(u) \quad \ldots(2)
\]
where \[ 4 = \frac{r^2S}{4\pi} \]

or \[ S = \frac{4Tu}{r^2} \] \ ...(3)

where

- \( r \) - distance in meters of an observation well from the pumped well.
- \( S \) - drawdown in meters in an observation well located at a distance \( r \) from the pumped well.
- \( Q \) - Constant well discharge in m³/day.
- \( S \) - Storativity.
- \( T \) - Transmissivity in m²/day.
- \( t \) - the time since pumping started.
- \( W(u) \) - well function of \( u \).

\[ W(u) = [-0.5722 - \ln u + 4u^2/2.21 + u^3/3.31 - 4^4/4.41 t \ldots] \] \ ...(4)

for the use of Theis method following assumption and limiting condition should be satisfied.

1. Aquifer is homogenous, isotropic, of uniform thickness and infinite areal extent.
2. Before pumping, the piezometric surface is horizontal.
3. The well is pumped at constant the entire aquifers and flow is ever where horizontal within the aquifer to the well.
4. The pump well penetrates the entire aquifers and flow is ever where horizontal within the aquifer to the well.
The well diameter is infinitesimal to that storage within the well can be neglected.

Water removed from the storage is discharge instantaneously with decline of head.

5.1.2 Cooper-Jacob Method of Solution:

It was noted by Cooper and Jacob (1946) that for small values of r and large values of t, u is small so that the equation

\[ S = \frac{Q}{4\pi r} W(u) \]

can be simplified and expressed as

\[ S = \frac{2.30 Q}{4\pi} \log \frac{2.25 T}{r^2 S} \]  \( ... (5) \)

Thus a plot of drawdown 's' verses logarithmic of time t forms a straight line equation which can further be solved to given

\[ S = \frac{2.25 T}{r} \]  \( ... (6) \)

and

\[ T = \frac{2.30}{4\pi \Delta} \]  \( ... (7) \)

where to – time in days corresponding to interception of straight line with axis,

where S = 0

\[ \Delta s \] – slope of straight line in meters or difference of drawdown over one log cycle.

5.1.3 Recovery Test:

At the end of the pumping, when the pump is stopped, the water levels in pumping and observation wells will began to rise. This is referred to as the recovery of
groundwater lives, while measurements of drawdown below the original static water level (prior to pumping) during the recovery period are known as residual drawdown (Appendix).

It is a good practice to measure residual drawdown because analysis of the data enable transmissivity to be calculated, thereby providing an independent check on pumping test results.

If a well is pumped for a known period of time and then shut down, the drawdown thereafter will be identically the same as if the discharge had been continued and a hypothetical recharge well with the same flow were superposed on the discharging well at the instant the discharge is shutdown. From this principle, Theis showed that the residual drawdowns' can be given as:

\[ S' = \frac{Q}{\pi r^2} [W(u) - W(u')] \] ...(8)

where

\[ u = \frac{r^2 S}{4\pi} \quad \text{and} \quad u' = \frac{r^2 S}{4T't'} \] ...(9)

For small \( r \) and large \( t \) the well function can be approximated by the first two term of eqn. 4 so that eqn. 8 can be written as:

\[ S' = \frac{2.30Q}{4\pi} \log \frac{t}{t'} \] ...(10)

Thus a plot of residual drawdown \( s' \) versus the logarithm of \( t/t' \) forms a straight line. The slope of the line equals \( \frac{2.30Q}{4\pi} \) so that for \( \Delta s' \) the residual drawdown per log cycle of \( t/t' \) the transmissivity becomes:
\[ T = \frac{2.30Q}{4\pi^2} \] ...(11)

No comparable value of \( s \) can be determined by the recovery test method.

5.2 AQUIFER PERFORMANCE TEST

In order to determine the aquifer characteristics an aquifer performance test was conducted on state tube well No. 8, Atrauli Block. The tube well was pumped at a constant discharge from a fixed time. After the tube well had been pumped sufficiently long, when the rate of decline of water level became feeble, the pump was shut off. During the period of pumping water level measurement in the tube wells were taken at regular intervals. Again when pump was shut off recovery reading of water levels was initially taken at one minute intervals and subsequently at longer intervals. Exact time when the pump was started and stopped was precisely recorded. Discharge of the tube well was measured over 90\(^\circ\) \( V \) notch (Appendix 5.1 to 5.5).

The data of test were analyzed and various aquifer parameters were determined which are tabulated below:

5.3 SUMMARY OF OBSERVATION

5.4 NAME OF THE SITE : ATRAULI

1. Name of the site : Atrauli

2. Discharge maintained : 3544.7616 m\(^3\)/day

Duration of pumping : 120 minutes

(a) Analysis of data:

(i) Cooper Jacob method (Fig 5.1) the transmissivity comes in order to 810.989 m\(^3\)/day.
(ii). Theis recovery method (Fig 5.2.) the value of transmissivity comes in order to
810.989 m$^2$/day and the hydraulic conductivity is 28.922 m/day.

**Pump test data on state tube wells:**

State water level 7.22 m constant discharge 2461.641 pm pump started 0740 hrs
pump stopped 1100 hrs

\[ \Delta S = 0.8 \text{ m} \quad Q = 3544.7616 \text{ m}^3/\text{day} \]

\[ T = \frac{2.30Q}{4\pi\Delta} \]

\[ = \frac{2.30 \times 3544.7616}{4 \times 3.16 \times 0.8} = 810.989 \text{ m}^2/\text{day} \]

\[ K = \frac{T}{b} = \frac{810.989}{28.04} = 28.922 \text{ m/day} \]

5.5 SUMMARY OF OBSERVATION

5.5 NAME OF THE SITE : Near Jawan

Name of Site: Near Jawan

Discharge maintained

During the test: 328 m$^3$/day

Duration of pumping 1220 minutes

(a) Analysis of the data:

The time drawdown field data curves of observation well were prepared for Theis's methods and for Jacob method. The time drawdown field data curves resemble the typical time-drawdown curve of a confine aquifer.

<table>
<thead>
<tr>
<th>Observation well</th>
<th>Method</th>
<th>T m$^2$/day</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Theis</td>
<td>544.05</td>
<td>2.46x10^{-4}</td>
</tr>
<tr>
<td></td>
<td>Jacob</td>
<td>522.29</td>
<td>3.67x10^{-4}</td>
</tr>
<tr>
<td>II</td>
<td>Theis</td>
<td>522.29</td>
<td>1.13x10^{-3}</td>
</tr>
<tr>
<td></td>
<td>Jacob</td>
<td>523.88</td>
<td>1.36x10^{-3}</td>
</tr>
</tbody>
</table>
As the field data curve of observation wells match well with Theis type curve, the hydraulic parameters of the aquifer determined by theis method have taken alone as a best approximated parameters.

(a) Transmissivity  
522.29 m$^2$/day

(b) Storativity  
$1.13 \times 10^{-3}$

(c) Hydraulic conductivity  
37.31 m/day

5.6 SUMMARY OF OBSERVATION

Name  
Near Sikandra Rao

Discharge  
0.368 m$^3$/sec

Duration of Pumping  
1465 minutes

(a) Analysis of the data:

The aquifer performance tests have been conducted near Sikandra Rao with observation wells and their field data curves have been prepared for Theis’s method and for Jacob’s method.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Well Data</th>
<th>T m$^2$/day</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theis Method</td>
<td>Observation well</td>
<td>506.29</td>
<td>$1.19 \times 10^{-4}$</td>
</tr>
<tr>
<td>Jacob’s Method</td>
<td>Observation well</td>
<td>520.92</td>
<td>$1.50 \times 10^{-4}$</td>
</tr>
<tr>
<td>Recovery Method</td>
<td>Main well</td>
<td>498.66</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Observation well</td>
<td>486.20</td>
<td>-</td>
</tr>
</tbody>
</table>

The aquifer parameters are as follows:

a) Transmissivity  
503 m$^2$/day

b) Storativity  
$1.34 \times 10^{-4}$

c) Hydraulic conductivity  
18.64
Fig 5.1 Time since pumping began (min.)

TIME VERSUS DRAWDOWN CURVE
(COOPER-JACOB METHOD)

\[ \Delta s = 0.8 \text{m} \]
RECOVERY TEST METHOD BY THEIS
TIME VERSUS RESIDUAL DRAWDOWN

Fig 5.2 TIME RATIO $t/t'$

Triangle symbol $\triangle s = 0.8\text{m}$
Site - NEAR JAWAN
Observation Well-I
Discharge - \( Q = 328 \text{ m}^3/\text{day} \)

Result
\[ T = 544.05 \text{ m}^2/\text{day} \]
\[ S = 2.46 \times 10^{-4} \]

Fig. 5.3 Time Vs Drawdown Curve (Theis's Method) near Jawan observation well.
Site - NEAR JAWAN
Observation Well-II
Discharge - (Q) = 328 m$^3$/day

Result
T = 522.29 m$^2$/day
S = 1.13 x 10^{-3}

Fig. 5.4 Time vs. Drawdown Curve (Theis Method) near Jawan Observation well
Fig 5.5 Time Vs Drawdown Curve (Jacob's method) Near Jawan observation well.

Site - NEAR JAWAN
Observation Well-I
Discharge - (Q) = 328 m³/day

Δs = 0.115

Result
T = 522.29 m²·day
S = 3.67 x 10⁻⁴
Fig. 5.7 Plot of Time Vs Drawdown curve (Theis method) Near Sikandra Rau observation well

\[ T = \frac{Q W(U)}{4 \pi d} = \frac{3179.5 \times 10}{4 \times 3.14 \times 5} = 5.06 \text{ m}^2 \text{day}^{-1} \]

\[ W(u) = 10^4 \]

\[ t / u = 10^4 \]

\[ d = 5 \text{ metres} \]

\[ t = 210 \text{ minutes} \]

\[ s = \frac{4 T t u}{r^2} \]

\[ 4 \times 506 \times 29 \times 0.1458 \]

\[ 248 \times 0.06 \times 10000 \]

\[ 0.000119 \]

\[ 1.19 \times 10^{-4} \]
Fig. 5.8 Plot of time Vs drawdown (Jacobs method) near Sikandra Rau observation well
Fig. 5.9 Plot of Residual drawdown Vs $t / t'$ (Recovery method)
Near Sikandra Rau (main well)

SITE - NEAR SIKANDRA RAO

$\Delta s = 1.17$

$T = \frac{264 Q}{\Delta s}$

$Q = 2.21 \text{ m}^3/\text{minute}$

$= \frac{264 \times 2.21}{1.17}$

$= 498.66 \text{ m}^2/\text{day}^{-1}$
Fig. 5.10 Plot of residual drawdown Vs $t/t'$ (Recovery method)
Near Sikandra Rau. (Observation well).

\[ Q = \frac{264 \times 2.21}{1.20} = 486.20 \text{ m}^2/\text{day}^{-1} \]