6 Pumping Tests: Planning, Preparation and Execution

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INTRODUCTION

The most important aspect of groundwater studies in an area is to determine how much groundwater can be safely withdrawn and also for management of the available source. This determination involves

(i) Transmissibility and storage coefficients of the aquifers
(ii) The lateral extent of aquifers and the nature of the boundary conditions
(iii) The effect of future developments on recharge and discharge

All the above information can be obtained by conducting pumping tests in the field. A pumping test involves the bailing out of water through a pumping well (Pw) and the measurement of water level changes induced in one or more observation wells (Ob well/s) located in the vicinity of the pumping well. In general, two types of tests are conducted in the field. A long duration test known as the aquifer performance test (APT) is for obtaining the characteristic features of the aquifer. The second type of test, step-draw down test (SDT) is for determining the optimal capacity of the well and to install proper pumping equipment. A step-draw down test is conducted with different pumping rates in three or five stages, each stage being of the same duration. The specific capacity versus the yield relationship is determined on a designed production well.

Since a pumping test is a costly proposition, an attempt has been made in the following paragraphs to briefly discuss the most important aspects of selection of a test site, preparation and procedures to accomplish the tests.

SELECTION OF TEST SITE

The factors to be considered before selecting a test site could be: (a) topography, (b) geology of the area, (c) porosity and permeability, (d) joints and faults and folds, (e) proximity to tanks, rivers, springs, lakes, unlined channels and (f) existing pumping wells.

As the aquifer parametres have to be utilized for effective planning and management of the groundwater in an area, it is very essential that the wells be so selected that they do not fall near contact zones of formations. The movement of water in hard rocks is through joints, fractures and cracks which are interconnected. Wells that tap the highly jointed rocks or along fault plane produce very high yield in comparison to surrounding areas. When the rocks are folded into anticlines and synclines, the synclines are favourable spots for groundwater storage in the pervious layers, while if a well taps the anticlines, it may not yield, since the crest forms a groundwater divide. Thus a judicious selection for a pumping test site should be made. The water levels in confined aquifers are subject to immediate changes in pressure heads caused due to heavy traffic passing nearby the test sites, such as railway lines or heavy road trucks.

In addition to the above factors, adequate subsurface investigations prior to performance of an aquifer test are to be determined for ascertaining the lithological character, thickness of aquifer, location of aquifer boundaries, character of bed overlying and underlying the aquifer, nature of barrier or recharge boundaries if any, direction of groundwater flow, water table gradients and regional water level trend. The thickness of aquifer, and the features of the overlying and underlying beds can be ascertained during the drilling of the bore-well. The depth vs. yield of the various formations could be collected from the data recorded during drilling. If the main aquifer is bounded by any partially permeable formations, then adequate care has to be exercised for sealing of the inflows by inserting a suitable packer assembly. It is also very important to dispose off the pumped water preferably through pipeline to a distant place so that it does not return back and cause interference with the water level changes in wells. Gradient of the water table should be low and, preferably, the boundary conditions of the aquifer should be clearly defined and simple.

Abstraction Well (Pumping Well - PW)

The diameter of the well should be able to accommodate pumping equipment and sufficient length of casing must be inserted to avoid collapsing of loose material if any. The length of the casing of the screen should at least be 70% of the aquifer thickness, so that it does not become a partially penetrating well.

Observation Well (Ob Well)

To measure drawdown within the cone of depression caused by discharging well. As a general rule, the observation wells should be placed at a distance of 1.5 to 2.0 times the thickness of the aquifer. More than one observation well, if available, would also give the directional inhomogeneities, if any.

The position of observation wells should be considered with respect to: (a) type of aquifer, (b) hydraulic conductivity, (c) well penetration, (d) geohydrologic boundaries, (e) discharge and (f) stratification. Observation wells should not be located near a recharge area, as the data from these wells may not reflect actual storage coefficient

The operation for pumping test involves prior information at the test site:

(a) measurement of static water level (before pumping begins), the depth below a measuring point or ground level
(b) the lithological characteristics and the details of well depth, length of casing inserted, the discharge of the well (say at the time of drilling)
(c) general water table, the performance of nearby wells.

EQUIPMENT REQUIRED

A truck-mounted test-pumping unit should comprise a submersible pump (with three-phase motor) and a (diesel) power generating set (since uninterrupted power may not be available at the test site as in most parts of India) and tripod/hydraulic arrangement for smooth lowering of pump and pipes. The pump and power unit for a pumping test should be capable of operating continuously at constant discharge rate for longer periods of time. Suitable measurement devices for time, discharge and water level. The time intervals may be best noted through a stopwatch, and if several wells have to be monitored then all the watches have to be matched to a common time.

Measurement of Water Level

Best device is automatic water level recorder since this gives a continuous record of changes in water level measurements. The other types of devices in usage are (a) chalked steel tape, (b) whistle tape, (c) hollow cylinder, (d) digital tape and (e) electrical tape. These can be used accurately for measurement in the observation wells since the water levels are not disturbed by changes in pumping rate and inflows into the well (as in the case of fractured rocks).

Since the water levels decline at a faster rate during the early stages of pumping, it is required that the frequency of measurements is high in the beginning of the test. The yield test is generally run for 10-15 hours continuously and till constant draw down is maintained in the well. Thus, the specific capacity of the well is its yield per unit draw down and for the given pumping period. This may also vary with the wet and dry seasons.

Measurements in Pumping well and Observation well

Time since pump started (minutes)	*Time intervals (minutes)*
0-5	1-5
5-60	5
60-120	10
120-360	(or till shut down) 20

Discharge Measurements

A pumping test requires correct measurement of discharge of the pumped well at a constant discharge rate. The flow rate is measured at regular intervals of time and adjustments made to keep it constant through deployment of (a) integrating type of water meter installed in the pipe, (b) Orifice meter and (c) 90° V-notch. Small discharges can also be measured by recording the time taken to fill a known volume of container.

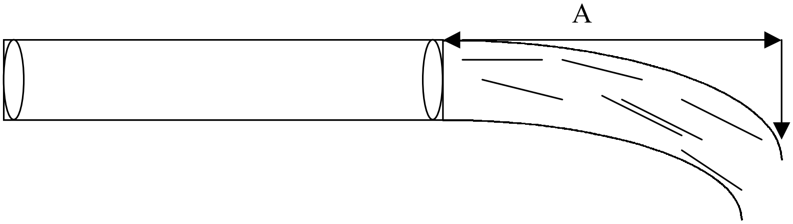
Discharge through a 90° V-notch

$Q = 1.38\ H^{2.5}$, where H = head in m and Q = discharge in m^3/sec.

Head H (cm)	*Discharge Q (lpm)*
2	4.7
4	26.5
6	73
8	149
10	255
12	414
15	725
20	1490
25	2580
30	4060

Estimation of Flow from Horizontal Pipes

A fairly close determination of the flow from full open pipes may be made by measuring the distance the stream of water travels parallel to the pipe in falling 12 inches vertically.



The flow in gallons per minute equals the distance (A) in inches multiplied by a constant k obtained from the following table.

Internal diameter of pipe (")	k
2.0	3.3
2.5	5.1
3.0	7.3
3.5	10.0
4.0	13.1
4.5	16.5
5.0	20.4
5.5	24.7
6.0	29.4
6.5	34.5

Approximate flow from pipe running full in gallons per minute

	Horizontal Distance (A)									
Dia-pipe	*12″*	*14″*	*16″*	*18″*	*20″*	*22″*	*24″*	*26″*	*28″*	*30″*
2″	41	48	55	61	68	75	82	89	96	102
3″	90	105	120	135	150	165	180	195	210	225
4″	150	181	207	232	258	284	310	336	361	387
6″	352	410	470	528	587	645	705	762	821	880

Minimum period of pumping test - at least 6 to 8 hrs or till a good response of the Aquifer is achieved.

Preparation, Compilation and Analysis of Data

Time to be expressed in days

Water level to be reduced to draw down in metres

Either time-draw down or distance-draw down data

Correction of observed draw down for variation in barometric pressure, changes in tidal height, rate of pumping changes in adjacent wells.

Type of aquifer

Suitable methods for analysis to be applied depending upon type of aquifer

The two important aquifer parameters in relation to groundwater flow are the transmissivity (T) and the Storage Coefficient (S). Pumping tests are the most practical and direct methods of determining these parameters. Some of the constraints in performing these tests are, however, the cost towards conducting the tests, and the availability of observation wells near the discharge wells. Theis (1935) has shown that transmissivity could be calculated from the recovery water level data and this method is often used in estimating transmissivity from single bore-wells. From the time-drawdown data of an observation well located at a distance 'r', the aquifer parametres can be determined. The other data required for the computation are the drawdown from the observed data, the time factor and the constant discharge of the pumped well. The type curve and the data curve (plotted on double logarithmic paper) are matched and the following data are noted from a common match point. (No attempt is made to elaborate the theoretical aspects of the method.) Another method has been described by Jacob, which involves plotting of observed data on a semi-logarithmic paper and fitting the data to straight line. Both transmissivity and storage coefficient can be determined.

Theis Method

$T = Q/4\pi s\ w\ (u);\ u = r^2\ S/4Tt$

from match point

where $s = 0.174$ m, $t = 5.2 \times 10^{-2}$ day, $w(u) = 1.0$, $1/u = 100$, $u = 0.01$ and $r = 130$ m

Jacob's Straight-line Method

$$T = 2.30\ Q/4\ \Delta s; \qquad S = \frac{2.25\,T\,t_0}{r^2},$$

where 'T' is the transmissibility (m^2/day), 'Q' is the discharge in m^3/day, Δs is log cycle difference in drawdown (m), 'S' is the storage coefficient, 't_0' time intercept on the zero-drawdown axis ($s = 0$) and 'r' is the distance between pumping well and observation well.

Selection of Pump Sets

The selection of proper pumping set is important to ensure yields from wells and factors to be considered are:

(a) finished inside diameter and total depth of the well
(b) yield from the well, the desired pumping rate and hours of pumping per day
(c) the lowest pumping water level (in dry season)
(d) the total head on the pump
(e) the power required

CONCLUSIONS

The chapter provides practical tips for carrying out the pumping tests that are at one hand important experiments in groundwater hydrology and on the other hand quite cumbersome and to be handled with utmost care to obtain a useful result. A number of relevant literatures exist and they are listed for further reading and consultation.

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