



**School of Graduate Studies  
Addis Ababa Institute of Technology**

**EVALUATION OF HYDRAULIC PARAMETERS IN KOBO  
IRRIGATION WELLS**

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## Abstract

The study area of this research is Kobo Valley catchment, situated south of Raya Valley in Northern part of Ethiopia. The low lying inter mountain valley part of the area is known by its high groundwater potential and semiarid climate. Currently, it is underground water source exploitation and investigation mainly for irrigation because of scarce surface water and low annual rainfall. In the study area 17 single well constant pumping test and recovery test data were collected besides 14 of 17 wells have the step drawdown test data. In this research where conducted to re- analyze the transmissivity value estimated for design. Having checked the data quality for all 17 wells in the Kobo well field transmissivity was estimated using Theis and Cooper-Jacob method for the time drawdown data collected and the residual drawdown analysis time residual drawdown data. For each well three transmissivity value were estimated the geometric mean value estimated ranges from a minimum of  $26\text{m}^2/\text{day}$  to  $2790\text{m}^2/\text{day}$ . For the same wells the range of transmissivity value used in the design of the kobo irrigation scheme was  $55.2\text{m}^2/\text{day}$  to  $3145\text{m}^2/\text{day}$ . Among the 17 wells 11 wells were found to under estimate transmissivity obtain in this research 4- 82% but one are found to overestimate the transmissivity with 8-178%.given the fact that both this research and the design document uses the same well test data, such huge variation in the estimation could only because by data interpretation techniques. Appropriate data correction shall be made test for any well analysis for hydraulic parameter estimations. In well data obtained for single well test such correction is even more vital. For the well with under estimated transmissivity values the well yield could have been larger conversely for over estimated transmissivity values will not supply the estimated yield.

**Key words: -kobo pressurize irrigation project, pumping test, single well test, step drawdown test**

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### List of Abbreviation

- T        transmissivity
- K        hydraulic conductivity
- S        storativity
- t        time measured since the start of pumping and
- t'        time since the start of the recovery phase
- $r_c$  radius of the unscreened
- $s_w$  drawdown in the well
- s'        residual drawdown
- Q        discharge
- W (u)   well function
- r        radius of well
- $\Delta$     delta (change drawdown on one log cycle)
- L        screen length
- Km      kilometer
- amsl    meter above sea level
- B        slope
- C        intercepts



## 1 INTRODUCTION

For many years and even at present, utilization of water has preceded without a basic understanding of the hydrologic system and the water budgets. Even, those ground water development projects that have been under implementation currently were planned based on limited data sources. This does not mean that the entire projects have planning limitations, as it needs its own investigation.

Groundwater is the sub-surface water that occurs beneath the water table in soils and geologic formations that are fully saturated (Freeze and Cherry, 1979). It is one of the most valuable natural resources, which supports human health, economic development, and ecological diversity. Because of its several inherent qualities (e.g., consistent temperature, widespread and continuous availability, excellent natural quality, limited vulnerability, low development cost, drought reliability), it has become an important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Todd, 1980). Of the 37 Mkm<sup>3</sup> of freshwater estimated to be present on the earth, about 22% exist as groundwater, which constitutes about 97% of all liquid freshwater potentially available for human use (Foster, 1998).

At present Ethiopia has a population of over 80 million growing at a rate of over 3 % per annum. Access to the fruits of water resources development is beyond the reach of the overwhelming majority of the Ethiopian population.

The water resources potential of the country pre-supposes a good scientific and technical capability for its judicious and sustained development Ethiopia, with a very limited experience in irrigation, hydropower, reliable water supply for community and other areas of water resources development needs to exert a concerted and systematic effort to raise its capability in water resources assessment and development. The fast growing population and the recurrent drought has demanded such an effort more than ever.

The country has enormous surface water and groundwater resources, although the distribution is uneven. Very little has been done in the study and development of the

water resources, particularly in areas of groundwater resources. Groundwater utilization has been highly confined to community water supply using shallow hand dug wells and unprotected springs. Limited deep boreholes were drilled in few rural areas, mainly in the rift valley, in some peripheral semi-arid regions and in the vast highland volcanic terrain.

The use of deep groundwater from boreholes for agriculture is almost non-existent. Very recently a new project is initiated in the Raya Valley of northern Ethiopia to irrigate the Raya Plain using groundwater from a number of deep and shallow wells. Few springs are also being used for local irrigation in the rugged arid and semi-arid regions of northern, central and parts of southern Ethiopia.

Analyzing and evaluating pumping test data, however, is as much an art as a science. It is a science because it is based on theoretical models that the engineer must understand and on thorough investigations that he must conduct into the geological formations in the area of the test. It is an art because different types of aquifers can exhibit similar drawdown behaviors, which demand interpretational skills on the part of the engineer.

The study area of this research is Kobo Valley catchment, situated south of Raya Valley in Northern part of Ethiopia. It covers a total area of 811 sq. kilometers and has a perimeter of 128km. The low lying inter mountain valley part of the area is known by its high groundwater potential and semiarid climate. Currently, it is underground water source exploitation and investigation mainly for irrigation because of scarce surface water and low annual rainfall that vary seasonally such gaps can be seen even during the current field visit that the boreholes are no meteorological stations on the highland part of the catchment and no surface water gauging stations over the area. However, safe groundwater abstraction and proper groundwater management is crucial for Sustainability of the resource.

The amount of groundwater that is currently discharged for irrigation purpose in Raya and Kobo valley is 10755.9 m<sup>3</sup>/day and 30600 m<sup>3</sup>/day, respectively. This is estimated to be about 0.06% and 6.91% of the total safe groundwater discharge of each valley,

respectively. The annual average groundwater recharge in the Raya valley is estimated to be 84 million cubic meters and that of the Kobo valley is 122.9 million cubic meters (dessie nadew 2005)

In the study area collect seventeen single well constant pumping test and recovery test data .from seventeen wells fourteen wells are including step draw down test data and from seventeen wells fourteen wells are unconfined aquifer and 3 wells are confined aquifer. Three contractors (CGC-OC,Chaina Geo and tana) are drilling all seventeen borehole.

In this thesis EXCEL tool is used to solve Theis, Cooper-Jacob equations and the curve fitting concluded on Ms Excel (2007).As an additional tool for estimating hydraulic parameters by AQUI TEST Software 3.5 via automatic curve fitting method with to use comparison. Theis type-curve fitting method is one of the widely applied methods, to determine the aquifer parameters and simplified such bulky tasks. This type-curve-matching with pumping test data conducted by adopting the EXCEL spread sheet, as EXCEL tool permits of the data entry and handling plotting features effectively .This method preferred to for it is handy and cheap to apply in analyzing the pumping test data for determination of the aquifer parameters. By using the above all method used to evaluate and compare kobo irrigation wells hydraulic parameters.

In the study area 17 single well constant pumping test and recovery test data were collected besides 14 of 17 wells have the step drawdown test data. In this research where conducted to re- analyze the transmissivity value estimated for design. For each well three transmissivity value were estimated the geometric mean value estimated ranges from a minimum of  $26\text{m}^2/\text{day}$  to  $2790\text{m}^2/\text{day}$ . For the same wells the range of transmissivity value used in the design of the kobo irrigation scheme was  $55.2\text{m}^2/\text{day}$  to  $3145\text{m}^2/\text{day}$ . Among the 17 wells 11 wells were found to under estimate transmissivity obtain in this research 4- 82% but one are found to overestimate the transmissivity with 8-178%.given the fact that both this research and the design document uses the same well test data, such huge variation in the estimation could only because by data interpretation techniques. Appropriate data correction shall be made test for any well analysis for hydraulic parameter estimations

It covers a total area 811 km<sup>2</sup> and named Horat – Golina basin. The largest portion of the area is highly dissected topographic high which accounts 65% and the remaining portion covers a valley and its escarpment. The catchment area has three types of physiographic features:- the planer inters mountains valley part, the valley escarpment, and highly dissected highlands. There is a large topographic difference between the valley and the highland. The average altitude of the valley floor ranges from 1355 m a.m.s.l. to 1610 m a.m.s.l, while the mountain ridges range from 1610m a.m.s.l. to 3600 m a.s.l. The average annual temperature in the valley plain ranges from 17.5°C to 26°C. The average monthly temperatures in Kobo area range from 18.7°C in December to about 26°C in June. The mean annual rainfall of the watershed is estimated to be about 798.4 mm. About 80% of the annual rainfall amount occurs during the main rainy season. The plain valley part of the area receives an average annual rainfall of 700 mm.

The Ethiopian flood basalts (or traps) cover an area of about 600,000 km<sup>2</sup> with a layer of basaltic and felsic volcanic rocks. The thickness of this layer is highly variable but reaches 2km in some regions. The volcanic and shallow intrusive rocks have a total volume of about 350,000 km<sup>3</sup> (Mohr, 1983b; Mohr and Zanettin, 1988 cited in Dessie Nadew, 2003). The studied area is a basin at the western edge of the Danakil basin.

The main lithological units in the study area are basaltic rocks that form the western highlands and escarpments, Rhyolite which form the eastern ridge (Zobel ridge) overlying the basalt and the alluvial deposits that originate from these basalts on the valley floor.

To achieve the intended objective stated appropriate methods were followed in three stages. The main stages of the activities are presented as pre-field, field work and post field stages

### **1.1 Statement of the problem**

Even though the kobo valley is rich in fertile soil for agricultural production, the lowland area has low rainfall which is insufficient for higher agricultural production. In the study area pumping test are single well test. The draw down in single well test influenced by well loses and well bore storage. Single well test advantages include their short

duration and (in some cases) their ease of application. Their main disadvantage is that, while a full pumping test will investigate the entire aquifer volume between the pumping well and the observation borehole, a single borehole test will typically only stress a small volume of aquifer immediately around the borehole. Therefore, the derived values may not be representative of the aquifer as a whole.

In kobo irrigation project wells hydraulic parameter of the alluvial sediment aquifer such as storativity and specific yield values do not resemble real world data of an aquifer. In reality storativity Value of confined aquifer ranges from 0.005 to 0.00005 and the value of specific yield of unconfined aquifer is 0.01-0.3.but kobo irrigation wells pumping test design data range out from this real world data. Such variation is by the data interpretation and evaluations. This study will investigate the cause behind such unexpected hydraulic parameter estimations.

## **1.2 Objective of the research**

### **1.2.1 General objective**

The primary objective of this study is evaluation of single well pumping test data to determine the aquifer hydraulic parameters of kobo irrigation well.

### **1.2.2 Specific objective**

- ❖ Evaluation of the existing well data interpretation
- ❖ To evaluate and compare estimated transmissivity, by using their curve matching method on excels sheet and aquifer test software.
- ❖ Estimating and comparing the hydraulic parameters on the basis of standard interpretation technique
- ❖ Evaluation of the cause behind under estimation or over estimation of hydraulic parameters
- ❖ The physical meaning behind under estimation or over estimation of hydraulic parameters

## 2 LITERATURE REVIEW

### 2.1 Ground water

Ground water is an important source of water supply throughout the world. Its use in irrigation, industry, municipalities and rural water homes continues to increase. Shortage of ground water in areas where excessive withdrawals have occurred

Emphasize the need for accurate estimates the importance of proper planning to insure the continued availability of water supplies. There is a tendency to think of ground water as being the primary water source in arid regions and of surface water is in humid regions.

Hydrologic budget, water budget, or water balance is a measurement of continuity of the flow of water, which holds true for any time interval and applies to any size area ranging from local scale areas to regional scale areas.

The hydrologists usually should consider an open system for which quantification of the hydrologic cycle for that system becomes a mass balance equation which the change of storage of water ( $ds/dt$ ) with respect to time within that system is equal to the inputs (I) to the system minus out (O) from the system. Ground water system hydrologic budget:-

$$\Delta S_g = I + G_i - G_o - Q_g - E_g - T_g \quad 2.1$$

Where:-  $G_i$  = ground water flow into the system,  $G_o$  = ground water flow out of the system,  $\Delta S_g$  = change in ground water storage,  $E_g$  = the evaporation. (David Keith TODD, groundwater hydrology) Aquifer well pumping test method is a widely adopted method to determine the aquifer parameters in groundwater hydrology. Equilibrium equation known as Thiem's equation can be used to determine the hydraulic conductivity or the transmissivity of confined aquifer from the fully penetrating well pumping test. Equilibrium equation also can be developed for the unconfined aquifer with Dupuit assumptions. However, equilibrium equations are valid only for steady flow conditions. Under this condition, the aquifer is in equilibrium in regard to flow to the well being pumped. The aquifer may take several days to reach the equilibrium condition for any constant pumping rate.

## 2.2 History of Groundwater Usage

It is uncertain when mankind first started extracting groundwater by artificial means such as wells or infiltration galleries. Early humans most likely drank from surface streams. They may also have discovered groundwater through the discharge of natural springs in some parts of the world, and used this source in addition to surface streams. As streams dried up in hot weather, people learned to dig into the alluvium to find water below the surface.

Much speculation arose about the origin of water emanating from springs, and early theories proposed a hollow earth filled with water. The ancient Greeks were the first to record their theories, germinated no doubt from their observation of disappearing rivers and emerging springs in the limestone *karst* areas of Greece and the rest of the Balkan Peninsula. Davis and Dewiest (1966) summarize the history of groundwater use and the development of the body of knowledge now surrounding it.

The earliest recorded use of groundwater is found in the 16th chapter of the *Book of Genesis*, in which it tells of a spring in the desert. Egyptians are reported to have perfected core drilling by 3000 BC. Ancient Chinese invented the churn drill (similar to the modern cable-tool drill) and drilled to a depth of 1500 meters (Tolman, 1937). Western Europe did not engage in drilling until the 12th century when churn drilling was developed there. Much of the impetus for development of drilling methods was generated in the area around Artois, France, where artesian water was in demand. In the latter part of the 19th century, the rotary drilling technique was developed, and by 1890 the *hydraulic rotary method* had been perfected. This was probably the most significant single advance in drilling technology (Davis and DeWiest, 1966).

## 2.3 Types of Aquifer

In the analysis and evaluation of aquifer test data, three main types of aquifer are distinguished: the confined, unconfined, and leaky aquifer (Figure 1).

### 2.3.1 Confined aquifer

Confined aquifer is a completely saturated aquifer upper and lower boundaries are *aquicludes*. In confined aquifers the pressure of the water is usually higher than that of the atmosphere and the water level in wells tapping such aquifers stands above the top of the aquifer (see Figure 1 A). The piezometric surface is the imaginary surface to which the water will rise in wells penetrating the aquifer. When the water level in wells tapping such aquifers stands above the ground surface, they are called free flowing wells or artesian wells.

### 2.3.2 Unconfined aquifer

An unconfined aquifer is a partly saturated aquifer bounded below by an aquiclude and above by the free water table or phreatic surface (see Figure 1B). At the free water table, the pressure of the groundwater equals that of the atmosphere. The water level in a well penetrating an unconfined aquifer does not, in general, rise above the water table, except when there is vertical flow.

### 2.3.3 Leaky aquifer

A leaky aquifer, also known as a semi confined aquifer, is a completely saturated aquifer that is bounded below by an aquiclude and above by an *aquitard*. The overlying aquitard may be partly saturated when it extends to the land surface (Figure 1 C )or is fully saturated when it ( Figure 1D). The piezometric level in a well tapping a leaky aquifer may coincide with the water table if there is a hydrologic equilibrium between the aquifer's recharge and discharge; it may rise or fall below the water table in areas with upward or downward flow, in other words, in discharge or recharge areas.

A multilayered aquifer is a special case of the leaky aquifer. The aquicludes in (Figures 1C and 1D) are then aquitards, with other aquifers occurring at greater depths. In deep sedimentary basins permeable and less permeable layers is very common. Aquifer bounded by an aquitard and an aquiclude (Figures1C and 1D). In both cases, the saturated thickness is a constant. For unconfined aquifers, the saturated thickness is equal to the difference between the free water table and the aquiclude (Figure 1B) Because the water table changes its position with time, the saturated thickness of an unconfined aquifer is not constant, but variable. Whether constant or variable, the

saturated thickness of an aquifer is denoted by the symbol  $D$ . Its order of magnitude can range from several meters to hundreds or even thousands of meters. For aquitards in leaky aquifers, the saturated thickness can be variable or constant. In Figure 1C, the aquitard is partly saturated and has a free water table. Its saturated thickness depends upon the position of the water table. In Figure 1D, the aquitard is bounded by two aquifers and is fully saturated. Its saturated thickness is physically determined and thus constant (Delleur –jw 1999)

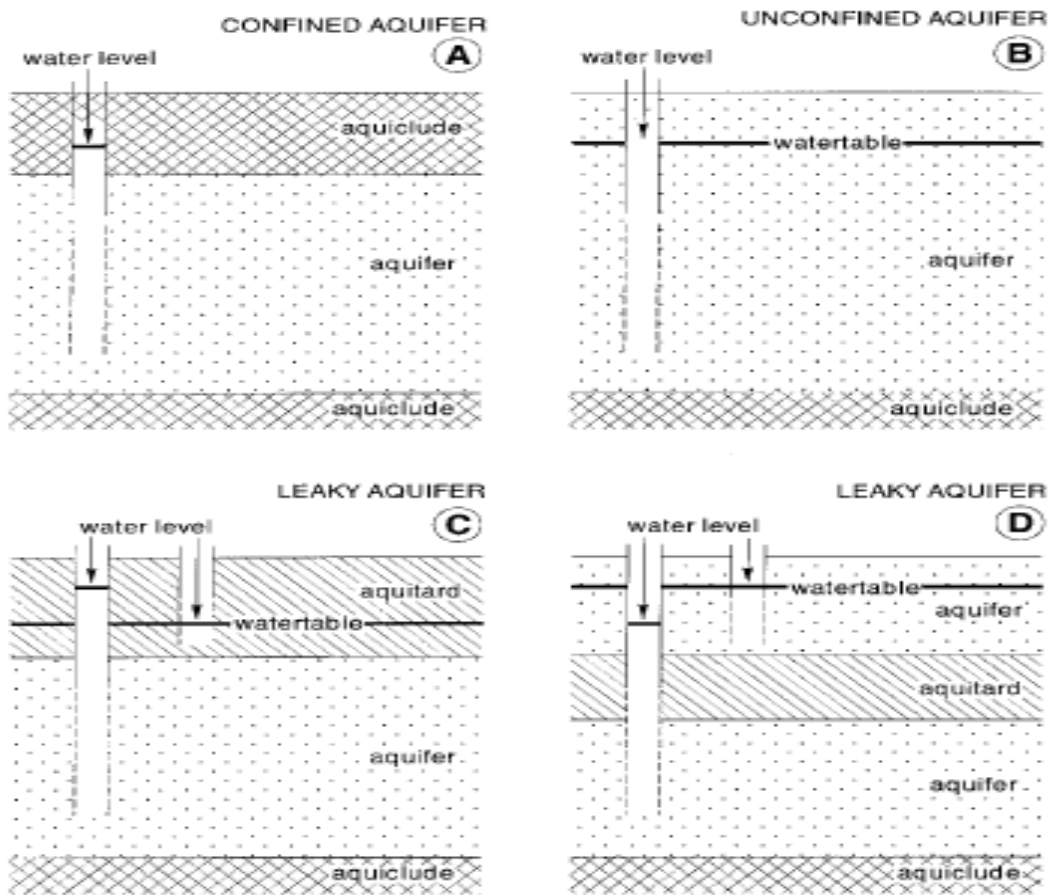


Figure1 Different types of aquifer

## 2.4 Pumping Tests

Pumping tests are used to determine in-situ properties of water-bearing formations and define the overall hydro geologic regime. Such tests can determine transmissivity (T), hydraulic conductivity (K), storativity (S), connection between saturated zones, identification of boundary conditions, and the cone of influence of a pumping well in a ground water extraction system. To enable proper test design, it is important to define objectives and understand site hydrogeology as much as possible.

The principle of a pumping test is that if we pump water from a well and measure the discharge of the well and the drawdown in the well and in piezometers at known distances from the well, we can substitute these measurements into an appropriate well-flow equation and can calculate the hydraulic characteristics of the aquifer.

### 2.4.1 Single Well Test

A single well test involves pumping, displacing, or adding water and measuring changes in water levels in the well. This type of test allows a rapid and economical calculation of K, and T of the zone of interest at a single location. Single well tests also can determine response criteria for observation wells in multiple well pumping tests.

Single well tests should be conducted in properly designed and developed wells or piezometers. If development is inadequate, the presence of drilling mud filter cake (use of mud is not recommended) or the smearing of fine-grained material along the borehole wall may result in data that indicate an artificially low K. This may lead to underestimation of contaminant migration potential.

A single well pumping test involves pumping at a constant or variable rate and measuring changes in water levels during pumping and recovery. Such tests are used to determine T and K when water level recovery is too rapid. The drawdown in a pumped well is influenced by well loss and well-bore storage. Well loss is responsible for drawdown being greater than expected from theoretical calculations and can be classified as linear or non-linear. Linear loss is caused by compaction and/or plugging of

subsurface material during well construction and installation and head loss in the filter pack and screen. Non-linear loss includes head loss from friction within the screen and suction pipe. Since well-bore storage is large when compared to an equal volume of formation material, it must be considered when analyzing drawdown data from single well pumping tests (Kruseman and de Ridder, 1991). However, Papadopoulos and Cooper (1967) observed that the influence of well-bore storage on drawdown decreases with time ( $t$ ) and becomes negligible at  $t > 25r_c$ , where  $r_c$  is the radius of the unscreened part of the well where the water level is changing. The effects of well-bore storage on early-time drawdown data can be determined by a log-log plot of drawdown ( $s_w$ ) versus time ( $t$ ). Borehole storage effects exist if the early-time drawdown data plots as a unit-slope straight line (Kruseman and de Ridder, 1991).

### **General Assumption of Single Well Test**

- ❖ The aquifer has an apparently infinite areal extent.
- ❖ The zone is homogeneous and of uniform thickness over the area influenced by the test
- ❖ Prior to the test, the water table or piezometric surface is (nearly) horizontal over the area influenced and extends infinitely in the radial direction.
- ❖ The head in the well is changed instantaneously at time  $t = 0$ .
- ❖ The inertia of the water column in the well and the linear and non-linear well losses are negligible (i.e, well installation and development process are assumed to have not changed the hydraulic characteristics of the formation).
- ❖ The well diameter is finite; hence storage in the well cannot be neglected.
- ❖ Ground water density and viscosity are constant.
- ❖ No phases other than water (such as gasoline) are assumed to be present in the well or saturated portion of the aquifer.
- ❖ Ground water flow can be described by Darcy's Law.
- ❖ Water is assumed to flow horizontally

## 2.4.2 Multiple Well Pumping Tests

A multiple well test is implemented by pumping a well continuously and measuring water level changes in both the pumped and observation wells during pumping or subsequent recovery. Properly designed and conducted multiple well tests can be used to define the overall hydro geologic regime of the area being investigated, including T, S and/or specific yield of a zone. They also can help design municipal well fields, predict rates of ground water flow, determine interconnectivity between saturated zones, and design a remediation system.

Two basic types are constant discharge and variable discharge. The former is performed by pumping at a constant rate for the duration of the test, while the latter is distinguished by changes in rate. Measurements obtained from the pumping well generally are less desirable for calculating hydraulic properties because of the irregularities induced from the operation of the pump and well bore storage. Obtaining data from observation well(s) allows for characterization of the pumped zone over a larger area.

### **General assumption of multiple well tests**

The aquifer is infinite in a real extent.

- ❖ The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test.
- ❖ Prior to pumping, the piezometric surface is horizontal, or nearly so, over the area to be influenced by the test.
- ❖ The well penetrates the entire thickness of the aquifer and, thus, receives water by horizontal flow.
- ❖ The water removed from storage in the aquifer is discharged instantaneously with decline of head.
- ❖ Non-linear well losses are negligible

### 2.4.3 Recovery Tests

When the pump is shut down after a pumping test, the water levels in the well and the piezometers will start to rise. This rise in water levels is known as residual drawdown,  $s'$ . It is expressed as the difference between the original water level before the start of pumping and the water level measured at a time  $t'$  after the cessation of pumping. Figure 3 shows the change in water level with time during and after a pumping test.

It is always good practice to measure the residual drawdowns during the recovery period. Recovery-test measurements allow the transmissivity of the aquifer to be calculated, thereby providing an independent check on the results of the pumping test, although costing very little in comparison with the pumping test. Residual drawdown data are more reliable than pumping test data because recovery occurs at a constant rate, whereas a constant discharge during pumping is often difficult to achieve in the field.

Applying this principle, we assume that, after the pump has been shut down, the well continues to be pumped at the same discharge as before, and that an imaginary recharge, equal to the discharge, is injected into the well. The recharge and the discharge thus cancel each other, resulting in an idle well as is required for the recovery period.

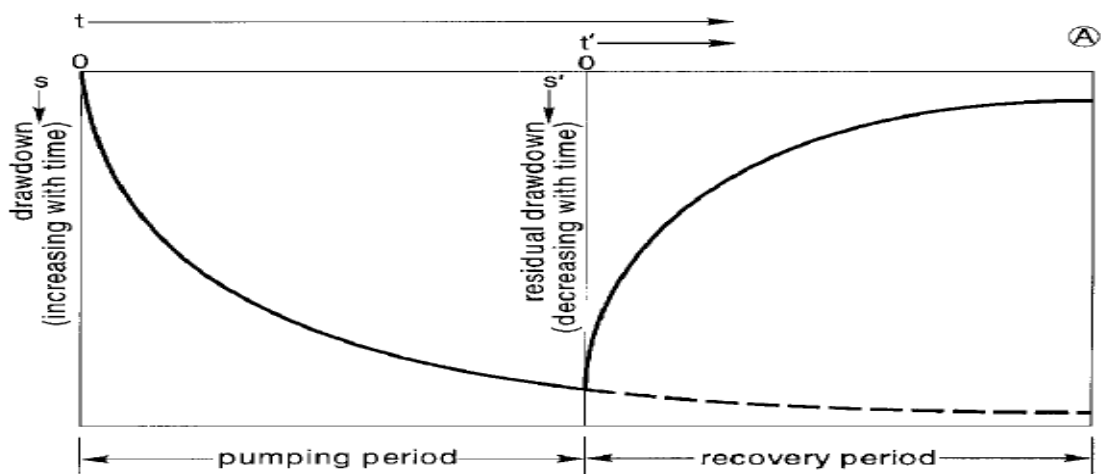


Figure 2 Recovery tests graph

### 2.4.4 Step-Drawdown Tests

A step-drawdown test is a single-well test in which the well is pumped at a low constant-discharge rate until the drawdown within the well stabilizes. The pumping rate is then increased to a higher constant discharge rate and the well is pumped until the drawdown stabilizes once more. This process is repeated through at least three steps, which should all be of equal duration, say, a few hours each.

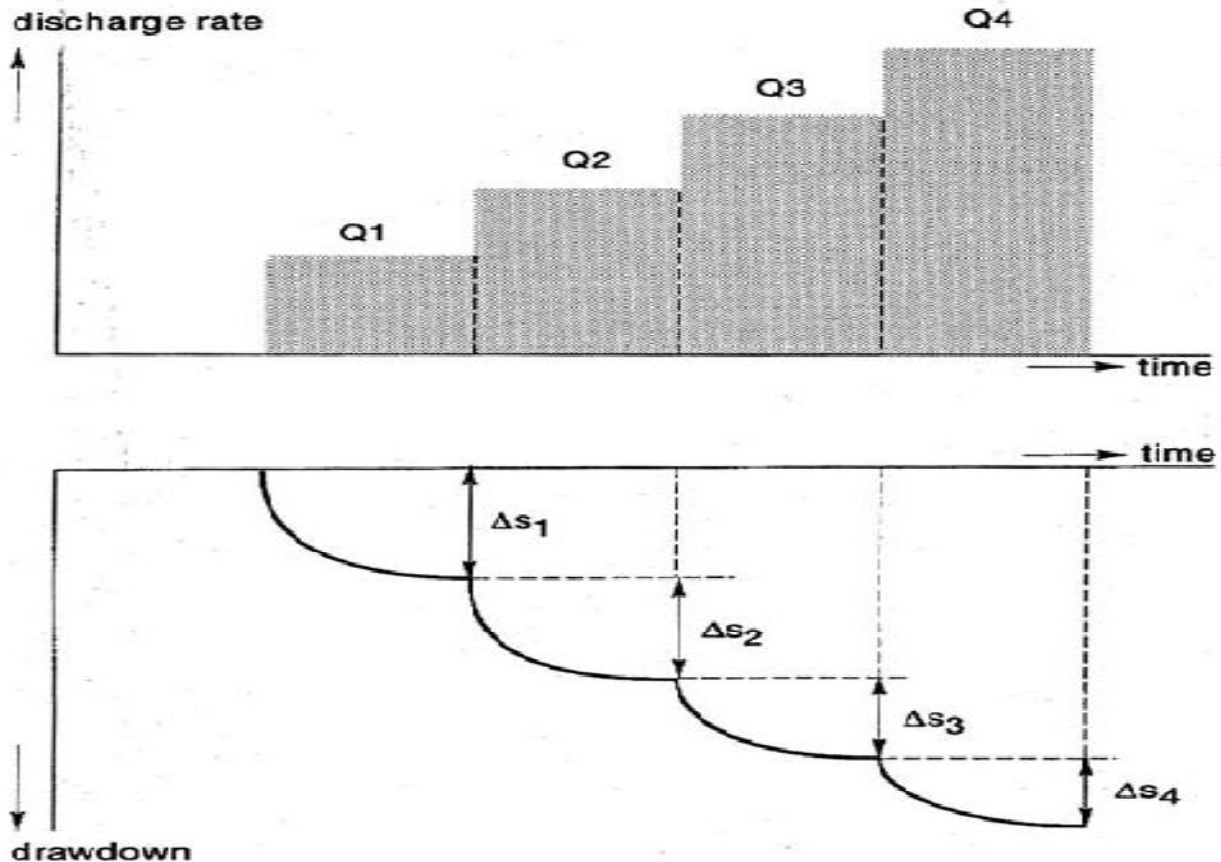


Figure 3 Principles of a step-drawdown test.

In step-drawdown analyses, use is made of so-called diagnostic plots. Values of  $\frac{s_w}{Q}$  versus  $Q$  are therefore plotted on arithmetic paper, where  $s_w$  represents the drawdown at the end of each step.

Various configurations of diagnostic plots are then possible

- ❖ The points fall on a horizontal line. This implies that  $\frac{s_w}{Q} = B$  reduces to

$$S_w = BQ \quad 2.2$$

Hence, there are no nonlinear well losses. This situation is only encountered with very low pumping rates. The well will act differently if the pumping rates are increased.

❖ The points fall on a straight line under a slope. This means that

$$\frac{S_w}{Q} = B + CQ \quad 2.3$$

Equation (2.2) then reduces to

$$S_w = BQ + CQ^2 \quad 2.4$$

Equation (2.3) is known as the Jacob's equation. Based on this equation, Jacob (1947) developed an analysis method to calculate the values of  $B$  and  $C$ .

The points fall on a curved line, i.e.,  $P \neq 2$  in Equation (2.4). When a concave curve can be drawn through the points, it implies that  $P > 2$  and for a convex curve that  $P < 2$ . For these cases, Rorabaugh (1953) developed an analysis method to calculate the values of  $B$ ,  $C$ , and  $P$ . Both analysis methods may be applied to confined, unconfined, and leaky aquifers.

The values of  $B$  and  $C$  can be found directly from the diagnostic plot of  $\frac{S_w}{Q}$  versus  $Q$  itself; it will yield a straight line whose slope is equal to  $C$ , the value of  $B$  can be found by extending the straight line until it intercepts the  $Q = 0$  axis.

A step-drawdown test was made in an unconfined aquifer shows the time drawdown plot on semi-log paper. This implies that the observed drawdown values at the end of each step need to be corrected. This can be done using the following procedure as developed by Hantush- Bierschenk (Hantush, 1964).

#### 2.4.5 Well-Performance Tests

The drawdown in a pumped well consists of two components aquifer losses and the well losses. A well-performance test is conducted to determine these losses. Aquifer losses are the head losses that occur in the aquifer where the flow is laminar. They are time-dependent and vary linearly with the well discharge. In practice, the extra head loss induced, for instance, by partial penetration of a well is also included in the aquifer losses.

Well losses are divided into linear and non-linear head losses. Linear well losses are caused by damage to the aquifer during drilling and completion of the well. They comprise, for example, head losses due to compaction of the aquifer material during drilling, head losses due to plugging of the aquifer with drilling mud, which reduce the permeability near the bore hole; head losses in the gravel pack; and head losses in the screen. Amongst the non-linear well losses are the friction losses that occur inside the well screen and in the suction pipe where the flow is turbulent, and the head losses that occur in the zone adjacent to the well where the flow is usually also turbulent. All these well losses are responsible for the drawdown inside the well being much greater than one would expect on theoretical grounds.

## 2.5 Well Efficiency

The relationship between drawdown and discharge can be expressed as the *specific capacity* of a well,  $Q/s_w$  which describes the productivity of both the aquifer and the well. The specific capacity is not a constant but decreases as pumping continues and also decreases with increasing  $Q$ . The well efficiency,  $E_W$  is defined as the ratio of the aquifer head loss to the total head losses; it reads when expressed as a percentage

$$E_W = \left\{ \frac{B_1 Q}{BQ + CQ^P} \right\} \quad 2.5$$

The well efficiency according to Equation (2.5) can be assessed when both the results of a step-drawdown and those of an aquifer test are available. The former are needed for the values of  $B$ ,  $C$ , and  $P$  and the latter for the value of  $B_1$ .

In practice, only the results of a step-drawdown test are usually available. The substitution of the  $B$ ,  $C$ , and  $P$  values into Equation (2.5) would overestimate the well

efficiency, because  $B > B_1$ . For these cases, Driscoll (1986) introduced another parameter  $L_p$  being the ratio of the laminar head loss to the total head losses; it reads when expressed as a percentage.

$$L_p = \left\{ \frac{B_1 Q}{BQ + CQ^F} \right\} * 100 \quad 2.6$$

## 2.6 Aquifer and Well Losses

The drawdown in a pumped well consists of two components: the aquifer losses and the well losses (see figure 5). Aquifer losses are the head losses that occur in the aquifer where the flow is laminar. They are time dependent and vary linearly with the well discharge. The drawdown  $s_1$  corresponding to this linear aquifer loss can be expressed as.

$$S_1 = B_1(r_w, t) * Q \quad 2.7$$

Where  $B_1$  is the linear aquifer loss coefficient in  $\text{day/m}^2$

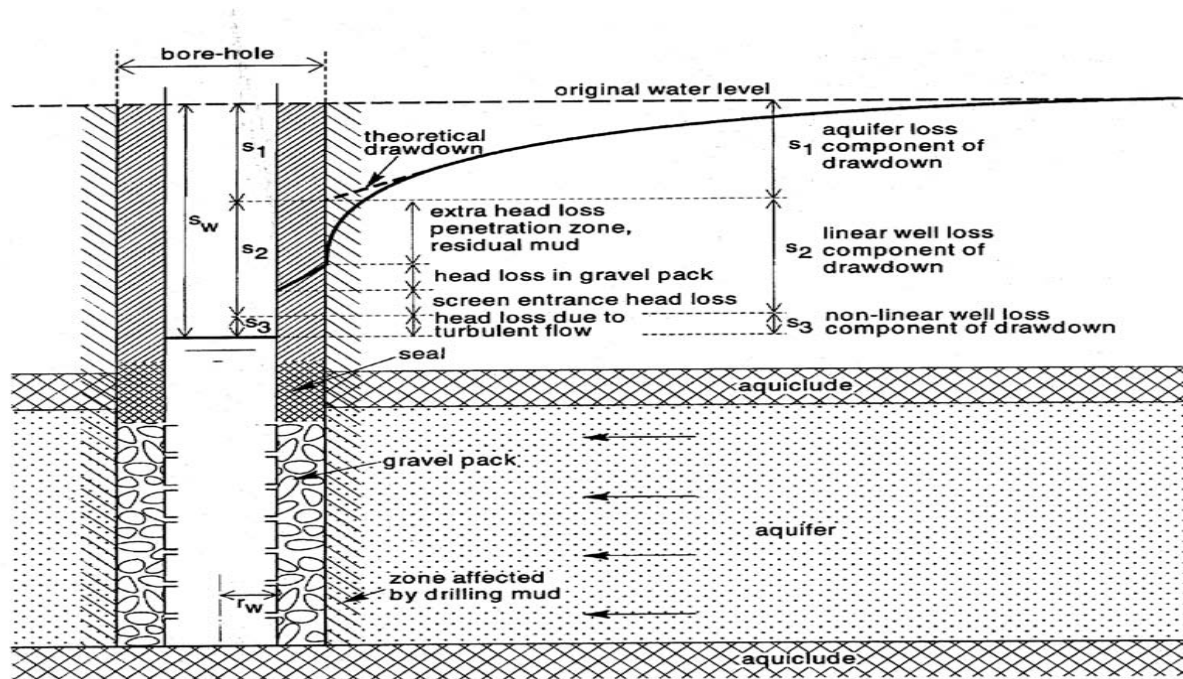


Figure 4 various components of head losses in a pumped well

This coefficient can be calculated from the well flow equations

$$B_1(r_w, t) = \frac{W(u)}{4\pi T} \quad 2.8$$

From the results of aquifer-test analyses, the values for transmissivity  $T$  and storativity  $S$  can be used to calculate  $B_1$  values as function of  $r_w$  and  $t$ . Well losses are divided into linear and nonlinear head losses. Linear well losses are caused by damaging the aquifer during drilling and completion of the well. They comprise, for example, head losses due to the compaction of the aquifer material during drilling; head losses due to plugging of the aquifer with drilling mud, which reduces the permeability near the bore hole; head losses in the gravel pack and head losses in the screen. The drawdown  $s_2$  corresponding to this linear well loss can be expressed as

$$S_2 = B_2 Q \quad 2.9$$

Where  $B_2$  is the linear well loss coefficient in day/m<sup>2</sup>

Among the nonlinear well losses are the friction losses that occur inside the well screen and in the suction pipe where the flow is turbulent, and head losses that occur in the zone adjacent to the well where the flow is usually also turbulent. All these losses responsible for the drawdown inside the well are much greater than one would expect on theoretical grounds. The drawdown  $s_3$  corresponding to this nonlinear well loss can be expressed as

$$S_3 = C Q^P \quad 2.10$$

Where  $C$  is the nonlinear well loss coefficient in day and  $P$  is an exponent. The general equation describing the drawdown in a pumped well as function of aquifer/well losses and discharge rate thus reads

$$S_W = (B_1 + B_2)Q + C Q^P = BQ + C Q^P \quad 2.11$$

Where  $S_W = S_1 + s_2 + s_3$  Jaco (1947) used a constant value of 2 for the exponent  $P$

According to Lennox (1966), the value of  $P$  can vary between 1.5 and 3.5

The value of  $P = 2$  as proposed by Jacob is, however, still widely accepted. Values of the three parameters  $B$ ,  $C$ , and  $P$  in (Equation 2.11) can be found from the analysis of so-called step-drawdown.

## 2.6 Well loss correction

The drawdown in a pumped well consists of two components. aquifer losses and the well losses. A well-performance test is conducted to determine these losses. Aquifer losses are the head losses that occur in the aquifer where the flow is laminar. They are time-dependent and vary linearly with the well discharge. In practice, the extra head loss induced, for instance, by partial penetration of a well is also included in the aquifer losses.

$$\eta = \frac{B}{B+CQ} \quad 2.12$$

The above equation written as

$$\eta = \frac{S_{aquifer}}{S_{aquifer} + S_{well}} \quad 2.13$$

Draw down on the aquifer

$$S_{Aquifer} = \eta S_{aquifer} + \eta S_{well} \quad 2.14$$

$$\text{Then calculate } w = \frac{S_{aquifer}}{\eta} - S_{aquifer} = S_{aquifer} \left( \frac{1}{\eta} - 1 \right) \quad 2.15$$

$$S_{measured} = S_{well} + S_{aquifer} \quad 2.16$$

Correct the drawdown data by the above formula by using step draw down test data.

## 2.7 Aquifer properties

Aquifer properties essential depend up on the composition of aquifer. The most important property of aquifer are transmissivity, storage, specific yield.

### 2.7.1 Transmissivity

The transmissivity is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. Consequently, the transmissivity is the rate of flow under a hydraulic gradient equal to unity through a cross section of unit width over the whole saturated thickness of the water-bearing layer.

The capacity of an aquifer to transmit water of the prevailing kinematic viscosity is referred to as its transmissivity. The transmissivity (T) of an aquifer is equal to the hydraulic conductivity of the aquifer multiplied by the saturated thickness of the aquifer.

Thus

$$T = Kb \quad 2.17$$

Where T is transmissivity, K is hydraulic conductivity, and b is aquifer thickness.

As is the case with hydraulic conductivity, transmissivity is also defined in terms of a unit hydraulic gradient. (equation 17) is combined with Darcy's the result is an equation that can be used to calculate the quantity of water (q) moving through a unit width (w) of an aquifer. Darcy's law is

$$q = KA \left( \frac{dh}{df} \right) \quad 2.18$$

Equation 19 modified to determine the quantity of water (Q) moving through a large width (W) of an aquifer is

$$Q = TW \left( \frac{dh}{df} \right) \quad 2.19$$

Equation 20 is also used to calculate transmissivity, where the quantity of water (Q) discharging from a known width of aquifer can be determined as, for example, with stream flow measurements. Rearranging terms, we obtain

$$T = \frac{Q}{W} \left( \frac{df}{dh} \right) \quad 2.20$$

### 2.7.2 Storage

A simple mass balance equation for groundwater flow through a unit volume of porous medium is given as

$$Q_{out\Delta t} = Q_{in\Delta t} + \Delta S \Delta t$$

2.21

where  $Q$  is total flow rate in volume per unit time, and  $\Delta S$  is the volume per unit of time going into or coming out of storage in time,  $t$ .

In a saturated porous medium that is confined between two transmissivity layers of rock or clay, water will be stored in the pores of the medium by a combination of two phenomena; these are water compression and aquifer expansion.

### 2.7.3 Specific storage

As water is forced into the system at a rate greater than it is being extracted, the water will compress and the matrix will expand to accommodate the excess. In a unit volume of saturated porous matrix, the volume of water that will be taken into storage under a unit increase in head, or the volume that will be released under a unit decrease in head is called *specific storage*, and is shown as

$$s_s = \rho g (\alpha + n\beta)$$

2.22

Where  $\beta$  is aquifer compressibility,  $\rho$  is fluid density,  $g$  is gravitational acceleration,  $n$  is porosity, and  $\alpha$  is water compressibility. This unit has the dimension of  $1/L$  and is quite small, usually 0.0001 or less.

The storage coefficient of an aquifer, or simply, the storativity,  $S$ , is given as

$$s = s_s b$$

2.23

Where  $b$  is the saturated thickness of the aquifer

Storativity is defined as the volume of water per unit aquifer surface area taken into or released from storage per unit increase or decrease in head, respectively. It is a dimensionless quantity. In confined aquifers the value of storativity ranges from 0.005 to 0.00005.

In unconfined porous media, that is, where there is no overlying confining cover, storage of water in its upper part is defined as specific yield,  $S_y$ . This is the ratio of the volume of water that drains from a saturated porous matrix under the influence of gravity to the

total volume of the matrix, per unit drop in the water table. Specific yield is normally much greater than specific storage, as water released from elastic storage leaves the pores still saturated. Specific yield is often in the range of 0.2 to 0.3, or three to four orders of magnitude greater than elastic storage.

#### 2.7.4 Specific retention

Gravity drainage will proceed until the forces of surface tension and molecular attraction to the matrix grains become equal to the force of gravity. The ratio of the volume of water retained in the pores to the total matrix volume is known as *specific retention*, or  $S_r$ . In the upper parts of an unconfined porous medium, where elastic storage is not significant, the sum of specific yield and specific retention equals porosity.

#### 2.7.5 Specific yield

The specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline of the water table. In unconfined aquifers, the effects of the elasticity of the aquifer material and the water are negligible, except for a short time after the beginning of pumping. Values of the specific yield of unconfined aquifers are much higher than the storativity of confined aquifers. The orders of magnitude of the specific yield denoted by the symbol  $S_y$  range from 0.01 for clay deposits to 0.47 for coarse sands. Specific yield is also referred to as effective porosity, unconfined storativity, or drainable pore space. Small interstices do not contribute to the effective porosity, because the retention forces in them are greater than the weight of water.

#### 2.7.6 Leakage Factor

The leakage factor describes the spatial distribution of leakage through one or two aquitards into a leaky aquifer or vice versa. It is the square root of the product of the aquifer's transmissivity and the aquitard's hydraulic resistance and is thus defined as  $L$  = it is expressed in meters. Large values of  $L$  originate from a high transmissivity of the aquifer and/or a high hydraulic resistance of the aquitard.

## 2.8 Partial Penetration

When an aquifer is pumped by a partially penetrating well, the assumption that the well receives water from horizontal flow is no longer valid. Hence, the previous equations cannot be used to describe the flow to pumped wells. Due to a contraction of flow lines, partial penetration causes the flow velocity in the immediate vicinity of the well to be higher than it would be otherwise, leading to an extra loss of head. This effect is strongest at the well face, and decreases with increasing distance from the well.

According to Hantush (1962) the drawdown due to pumping in a confined aquifer can be described by the following equation

$$s(r, t) \frac{Q}{4\pi T} [W(u) + fs] \quad 2.23$$

$$f_s \frac{2D}{\pi(b-d)} \sum_{n=1}^{\infty} \left(\frac{1}{n}\right) w(u) \left(u, \frac{n\pi r}{D}\right) * \left[\sin\left(\frac{n\pi d}{D}\right)\right] \left(\cos\frac{n\pi t}{D}\right) \quad 2.24$$

Where

$W(u, n\pi r/D)$  is the dimensionless Hantush well function,  $b$  and  $b'$  are the penetration depths in m of the pumped well and of the piezometer,  $d$  and  $d'$  are the non-screened parts in m of the pumped well and of the piezometer, and  $z = \frac{b'+d'}{2}$

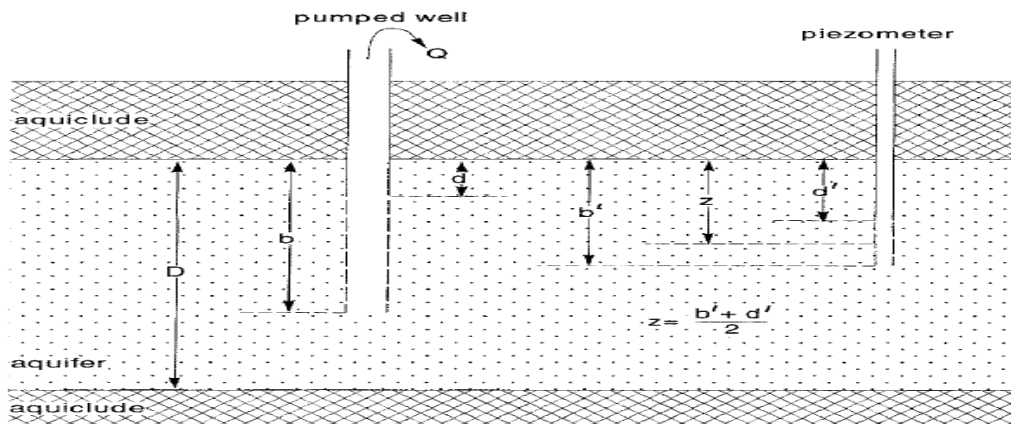


Figure 5 Schematic illustration of the parameters used for the analysis of partially penetrating wells

For a particular well/piezometer configuration, (Equation 2.23) yields constant values for  $f_s$ . The Hantush's modification of the Jacob equation was based on this phenomenon. Hantush (1962) showed that for the straight-line segment, Equation (2.24) can be approximated by

$$s(r, t) = \left( s \frac{2.3Q}{4\pi T} \log \frac{2.25Tt}{r^2 S} e^{f_s} \right) \quad 2.25$$

### 2.8.1 Correction for Partial Penetration

The Theis method assumes that pumping wells fully penetrate the aquifer and all releases from storage are derived directly and solely from the aquifer being pumped. Partial penetration of the well into the aquifer causes vertical component flow to happen in the vicinity of the well and as effect additional head loss is occurred. When the well only partially penetrates the aquifer, the average flow path length is increased so that a greater resistance to flow is encountered. The analysis of the partially penetrating case is difficult but (Kozeny; 1933) provides a practical method to estimate the change in specific capacity (Q/s). (Kozeny; 1933) contributes the following approximate reduction factor to correct specific capacity (Q/s) for the effects of partial penetrations.

$$F = \frac{L}{B} \left[ 1 + 7 \cos \left( \frac{\pi L}{2b} \right) * \sqrt{\frac{r}{2l}} \right] \quad 2.26$$

Where

$b$  = is the total aquifer thickness (m)

$r$  = is the well radius (m); and

$L$  = is screen length (m).

The equation is valid for  $\frac{L}{b} < 0.5$  and  $\frac{L}{r} > 30$ . Accordingly the required correction for the possible effect of partial penetration is conduct supposing the average values of the casing arrangements of the wells and the proposed reduction factor valued as the above equation so as to use the adjusted data for the analysis of such conditions.

## 2.9 Adjustment for Well Loss and Well-Bore Storage

The drawdown data obtained from single pumping well tests can be used to define the characteristics of aquifers parameters in many occasions. However; the drawdown and recovery data from such single pumped well tests are influenced by well losses and well bore storage. In theory of hydraulics of well flow, the well is assumed to have an infinitesimal radius so that the well bore storage can be ignored. Obviously, the effects of well-bore storage will appear at early pumping times, and may last from a few minutes to many minutes, depending on the storage capacity of the well. So as to recognize whether the early time drawdown data are dominated by well bore storage, a log -log plot of drawdown  $S$  versus pumping time  $t$  should be completed. If the early time drawdown plots as a straight-line segment with a slope of unity, we can conclude that the effect of well bore storage exists. This is because a significant amount of fluid may be contained in the pumping well when its radius is large enough. But when the radius of the pumping well is small and the early-time straight-line segment slope in a log-log plot is less than unity at the early pumping time, the well bore storage can be disregarded. Moreover, "Kruseman and N.A. de Ridder suggested that the Curve-fitting methods and straight line methods have been developed and are applicable to analyze single-well tests, even when the early time data are affected by well bore storage (G.P. Kruseman and N.A. de Ridder, 1994)". Hence, correction for the well loss and bore storage loss are not considered in this investigation considering that the radii of the pumping wells are small and curve fitting is applicable to analyze single well tests.

## 2.10 Pumping Test Data Analyses and Methods to Estimate Aquifer Hydraulic Parameters

It is relatively easy to calculate hydraulic characteristics if the aquifer system (i.e. aquifer plus well) are precisely known. This is generally not the case, so interpreting a pumping test is primarily a matter of identifying an unknown system. System identification includes the construction of diagnostic plots and specialised plots. Diagnostic plots are log-log plots of the drawdown versus time since pumping started. Specialised plots are semi-log plots of drawdown versus time, or drawdown versus distance to the well; they are specific for a given flow regime. Both plots must be constructed, because the

diagnostic value lies in the typical combination of the log-log and semi-log plots .The choice of a theoretical model is a crucial step in the interpretation of pumping tests. If the wrong model is chosen, the hydraulic characteristics calculated for the real aquifer will not be correct. Unfortunately the theoretical solutions of well flow problems are not unique. Some models developed for different aquifer systems, yield similar responses when required to handle a given stress. This means that besides the log-log and semi-log plots of the drawdown versus time, all other relevant hydro geological information, e.g litho logy, boundary conditions, should be taken into account.

### 2.10.1 Theis's Curve-Fitting Method

Theis (1935) noted that when a well penetrating an extensive confined aquifer is pumped at a constant rate, the influence of the discharge extends out ward with time. The rate of decline in head, multiplied by the storativity and summed over the area of influence equals the discharge.Theis' equation, which was derived from the analogy between the flow of ground waterand the conduction of heat, is written as:-

$$S = \frac{Q}{4\pi T} W(u) \quad 2.27$$

Where: - S= the drawdown in m measured in a piezometer at a distance r in m from the well

Q = the constant well discharge in m<sup>3</sup>/d;

T = the transmissivity of the aquifer in m<sup>2</sup>/d;

W (u) = is a particular exponential integral, with u as the argument, which in this usage is read as the well function of u.

$$U = \frac{r^2 S}{4Tt} \text{ and consequently}$$

$$S = \frac{4Ttu}{r^2} \quad 2.28$$

S = the storage coefficient;

t = the time since pumping started.

W (u) can be written as a series:

$$W(U) = -0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} \dots \dots \dots \quad 2.29$$

This method is one of the widely applied methods in groundwater hydrology to determine S and T. However, this method requires curve matching of a type-curve and time drawdown data from a pumping well test. Typically, this is done using a type-curve (W (u) Vs u) plotted on a logarithmic graph paper and the drawdown(s) data curve plotted on another transparent logarithmic graph paper (s Vs r<sup>2</sup>/t) with the same scale, and superimposing and sliding the transparent one over the other to get the best possible match while keeping the coordinate axes of two plots parallel. Obviously this is a tedious approach. Based on the coordinates of a matching point from both plots (W (u), u, s, and r<sup>2</sup>/t) in the matched position, the values of S and T can be determined using Theis non equilibrium equation.

This equation describes the flow to a well in an aquifer system with the following characteristics:

- ❖ A confined aquifer of seemingly infinite areal extent that is homogeneous and isotropic, and uniformly thick over the area influenced by the test;
- ❖ Piezometric surface that is horizontal (or nearly so) prior to pumping, over the area that will be influenced by the test
- ❖ The aquifer is pumped at a constant discharge rate;
- ❖ The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow;
- ❖ The water removed from storage is discharged instantaneously with decline of head;
- ❖ The diameter of the well is small, i.e. the storage in the well can be ignored.

The following procedures are gone through while conducting Theis curve-fitting task

1. The plots of drawdown ( $s$ ) versus pumping time ( $t$ ) at three boreholes on log-log paper are prepared in Excel Spread Sheet, using the same scale paper as a log-log plot of  $W(u)$  versus  $u$  which is previously produced in similar manner.
2. The two plots on excel window is overlaying and until the best fitting point of the two curves as much as possible. The axes of both plots are kept parallel while doing the curve fitting.
3. Create the EXCEL plot of type-curve i.e.,  $W(u)$  Vs  $u$  in log-log scale. To create the plot, highlight the entire type-curve data set i.e. ( $u$ ),  $u$ . Then, select the insert menu, and select the "Scatter" button and from the pull down menu select the "scatter with straight lines and markers" graph (to convert the X and Y axis to logarithmic scale, right click on the axes then select format axis, after that select the axis option and select the logarithmic scale base 10). Moreover, fix the major unit and minor unit values to 10; and assign fixed values for minimum and maximum values for both axes (i.e., for confined aquifer type-curve, vertical axis minimum  $1 \times 10^{-5}$ , maximum  $1 \times 10^2$ ; and horizontal axis minimum  $1 \times 10^{-15}$ , maximum  $1 \times 10$ ). Add the grid lines and axis titles for both axes. Format the chart area, gridline, data series, and axes for clear visualization
4. Plot the drawdown curve with the same size and scale as the type-curve. This can be performed by making a copy of the type-curve, and change the data series to drawdown data. However, both plots should have same number of log cycles in vertical and horizontal axis to preserve the same size and scale. The vertical axis (drawdown) range fall within the range of  $W(u)$ , so there is no need to change the axis range of vertical axis. However, horizontal axis range ( $r^2/t$ ) is not within the range of horizontal axis range of type-curve i.e.,  $u$ . In this situation, the horizontal axis range needs to be changed in the drawdown curve. At this point, make sure that both curves have the same number of log cycles for horizontal and vertical axis. If not, appropriate minimum and maximum values need to be fixed. It is necessary to format the chart area, axes, gridlines, and data series for both plots so that they can be easily differentiated.

5. In order to perform the curve matching, one of the plots should be transparent. Then, the chart area of the drawdown curve needs to be moved over the type-curve while keeping the coordinate axes of two plots parallel until the best match is achieved.

6. Though curve matching is obtained, it is difficult to get the required parameters to calculate aquifer properties. The curve matching of the drawdown curve was performed with the entire type-curve, but only a portion of the type-curve is required. It is difficult to determine which portion of the type-curve is required for curve matching. The curve matching is performed with the entire type-curve to identify the matching portion. Then, the matching portion is enlarged to obtain the required parameters. Once the required range of values is determined for curve matching, and to keep the same number of log cycles for both axes, the axis minimum and maximum values need to be assigned for the axes. Thereafter, curve matching needs to be performed again using enlarged plots to get the best matching. Once the best matching is achieved, record from both plots the coordinates of any matching point, i.e.,  $u$ ,  $W(u)$ ,  $s$ , and  $r^2/t$  to determine the aquifer parameters using Theis's equation.

Then  $T$  is calculated for each well using

$$T = \frac{Q}{4\pi s} W(u) \tag{2.30}$$

$S$  is calculated for each well using

$$S = \frac{4TU}{r^2 t} \tag{2.31}$$

### 2.10.2 Cooper -Jacob Method

The Jacob method (Cooper and Jacob 1946) is based on the Theis formula, Equation

$$s = \frac{Q}{4\pi T} W(U) = \frac{Q}{4\pi T} * (-0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} \dots \dots \dots) \tag{2.32}$$

From  $u = \frac{r^2 S}{4Tt}$  it will be seen that  $u$  decreases as the time of pumping  $t$  increases and the distance from the well  $r$  decreases. Accordingly, for drawdown observations made in the near vicinity of the well after a sufficiently long pumping time, the terms beyond  $\ln u$  in

the series become so small that they can be neglected. So for small values of  $u$  ( $u < 0.01$ ), the drawdown can be approximated by

$$s = \frac{Q}{4\pi T} \left( -0.5772 - \ln \frac{r^2 S}{4Tt} \right) \quad 2.33$$

The Jacob method should be following assumptions and conditions should be satisfied:-

- ❖ The assumptions listed at the beginning of this chapter;
- ❖ The flow to the well is in unsteady state;
- ❖ The values of  $u$  are small ( $u < 0.01$ ), i.e.  $r$  is small and  $t$  is sufficiently large.

The condition that  $u$  be small in confined aquifers is usually satisfied at moderate distances from the well within an hour or less. The condition  $u < 0.01$  is rather rigid. For a five or even ten times higher value ( $u < 0.05$  and  $u < 0.10$ ), the error introduced in the result is less than 2 and 5%, respectively. Further, a visual inspection of the graph in the range  $u < 0.01$  and  $u < 0.1$  shows that it is difficult, if not impossible, to indicate precisely where the field data start to deviate from the straight-line relationship or all practical purposes, therefore, we suggest using  $u < 0.1$  as a condition for Jacob's method. for the determination of the difference in drawdown  $s_1 - s_2$  between two piezometers at distances .

### Procedure Cooper -Jacob Method

- ❖ Drawdown,  $s$  versus the corresponding time,  $t$  plot is produced on semi-log paper ( $t$  on log scale) and a straight line is drawn through the plotted points.
- ❖ The straight line is extended until it is intercepting the time axis at the point where drawdown,  $s = 0$  and the initial time,  $t_0$  is read from the prepared graph.
- ❖ From the prepared plot the slope of the straight line (i.e. the drawdown difference per log cycle) of time is determined. Letting  $s = ax + y$  such that when  $s = 0$ , the slope is computed as  $0 = ax + y$  implies  $a = -y/x$
- ❖ Finally, the obtained values of the measured parameters are substituted in the equations (34) and (35) the required parameters ( $T$  and  $S$ ) are computed respectively.

$$T = \frac{2.3Q}{4\pi\Delta S} \quad 2.34$$

$$S = \frac{2.25Tt_o}{r^2} \quad 2.35$$

### 2.10.3 Recovery/Residual Drawdown Method

When the pump is shut down after a pumping test, the water levels in the well and the piezometers will start to rise. This rise in water levels is known as residual drawdown,  $s'$ . It is expressed as the difference between the original water level before the start of pumping and the water level measured at a time  $t'$  after the cessation of pumping.

It is always good practice to measure the residual drawdown during the recovery period. Recovery-test measurements allow the transmissivity of the aquifer to be calculated, thereby providing an independent check on the results of the pumping test, although costing very little in comparison with the pumping test. Residual drawdown data are more reliable than pumping test data because recovery occurs at a constant rate, whereas a constant discharge during pumping is often difficult to achieve in the field.

The analysis of the data collected during the pumping period of single well tests and pumping tests can be checked by the analysis of the recovery data collected after the pumping has stopped. The analysis is based on the principle of superposition, i.e. it is assumed that after the pump has been shut down, the well continues to be pumped at the same discharge as before, and that from the time pumping ceased, the well receives an imaginary recharge equal to the discharge. The recharge and the discharge thus cancel each other out, resulting in an idle well, as is required for the recovery period.

The analysis of a recovery test is based on the principle of superposition. Applying this principle, we assume that, after the pump has been shut down, the well continues to be pumped at the same discharge as before, and that an imaginary recharge, equal to the discharge, is injected into the well. The recharge and the discharge thus cancel each other, resulting in an idle well as is required for the recovery period. For any of the well-

flow equations presented in the previous chapters, a corresponding 'recovery equation' can be formulated.

The Theis recovery method is widely used for the analysis of recovery tests. Strictly speaking, this method is only valid for confined aquifers which are fully penetrated by a well that is pumped at a constant rate. Nevertheless, if additional limiting conditions are satisfied, the Theis method can also be used for leaky aquifers and unconfined aquifers, and aquifers that are only partially penetrated by a well.

The well-flow equations describing the drawdown behavior during the recovery period are based on the principle of superposition. Applying this principle, it is assumed that, after the pump has been shut down, the well continues to be pumped at the same discharge as before, and that an imaginary recharge, equal to the discharge, is injected into the well. The recharge and discharge thus cancel each other, resulting in an idle well as is required for the recovery period. For any of the well-flow equations presented in the previous sections, a corresponding recovery equation can be formulated.

Theis (1935) developed his recovery method for confined aquifers. After a constant-rate pumping test, the residual drawdown during the recovery period is given by

$$S' (r,t/t') = \frac{Q}{4\pi t} \{w(u) - w(u')\} \quad 2.36$$

Where: -

$S'$  = residual drawdown

$t$  = is time measured since the start of pumping and

$t'$  = is time since the start of the recovery phase

$$u' = \frac{r^2 s t'}{4T t} \quad 2.37$$

When  $u$  and  $u'$  are sufficiently small values and large values of  $t'$ , the well functions can be approximated by the above equation is written as:-

$$S' = \frac{Q}{4\pi T} \left( \ln \frac{4Tt}{r^2 S} - \ln \frac{4Tt'}{r^2 S'} \right) \quad 2.37$$

Where: -

$s'$  = residual drawdown

$S$  = storativity during recovery

$S'$  = storativity during pumping

$t$  = time in days since the start of pumping

$t'$  = time in days since the cessation of pumping

$r$  = distance from well to piezometer

When  $s$  and  $s'$  are constant and equal and  $T$  constant the above equation can be rewritten as:-

$$S' = \frac{2.3Q}{4\pi T} \log \frac{t}{t'} \quad 2.38$$

A plot of residual drawdown  $s'$  versus the logarithm of  $t/t'$  ( $t/t'$  on logarithmic scale) should provide a straight line. The gradient of the line equals  $2.3Q/4\pi T$  so that  $\Delta s'$ , the change in residual drawdown over one log cycle of  $t/t'$  enables a value of transmissivity to be found from:-

$$T = \frac{2.3Q}{4\pi \Delta s'} \quad 2.39$$

Where: -

$\Delta s'$  = is the residual drawdown difference per log cycle of  $t/t'$

The following procedures can be determining the aquifer parameter via the analyzing of the recovery testing phase is: -

- ❖ For each observed value of  $s'$  the corresponding value of  $t/t'$  is calculated
- ❖ The plots for  $s'$  versus  $t/t'$  on semi-log paper for each pumping well is prepared
- ❖ Then fitting a straight line through the plotted points is carried out

- ❖ The slope of the straight line is determined
- ❖ Lastly, the known values of  $Q$  and  $s'$  are substituted in equation (2.20) the value of transmissivity  $T$  is calculated.

#### 2.10.4 Aquifer Test Software

Aquifer Test designed by hydro geologists for hydro geologists giving all the tools need to efficiently manage hydraulic testing results and provide a selection of the most commonly used solution methods for data analysis all in the familiar and easy-to-use Microsoft Windows environment. The main interface for AquiferTest has much of the same user-friendly look and feel as the previous version, but with some significant improvements to analysis

Aquifer Test has the following key features and enhancements:

- ❖ Easy-to-use, intuitive interface
- ❖ Solution methods for unconfined, confined, leaky confined and fractured rock aquifers
- ❖ Derivative drawdown plots
- ❖ Professional style report templates
- ❖ Easily create and compare multiple analysis methods for the same data set
- ❖ Step test/well loss methods
- ❖ Single well solutions
- ❖ Universal Data Logger Import utility (supports a wide variety of column delimiters and file layouts).
- ❖ Support for Level Loggers and Diver Data loggers
- ❖ Import well locations and geometry from an ASCII file
- ❖ Import water level data from text or Excel format
- ❖ Windows clipboard support for cutting and pasting of data into grids, and output graphics directly into your project report

AquiferTest provides a flexible, user-friendly environment that will allow you to become more efficient in your aquifer testing projects. Data can be directly entered in

AquiferTest via the keyboard, imported from a Microsoft Excel workbook file, or imported from any data logger file (in ASCII format). Test data can also be inserted from a Windows text editor, spreadsheet, or database by “cutting and pasting” through the clipboard.

Automatic type curve fitting to a data set can be performed for standard graphical solution methods in AquiferTest. However, you are encouraged to use your professional judgment to validate the graphical match based on your knowledge of the geologic and hydro geologic setting of the test. To easily refine the curve fit, you can manually fit the data to a type curve using the parameter controls.

With AquiferTest, you can analyze two types of test results:

1. Pumping tests, where water is pumped from a well and the change in water level is measured inside one or more observation wells (or, in some cases, inside the pumping well itself). You can present data in three different forms:

- ❖ Time versus water level
- ❖ Time versus discharge (applicable for variable rate pumping tests)
- ❖ Discharge versus water level (applicable for well performance analysis)

The following pumping test analysis methods are available, with fixed analysis assumptions:

- ❖ Cooper-Jacob Time Drawdown
- ❖ Cooper-Jacob Distance-Drawdown
- ❖ Cooper-Jacob Time-Distance-Drawdown
- ❖ Theis Recovery

With these analysis methods, it is not possible to modify the model assumptions.

The following pumping test analysis methods allow adjusting the model assumptions for customized analysis:

- ❖ Theis (1935)
- ❖ Hantush-Jacob (Walton) (1955)

### 3 MATERIALS AND METHDODOLOGY

#### 3.1 General description of the study area

##### 3.2 Location

The studied area is located in Northern part of Ethiopia some 570 km north of the capital Addis Ababa. It is bounded within the limits of 11°55'40" to 12°10'11" north latitude and 39°22'30" to 39°46'44" east longitude. The largest portion of the area is highly dissected topographic high which accounts 65% and the remaining portion covers a valley and its escarpment. It is considered as part of interconnected valleys of the Ethiopian rift system.

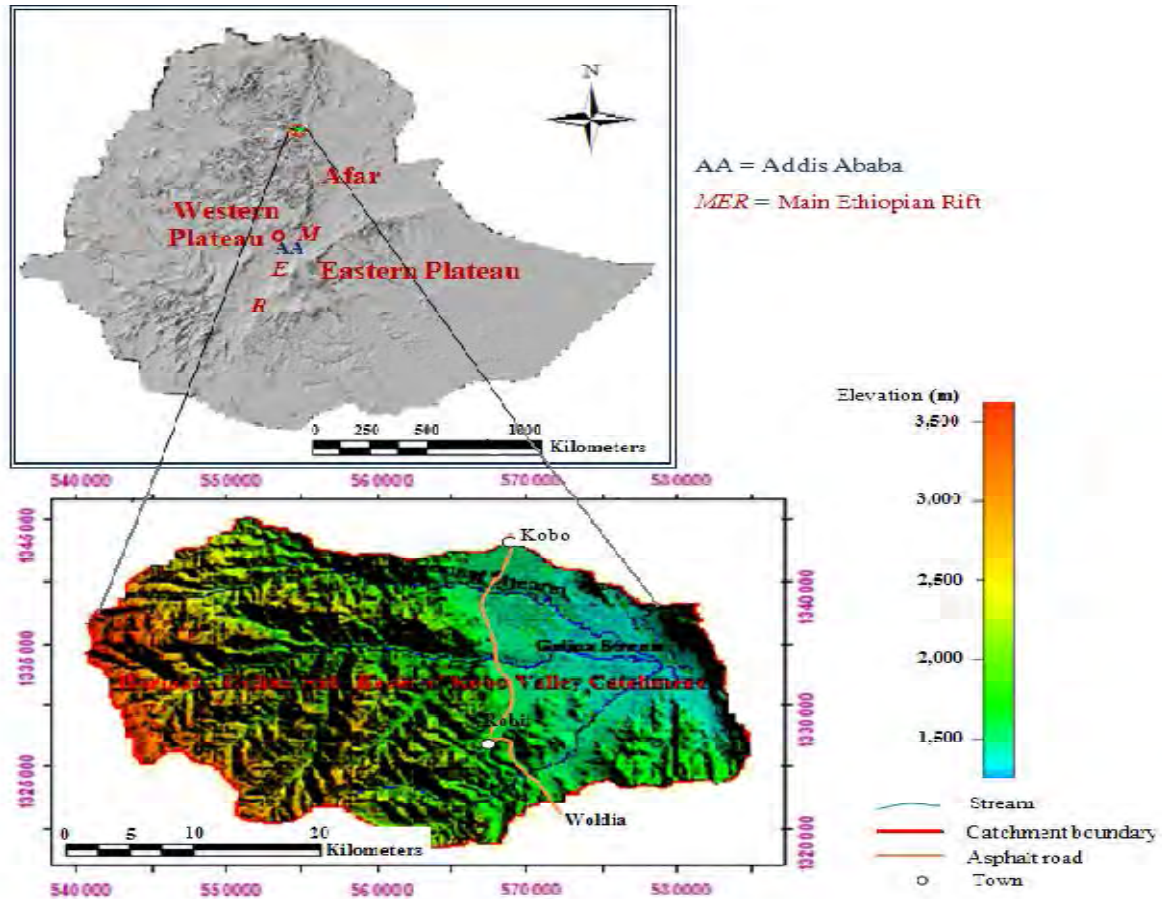


Figure 5 Location map of the study area

### 3.1.2 Climate

The main feature of rainfall in the area is seasonal, poor distribution and variable from year to year. Rainfall distribution over the valley is bimodal, followed by the long and short rainy season that occurs in July-October and February -April respectively. The rest of the months are generally dry. The mean monthly temperatures in kobo valley vary from 12°C in December to about 35°C in June.

### 3.1.3 Topography

The studied catchment has three types of topographic features: the planer intermountain valley part, the valley escarpment, and highly dissected highlands. There is a large topographic difference between the valley and the highland. The lowest elevation is the outlet of Golina stream (1304m a.m.s.l) and the highest is Aboyi Gara mountain (3974 m a.m.s.l). The average altitude of the valley floor ranges from 1355 m a.m.s.l. to 1610 m a.m.s.l, while the mountain ridges range from 1610m a.m.s.l. to 3600 m a.s.l.

### 3.1.4 Land use and cover

Land use is essential in the hydrological and groundwater studies since it is a prominent factor influencing the recharge. From field observation and Arial photos, the land use was identified as agricultural area, woodland, forest, and bare land. The first two were the dominant land uses.

### 3.1.5 Geology

In northern Ethiopia and Yemen, volcanism started during the Oligocene with the emplacement of a thick continental flood basalt pile. These basaltic highlands now encircle the Afar depression. Most of these flood basalts were extruded over a short time period (possibly 1-2 Ma) 30 Ma and significantly predate the main extensional phases (Pik et al., 1999).

The Ethiopian flood basalts (or traps) cover an area of about 600,000 km<sup>2</sup> with a layer of basaltic and felsic volcanic rocks. The studied area is a basin at the western edge of the Danakil basin. The main litho logical units in the study area are basaltic rocks that form the western highlands and escarpments, Rhyolite which form the eastern ridge

(Zobel ridge) overlying the basalt and the alluvial deposits that originate from these basalts on the valley floor). The basaltic rocks that form the western highlands and escarpments of the area are characterized by fine grained and light to dark greenish gray, light pinkish fine grained, and dark olivine, plagioclase, pyroxene and hornblende porphyry basalt layers. It is slightly to moderately fractured and highly weathered in the upper part. Aphanitic basalt dykes intrude this formation at places. Owing to a number of fractures, faults and lineaments, it is possesses highly rugged topographic terrain.

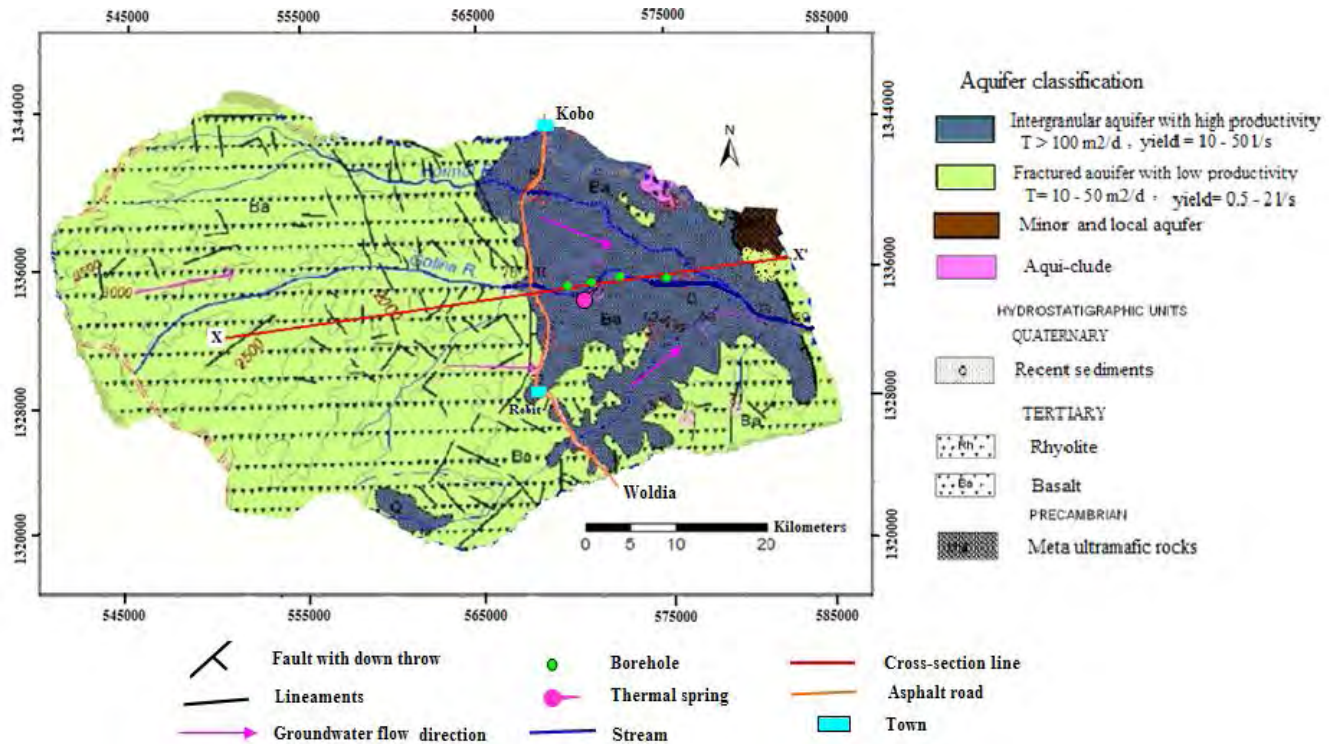


Figure 6 hydro geological map of the study area

The alluvial deposits make up the low-lying valley part of the study area and constitute 25 % of the total catchment area. Braided streams and rivers that drain the western highly dissected steep slope highlands and surface runoff along either side of the valley (Kobo valley) escarpment and early damming effect of the eastern ridge were believed to be the source for the formation of the alluvial deposits.

Based on the litho logic two main hydrogeology units or aquifers were identified in the study area .These are the Quaternary alluvial deposits and the upper fractured and weathered basalt. According to Freeze and Cherry, an aquifer is saturated geologic

material that is sufficiently permeable to yield water in significant quantities to a well or spring, whereas a confining unit has low permeability that restricts the movement of ground water and limits the usefulness of the unit as a source of water supply.

The Rhyolite is often light pink with K-feldspar, plagioclase, quartz and some mafic minerals porphyry, and at places it is quartz, K-feldspar and plagioclase porphyry. Light pink, fine-grained outcrop was seen with basalt xenoliths above the basalt, at the outlet of Golina stream to Afar. The sediments are poorly sorted and sub-angular in shape because they may not have transported far distance from their origin. Adjacent to the colluvial, there are alluvial deposits that are mainly transported by surface run-off along streams and rivers during the rainy seasons. The alluvial sediments are relatively fine, well sorted and sub-rounded to spherical shaped. They are dominantly composed of sands and silts with some proportion of fine gravel, especially adjacent.

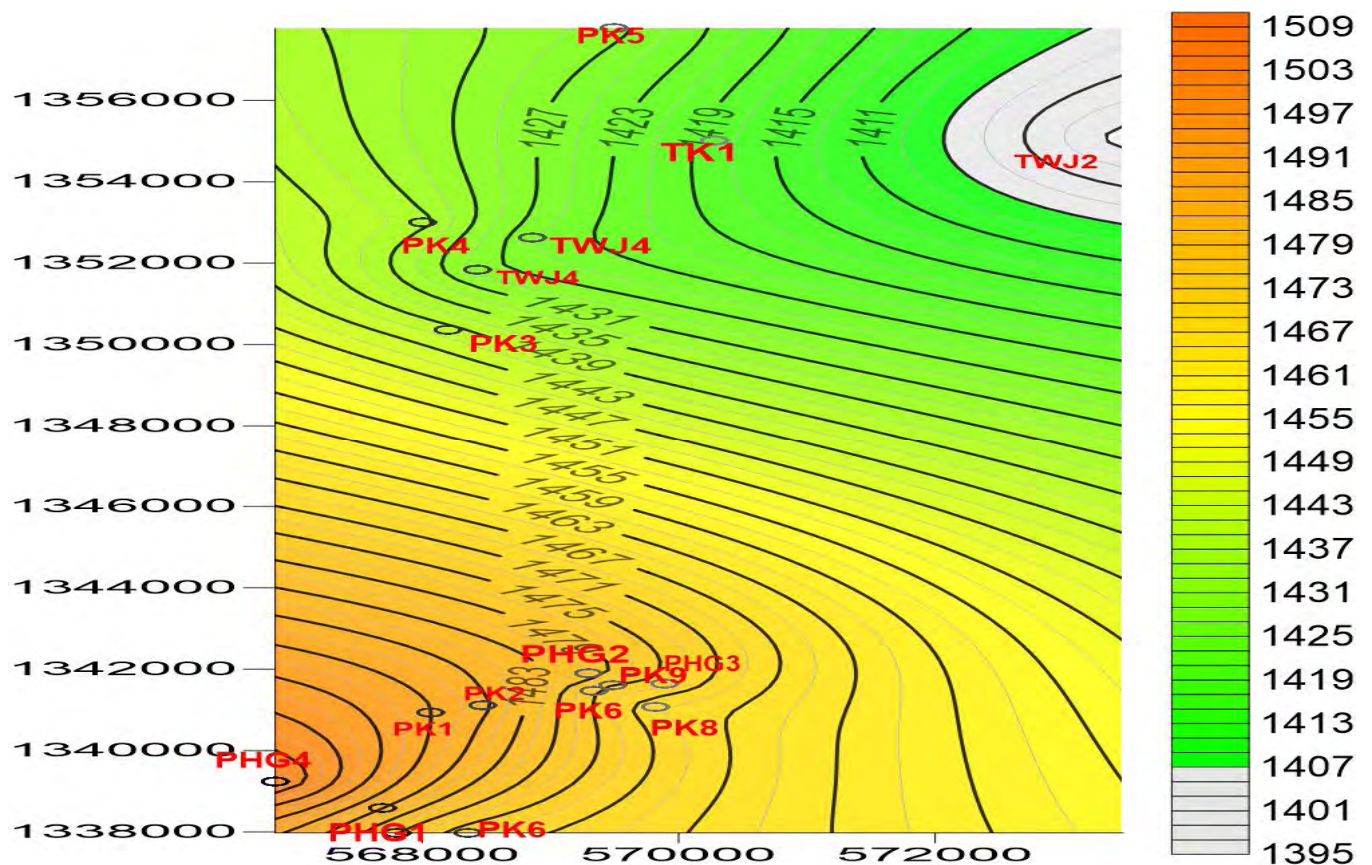


Figure 7 well location map

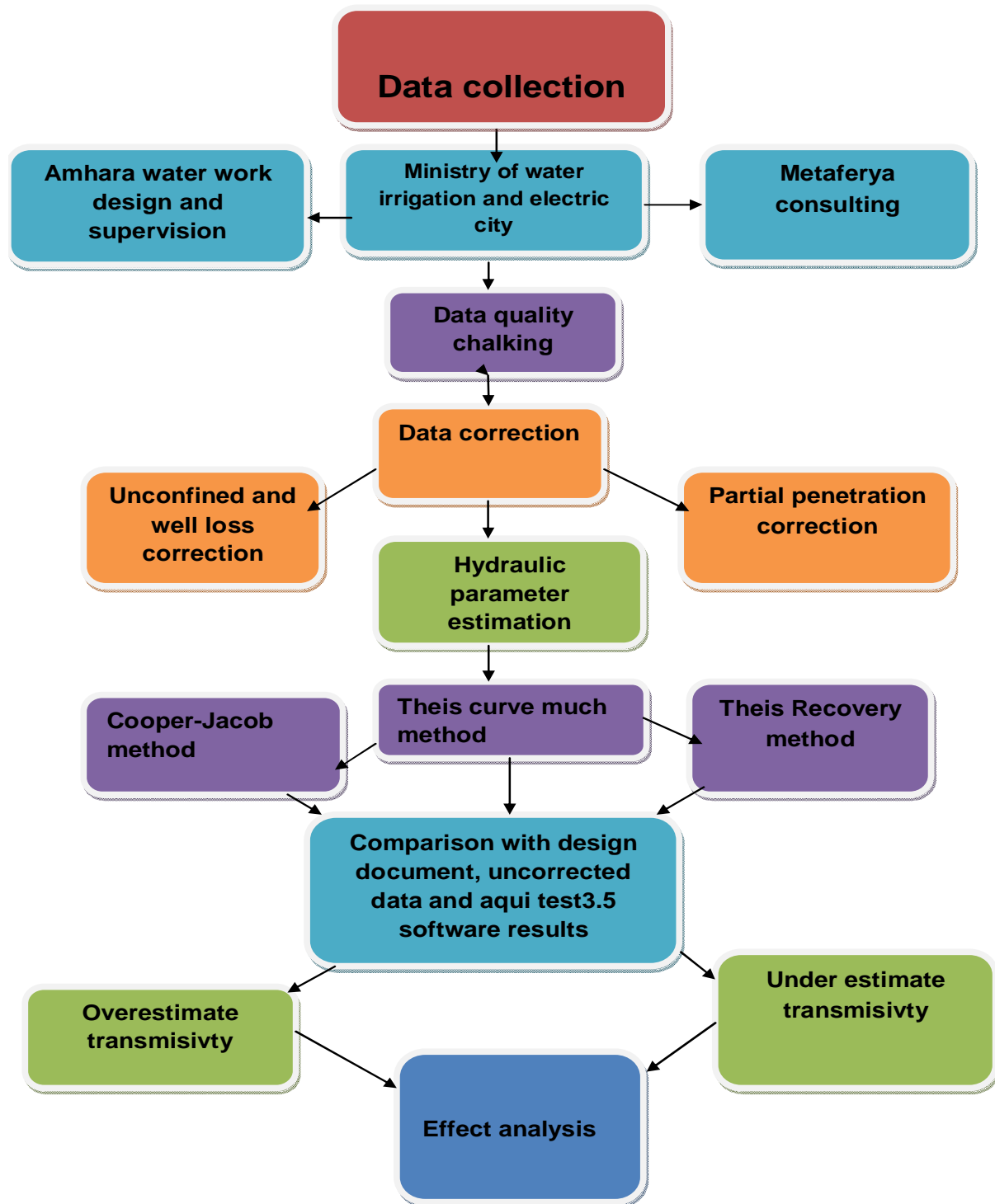


Figure 8 methodology flow chart

## **Pre-field work**

Previous works and data have been collected from different offices (Ministry of Water Resources, Metaferia Consulting Engineers, Ethiopian Geological Survey, kobo girana irrigation project, amhara design and supervision and were organized to prepare the research proposal. Then, following the appraisal of the proposal all the reliable secondary data were arranged to prepare excel spread sheet, data quality caking and create excel spread sheet of each wells. After identifying the gaps to be filled and data that need field verification, field preparation was conducted that involves acquisition of equipments such as groundwater level measuring device or deep meter and GPS. Literature review related to evaluation of hydraulic parameter was also included in this stage.

## **Post-field work**

In post field work to collect both primary and secondary essential data collection at field investigation and office work stage so as to achieve the objective of the study. The primary data gathering includes the works accomplished at the field investigation level. This task was carried out by collecting sites using GPS instrument to measure coordinates of the wells and to measure water level of the wells .The secondary data colleted from different sources. In this stage gathering of validated and organized data (secondary data) of well information such as:- constant rate pumping test, step drawdown test, recover test, final drawdown, pumping duration, static water level, dynamic water level, well depth, design discharge. This duty covers the methods employed to achieve the subject matter as the citation of literature review on ground water books is substantially completed at the office work level. Physical characteristics of the aquifers, the necessary parameters such as the aquifer's design discharge, transmissivity and storage coefficient are computed. Evaluate and analysis the pumping test data by using four common methods are included: - Theis's Curve-Fitting Method, Cooper -Jacob method, recovery method and Aquifer Test Model methods.

The data collected from different sectors and caking the data by viewing by eye, draw the graphs time versus draw down on log-log excel spread sheet and draw trend line

on the graph compute the value of  $R^2$ . maximum  $R^2$  value is 1 means the graph is best fit to straight line. In this case  $R^2$  value greater than 0.5 the collected data is good data quality.  $R^2$  value below 0.5 the collected data quality is poor.

Recovery test data of well ID PHG2 not real because the recorded recovery very is very interrupted and the well recover very short time. The draw trend line is not fit to log-log graph and the draw graph values up down immediately. So PGH2 recovery test data quality is very low and not used to calculate hydraulic parameter of the well by recovery data only used to calculate time versus draw down pumping test data used to for analysis.

Recovery test data of well ID PHG3 data quality is low and the graph is drop suddenly. I am solving transmissivity by divide the graph in to two parts. The first graph is early time data and the second graph is late time data. Compute transmissivity of the well by using geometric mean of the two graph transmissivity values.

A step draw down test should have at least three steps that cover a wide range of flows, preferably matching or exceeding the proposed design flow. Step drawdown test data can be analyzed with the Eden-Hazel (1973) method, which is based on the Jacob straight line method to give an estimate of transmissivity.

Step draw down test my data summarized by four stages. By this four step draw down data draw on excel spread sheet calculate the value of B and C values from trend line equation of the step draw down test graph. Using by B and C calculate all well efficiency values. Minimum recommended well efficiency is 65%-80%. Below 65% well efficiency means used over discharge on the wells on the step draw down test and pumping test.

To identify the aquifer system of my wells comparison of recorded draw down with varies theoretical curve with the log-log plot and semi log plots of draw versus time. The time draw down curve indicate the aquifer type where the wells are located and grouped the following type

- Unconfined aquifer
- TK1,PK1,PK2,PK3,PK4,PK5,TK7,PK6,PK7,PK87,PK9,PHG1,PHG2,PHG4,and TWJ2 boreholes
- Confined aquifer  
PGH3, TWJ3 and TWJ4 boreholes

The above all unconfined aquifer change to confined aquifer by using the Jacob (1944) correction

$$S_{corrected} = Sa(1 - \frac{S_a}{S_b})$$

Prior to analysis of drawdown data from an aquifer test it may be necessary to correct the datasets for external effects, or effects induced by the test. External effects include groundwater level changes due to barometric pressure variations, tidal fluctuations, and other recharge or discharge sources such as rainfall or river flow. Effects induced by the test may include the unintentional recharge of the aquifer from the in appropriate discharge of pumped water. To determine if corrections are required, trends in background water levels need to be analyzed. For most analysis solutions, the aquifer is assumed to be of constant thickness. In an unconfined aquifer, this condition is not met if the drawdown is large compared to the aquifer s original saturated thickness. All method of analysis such as Theis Curve-Fitting Method, Cooper -Jacob method, recovery method is applied on confined aquifer. Because of this all unconfined aquifer change to confined aquifer by using the above equation.

All wells in this are partially penetrate wells. Step dawn test are used to calculate well loss and aquifer loss .partial penetration is including on well loss due to radial flow of the water. Some pumping wells are not step draw down test data due to absence of this step draw down test not calculating aquifer and well loss .In this case correct the wells loss using by partial penetration (Kozeny; 1933) formula.

Corrections may also be required to account for partially penetrating pumping wells. In these circumstances flow in the vicinity of the pumped well will be higher than a fully penetrating well and can result in additional head loss. This effect decreases with

increasing distance from the pumping well, and no corrections are required at distances greater than 1.5 to 2 times the saturated thickness of the aquifer.

To achieve the objective used for calculating and analyzing and evaluate my data for calculating hydraulic parameters by using the following four methods:-

- ❖ **Theis (1935)**
- ❖ **Cooper-Jacob Time-Drawdown (1946)**
- ❖ **Theis Recovery (1935)**
- ❖ **Aquifer test software**

Theis type curve classic analysis method is the basis for several other more complex analysis methods, described by Kruseman and de Ridder (1994). This method yields the following aquifer characteristics:

- ❖ Transmissivity [ $L^2/T$ ].
- ❖ Storativity (with an observation well).

Theis type curve overlapping method used to compute confined aquifer hydraulic parameters such as transmissivity, storativity. This method used to time versus residual draw down data on log-log scale of all wells on excel spread sheet 2007.

However, this method requires curve matching of a type-curve and time drawdown data from a pumping well test. Typically, this is done using a type-curve ( $W(u)$  Vs  $u$ ) plotted on a logarithmic graph paper and the drawdown(s) data curve plotted on another transparent logarithmic graph paper ( $s$  Vs  $r^2/t$ ) with the same scale, and superimposing and sliding the transparent one over the other to get the best possible match while keeping the coordinate axes of two plots parallel. Obviously this is a tedious approach. Based on the coordinates of a matching point from both plots ( $W(u)$ ,  $u$ ,  $s$ , and  $r^2/t$ ) in the matched position, the values of  $S$  and  $T$  can be determined using Theis equation. The detailed descriptions about the manual type-curve matching can be found in many text books including Fetter<sup>1</sup> and Todd and Mays.

Type curve match between theis type curve and corrected field data curve on log-log spread sheet first Tabulate the well function data ( $W(u)$  and  $u$ ) in EXCEL spread sheet .

This needs to be done only once for the given type-curve. The next step is tabulate the aquifer well pumping test data in EXCEL 2007 i.e, drawdown data with time, and creates a column  $r^2/t$ ; where  $r$  is the radial distance of the observation well from pumping well. Plot the drawdown curve with the same size and scale as the type-curve. This can be performed by making a copy of the type-curve, and change the date series to drawdown data. However, both plots should have same number of log cycles in vertical and horizontal axis to preserve the same size and scale. In order to perform the curve matching, one of the plots should be transparent. In my log-log graph, the transparency is set to 75% for the drawdown curve. The Cooper and Jacob method is based on the Theis formula, but uses a straight line approximation assuming that  $u$  ( $u=r^2S/4Tt$ ) is small. This method is described by Fetter (2001) and Kruseman and de Ridder (1994). The Jacob method is a suitable method for verification of other analysis results by combining the final draw downs in one plot. The Jacob method yields the following aquifer characteristics:

- ❖ Transmissivity [ $L^2/T$ ].
- ❖ Storativity.

Cooper and Jacob method is used to time versus corrected drawdown data and draw the graphs on semi log form. First input time on X axis and residual draw down on Y axis. After draw the graph the X axis value changes to logarithm scale. Draw down data or Y axis values set on linear scale. After that draw the trend line and compute equation of the trend line. From the trend line calculate slope, intercept and change in draw down on one log scale. By using the above step calculate transmissivity and storativity of the well by using cooper - Jacob formula and compare with previous design values.

Recovery test is more reliable than pumping test data because recovery test is not disturbing with pumping turbulence effect. When the pump is shut down after a pumping test, the water levels in the well and the piezometers will start to rise. This rise in water levels is known as residual drawdown,  $s'$ . It is expressed as the difference between the original water level before the start of pumping and the water level measured at a time  $t'$  after the cessation of pumping. shows the change in water level with time during and after a pumping test It is always good practice to measure the residual draw downs

during the recovery period. Recovery-test measurements allow the transmissivity of the aquifer to be calculated, thereby providing an independent check on the results of the pumping test, although costing very little in comparison with the pumping test. Residual drawdown data are more reliable than pumping test data because recovery occurs at a constant rate, whereas a constant discharge during pumping is often difficult to achieve in the field.

In recovery test first correct drawdown data by using (Kozeny; 1933) and well efficiency formulas. After correcting recovery test data calculating  $t'/t$  and draw on semi log graph and draw trend line on semi log graph. On the trend line calculating slope of the line, intercept of the line and change of draw down on one loge cycle. After analyze the above data calculating transmissivity by Theis recovery formula. By recovery test data not calculating storativity because the calculated storativity values are out of real world storativity values or very high storativity value. After calculating transmissivity values by using Theis recovery formula and comparing the previous design values.

Aquifer test provides a flexible, user-friendly environment that will allow you to become more efficient in your aquifer testing projects. Data can be directly entered in Aquifer test via the keyboard, imported from a Microsoft Excel workbook file, or imported from any data logger file (in ASCII format). Test data can also be inserted from a Windows text editor, spreadsheet, or database by "cutting and pasting" through the clipboard.

Automatic type curve fitting to a data set can be performed for standard graphical solution methods in Aquifer test. However, you are encouraged to use your professional judgment to validate the graphical match based on your knowledge of the geologic and hydro geologic setting of the test. To easily refine the curve fit, you can manually fit the data to a type curve using the parameter controls.

Pumping tests, where water is pumped from a well and the change in water level is measured inside one or more observation wells (or, in some cases, inside the pumping well itself). You can present data in three different forms time versus water level, time versus discharge (applicable for variable rate pumping tests), and discharge versus water level (applicable for well performance analysis).

By aquifer test software to calculate all hydraulic parameters by Theis Curve-Fitting Method, Cooper -Jacob method, recovery methods. Aquifer test software is required the following data .

First fill all information on pumping test tool bar project name, date, site plane, time, unit and dimensions, aquifer type, aquifer thickness aquifer type, elevation, type of penetration etc.

The second step is fill discharge tool bar .insert the value of discharge, type of discharge such as constant or variable discharge and draw time versus discharge graph.

Third step is fill water level data such as static water level data ,import time versus water level pumping test data .

Final step of aquifer test software is analyzing method .in analyzing step compute all hydraulic parameters by Theis Curve-Fitting Method, Cooper -Jacob method, recovery methods and compare with design values.

## 4. Result and discussion

In the study area all seventeen collecting wells are constant-rate single well test. constant-rate test is most common type of pumping test performed, and its concept is very simple the borehole is pumped at a constant rate for an extended period (most of the well pumped 3 day or 72 hour) while the water levels and pumping rates are monitored. If the most value is to be gained from constant-rate tests, water levels should be monitored in an observation borehole as well as in the pumping borehole (or better still, several observation boreholes at different distances from the pumping borehole). Data from constant-rate tests can be analyzed to derive the transmissivity of the aquifer. The storage coefficient of the aquifer can be calculated only if data from observation boreholes are available.

Irrigation wells must be capable of producing adequate water during peak season and under draught condition. Without reliable, efficient, and economical supply of water, the entailer irrigation system .well is heart of irrigation system with ground water supplies it must be properly design and compatible with the pump and distribution system to ensure long life, efficiency and economical operation.

### 4.1 Well Information

Water well is an excavation or structure created in the ground digging driving boring or drilling to access ground water in underground aquifer. All collected well information of kobo irrigation project such as northing, easting, elevation, aquifer type, aquifer thickness, well depth, well yield etc summarizing in table 1

Well ID	x	Y	z	depth	Q(l/s)	T <sub>av</sub> (m <sup>2</sup> d <sup>-1</sup> )	aquifer type	casing radius	boring radius	screen length	aquifer thickness	Test conducted		
												step draw down	pumping test	recovery test
PK1	568066	1340931	1491	170	55	280	unconfined	0.152m	0.254m	54	56	✓	✓	✓
PK2	568476	1341101	1488	137	80	341	unconfined	0.152m	0.254m	54	84		✓	✓
PK3	568204	1350350	1440	153	70	1172.5	unconfined	0.152m	0.254m	48	111		✓	✓
PK4	568000	1353000	1436	137	60	1126.25	unconfined	0.152m	0.254m	36	58	✓	✓	✓
PK5	568227	1351843	1428	118	30	55.2	unconfined	0.152m	0.254m	41.5	60	✓	✓	✓
PK6	569299	1341890	1481	145	40	198	unconfined	0.152m	0.254m	52.83	76	✓	✓	✓
PK7	569892	1341651	1464	203	40	577.5	unconfined	0.152m	0.254m	66	78	✓	✓	✓
PK8	569814	1341065	1469	181	50	168	unconfined	0.152m	0.254m	76.31	118	✓	✓	✓
PK9	569485	1341610	1475	145	50	768.5	unconfined	0.152m	0.254m	52.83	92	✓	✓	✓
PGH1	567688	1338578	1487	129	50	1245	unconfined	0.152m	0.254m	52.83	92		✓	✓
PGH2	567801	1337977	1479	108	45	3145	unconfined	0.152m	0.254m	35.22	70	✓	✓	✓
PGH3	568356	1337982	1473	156	50	513.5	confined	0.152m	0.254m	58.2	104	✓	✓	✓
PGH4	566854	1339244	1507	128	45	1411.5	unconfined	0.152m	0.254m	41	62	✓	✓	✓
TWJ2	573465	1355068	1398	121	15	51.9	unconfined	0.152m	0.254m	36	74	✓	✓	✓
TWJ3	569491	1357769	1433	154	60	624.33	confined	0.152m	0.254m	66	100		✓	✓
TWJ4	568854	1352624	1425	158	60	475.5	confined	0.152m	0.254m	66	107	✓	✓	✓
TK1	570275	1355009	1481	277	75	457.5	unconfined	0.152m	0.254m	54	55	✓	✓	✓

Table 1 kobo irrigation project well information

## 4.2 Data analysis

Kobo irrigation design document report not using pumping test data correction on all wells only use raw data for pumping test analysis. In this thesis correct all pumping test and recovery test data correct by using step draw down test data for well loss correction and by using kozeny(1933) partial penetration formula. kozeny formula is valid for  $L/b < 0.5$ . Data quality check by all the wells by using best fit straight line regression values ( $R^2$ ). most of the wells  $R^2$  is above 0.5 except well ID PK9 pumping test data .pumping test data well ID PK9 ignored because of low data quality and data quality error come not using constant pumping rate. For Well IDPK9 used correct recovery data for computing hydraulic parameters.

For this thesis transmissivity values analysis by using average geometric mean of pumping test and recovery test results of Theis type curve method, cooper-Jacob and Theis recovery method. Geometric means normalize the range being averaged so that no range dominates the weight and a given percentage changes in any of the property the same effect on the range being. Arithmetic mean greatly influenced by outliers value that is very much larger or smaller than other value.

### 4.2.1 Unconfined aquifer correction

All method of analysis such as Theis Curve-Fitting Method, Cooper -Jacob method, recovery method is applied on confined aquifer. All unconfined aquifer change to confined aquifer by using the Jacob (1944) correction.

$$S_{corrected} = Sa \left(1 - \frac{S_a}{2b}\right) \quad 4.1$$

### 4.2.2 Partial penetration correction

Some of the wells are not done step draw test so correct pumping test and recovery test data by using kozeny(1933) partial penetration correction method to compute all hydraulic parameters.

$$F = \frac{L}{B} \left[ 1 + 7 \cos \left( \frac{\pi L}{2b} \right) \sqrt{\frac{r}{2l}} \right] \quad 4.2$$

### 4.3 Step draw down test

Step-drawdown test is a single-well test in which the well is pumped at a low constant-discharge rate until the drawdown within the well stabilizes. The pumping rate is then increased to a higher constant discharge rate and the well is pumped until the drawdown stabilizes once more. This process is repeated through at least three steps, which should all be of equal duration, say, a few hours each.

The ratio of actual capacity of the well at the design yield to the maximum specific capacity possible calculated from hydraulic characteristics and well geometry is well efficiency. This is the same as the ratio of theoretical draw down to obtained design yield from a 100% efficient well to actual draw down measured in the well when producing at the design yield.

Collecting Step draw down test data summarized by five stages. From summarized step draw down test calculate efficiency of the well. Well is poor efficiency result high pump cost due to excessive drawdown. Irrigation well efficiency should be at least 65%-80% efficiency. Well efficacy values used for correcting aquifer loss and well loss calculation. According to step draw down test value summary of well efficiency listed on table 2

NO	WELL ID	Q(I/S)	B	C	R <sup>2</sup>	EFFICIENCY %
1	TK1	75	0.005	9.00E-08	0.718	89.55
2	PK1	55	0.005	4.00E-07	0.92	72.34
3	PK4	60	0.006	4.00E-07	0.988	74.31
4	PK5	30	0.008	9.00E-07	0.982	77.42
5	PK6	40	0.003	1.00E-07	0.224	89.67
6	PK7	40	0.005	8.00E-07	0.121	60.66
7	PK8	50	0.002	2.00E-07	0.848	69.83
8	PK9	50	0.001	2.00E-08	0.4	92.04
9	PGH2	45	0.002	2.00E-07	0.838	69.83
10	PGH3	50	0.001	7.00E-08	0.223	76.78
11	PGH4	45	0.001	8.00E-08	0.901	74.31
12	TWJ2	15	0.023	4.00E-06	0.45	81.6
13	TWJ4	60	0.002	1.00E-07	0.757	79.52

Table 2 summary of kobo irrigation well efficiency

Each step draw down test is important to calculate well efficiency and correct draw down data that used to estimated hydraulic parameters in the base of standard interpretation techniques. All step draw down test data graphs are shown below figure 3(a) up to figure 3(n)

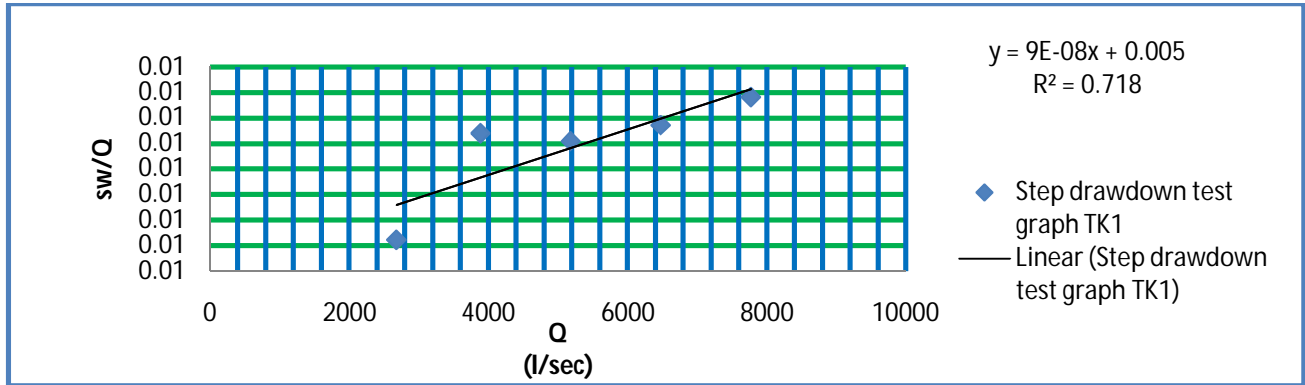


Figure 9 (a) step draw down test graph of well ID TK1

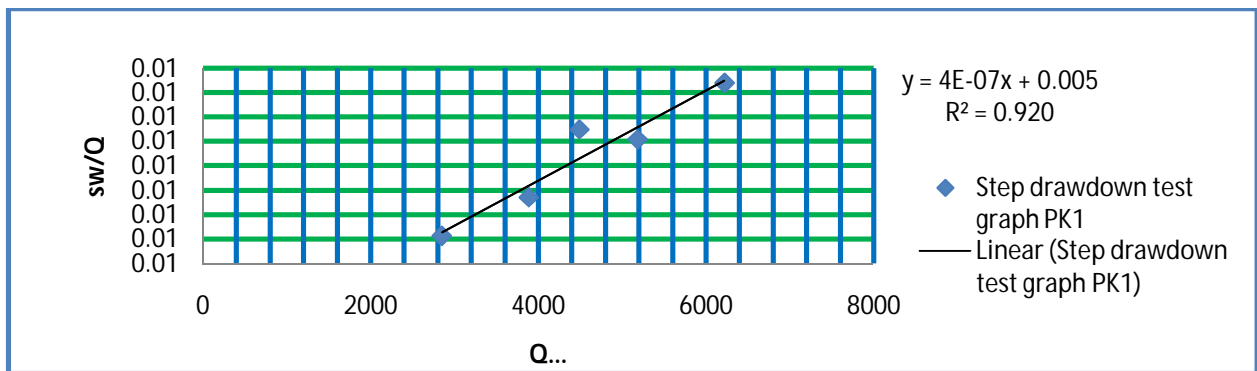


Figure 9 (b) step draw down test graph of well ID PK1

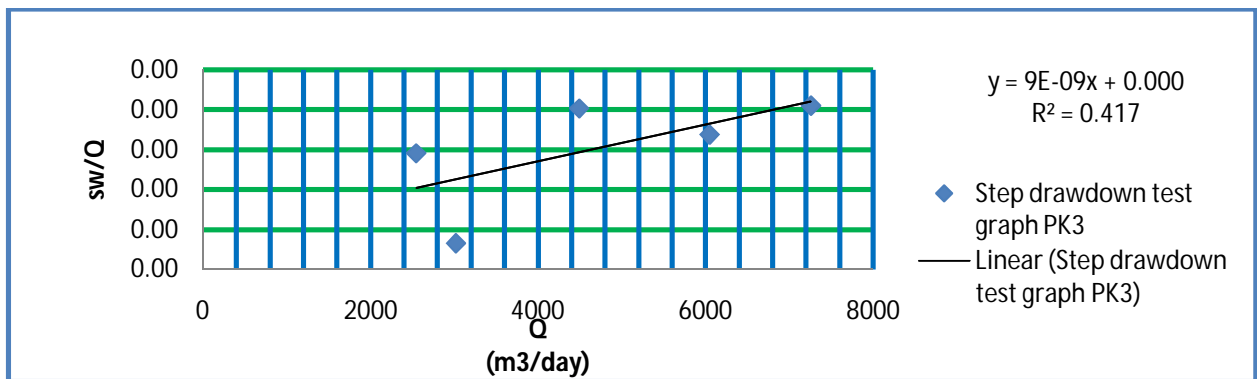


Figure 9 (c) step draw down test graph of well ID PK3

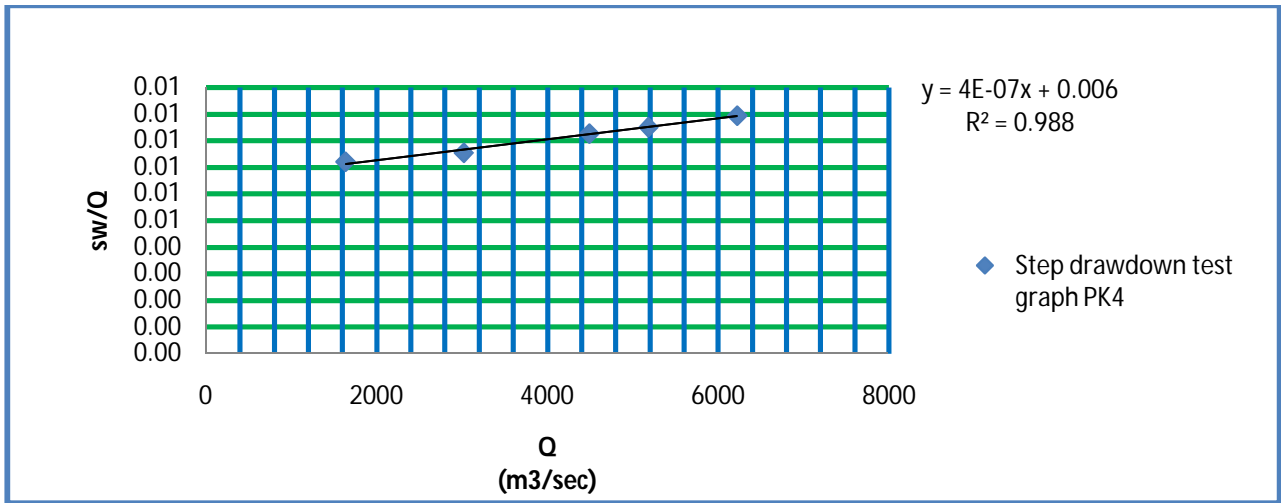


Figure 9(d) step draw down test graph of well ID PK4

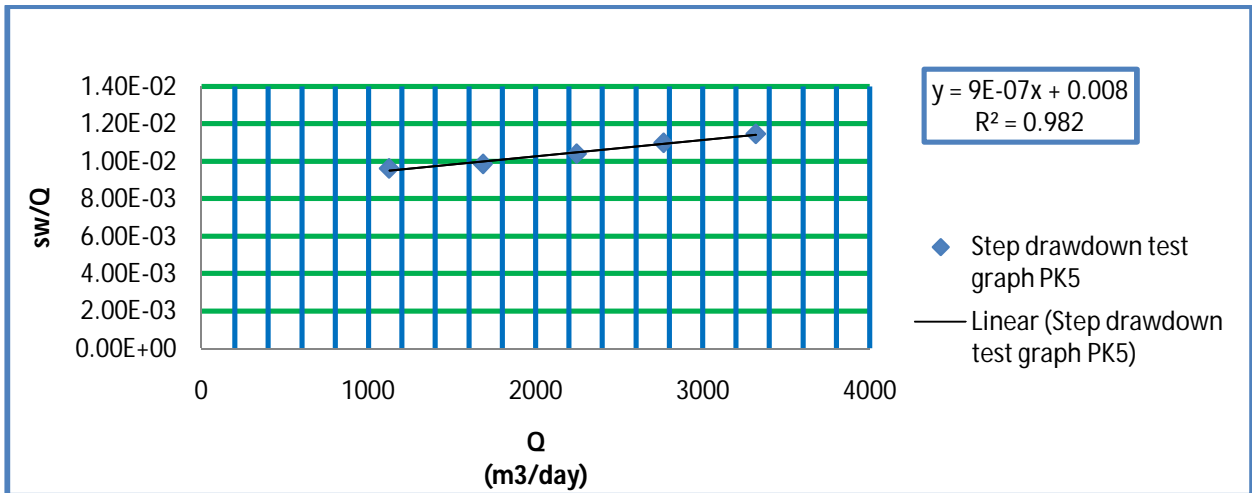


Figure 9 (e) step draw down test graph of well ID PK5

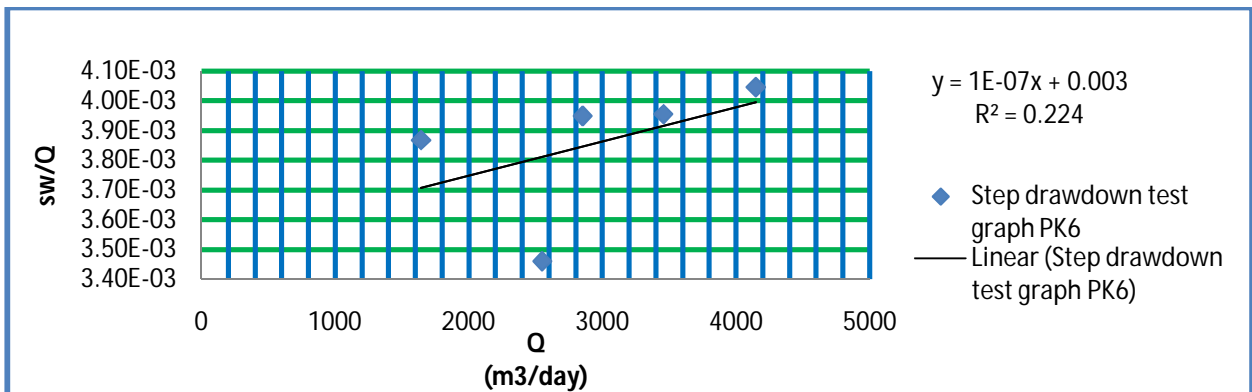


Figure 9(f) a step draw down graph of well ID PK6

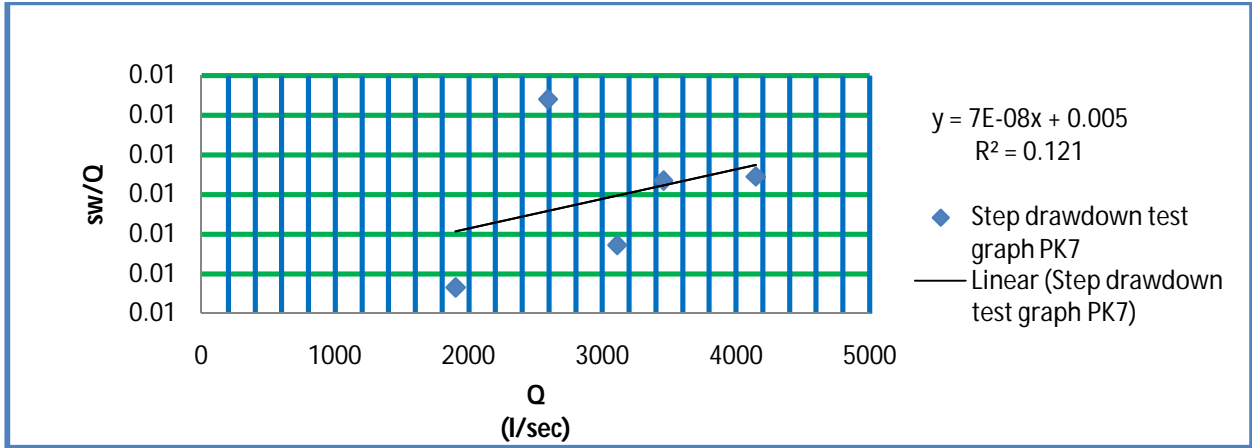


Figure 9 (g) step draw down graph of well ID PK7

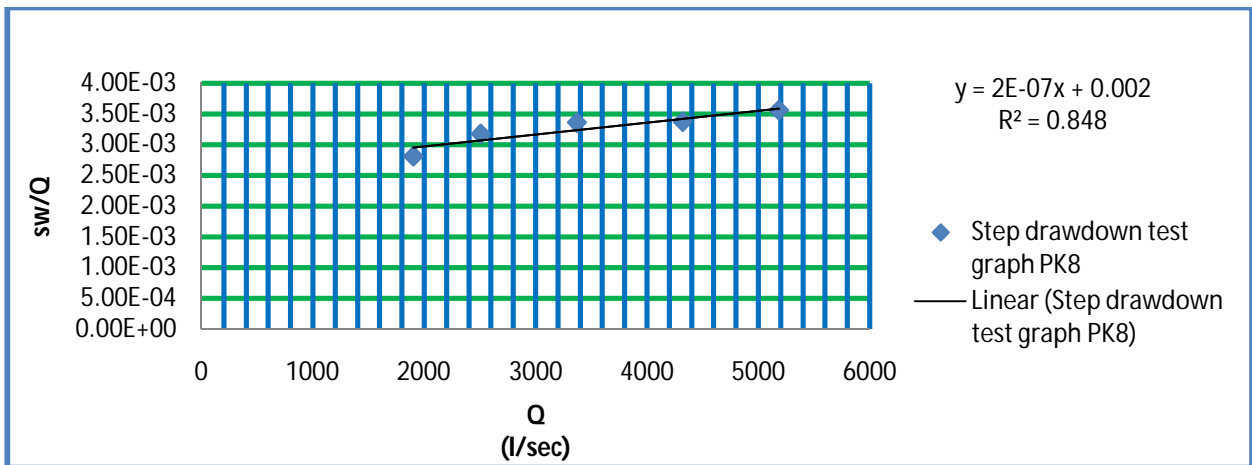


Figure 9 (h) step draw down test graph of well ID PK8

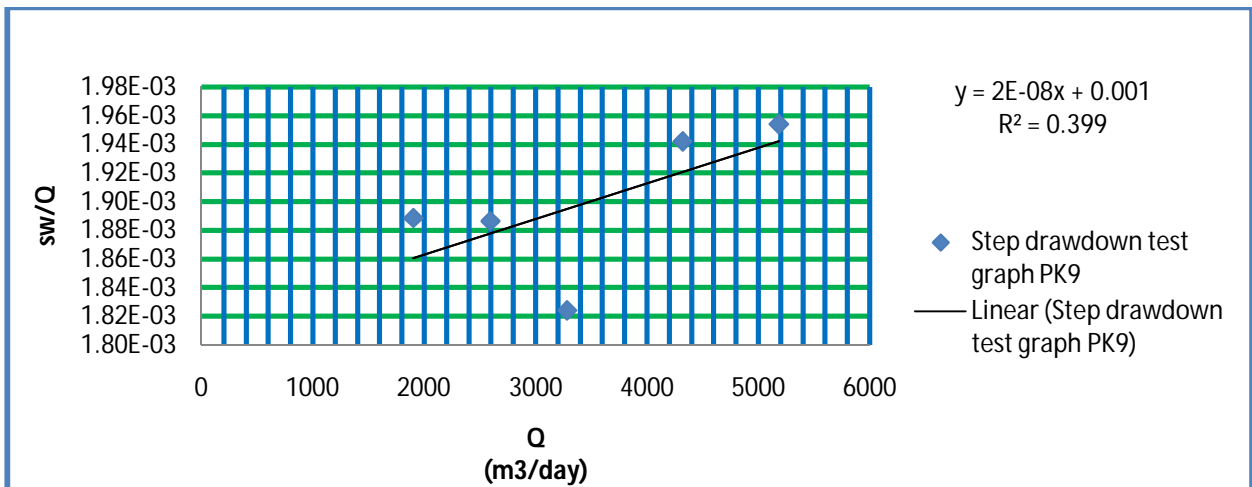


Figure 9 (i) step draw down test graph of well ID PK9

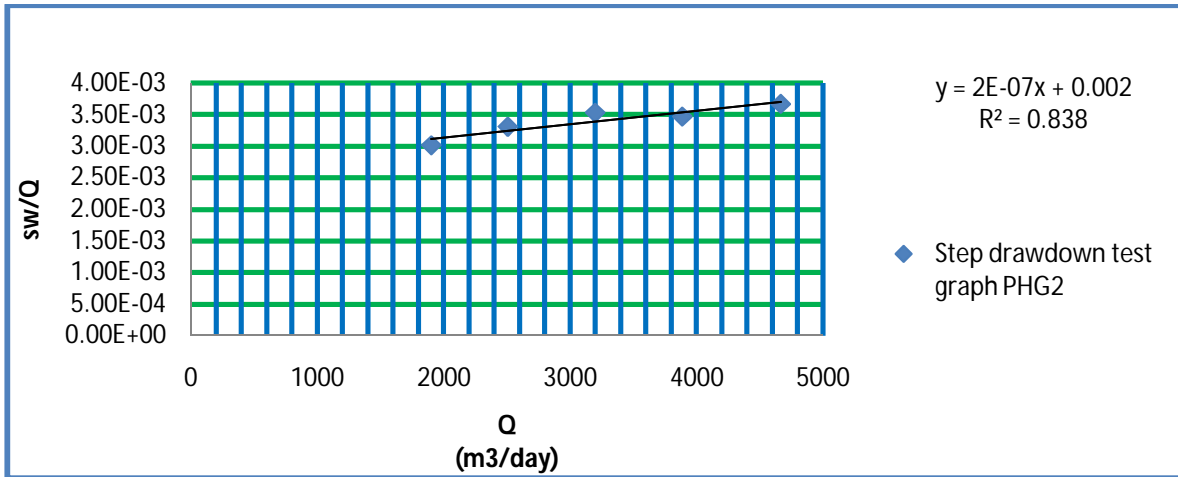


Figure 9 (j) step draw down test graph of well ID PHG2

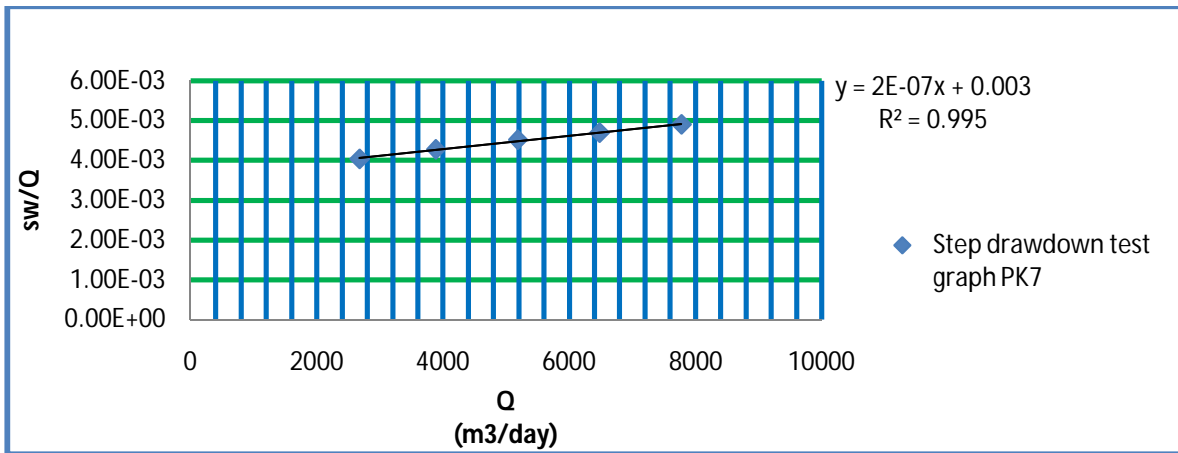


Figure 9 (k) step draw down test graph of well ID PHG3

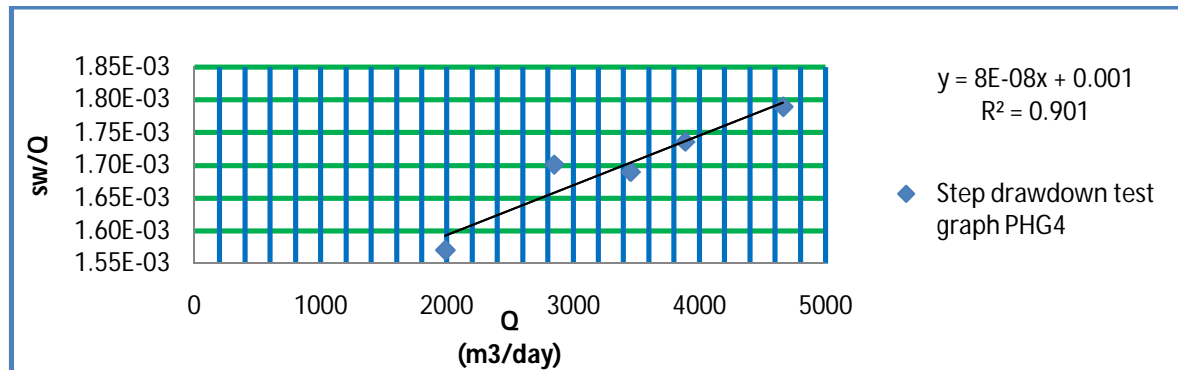


Figure 9 (l) step draw down test graph of well ID PHG4

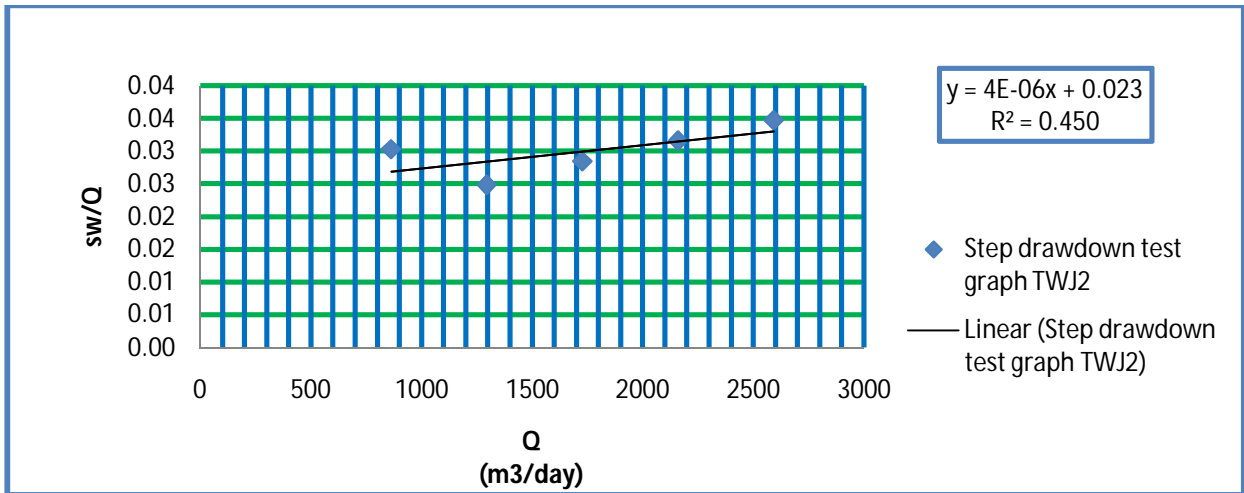


Figure 9 (m) step draw down test graph of well ID TWJ2

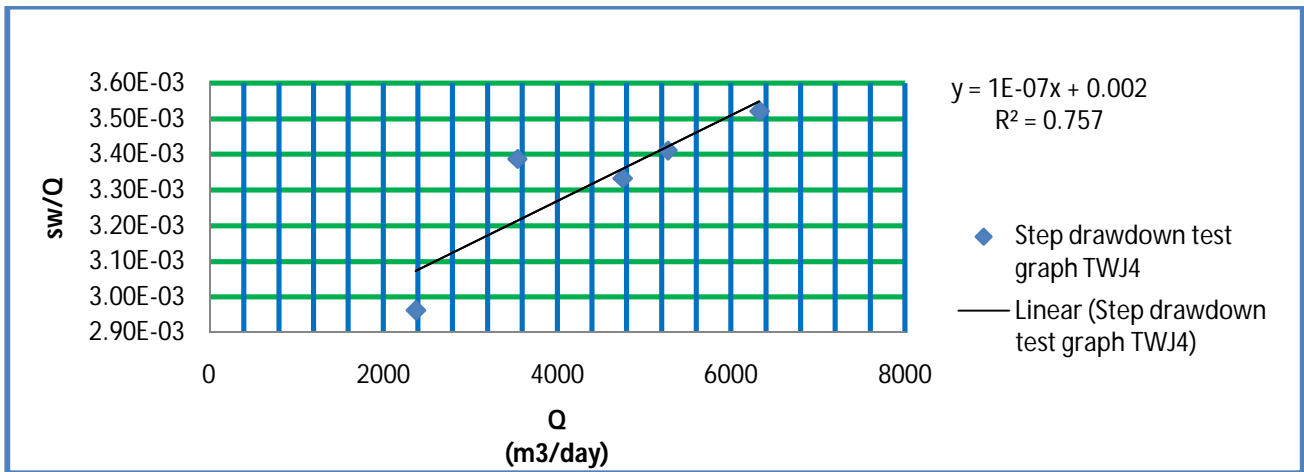


Figure 9 (n) step draw down test graph of well ID TWJ4

All above graphs are used to calculate well efficiency for the purpose of aquifer loss and well loss correction by using step draw down data.

## 4.4 Time draw down test results

### 4.4.1 Cooper-Jacob straight line method

The first method of analysis presented here is called the Jacob (sometimes referred to as the Cooper-Jacob) straight-line method, which is based on a simplification of the Theis method. When a straight line was fitted to the data points. Early time data were ignored because they tend to be affected by the volume of water stored in the borehole itself, and the points would probably not have fallen on the straight line. Because of the above reason used to calculate and analyze hydraulic parameter late time data.

most of the well in this paper drawdown is gradually increase except well ID pk9. This indicates that the aquifer properties away from the borehole are poorer than those closer to the borehole. This can be because the aquifer is limited in extent in other words, the expanding cone of depression has encountered a hydraulic barrier, or because shallow parts of the aquifer are being dewatered. This is not an encouraging sign, and indicates that less water is available than appeared at first. If the test has been continued long enough (for the data to stabilize on a new straight line), calculate the transmissivity from the late data.

For all pumping test data ignored early time data because they tend to be affected by the volume of water stored in the borehole itself, and the points would probably not have drop on the straight line.

The obtained values of the measured parameters are substituted in the equations the required parameters transmissivity computed by (Cooper and Jacob 1946)

$$T = \frac{2.3Q}{4\pi\Delta S} \quad 4.3$$

For each time draw down data obtained during pumping test where used to fix important parameter that are used in estimate of hydraulic parameter table (3) and the corresponding estimated transmissivity value. In same table the value of transmissivity used in original study kobo irrigation wells

NO	well ID	Q(l/s)	Best Fit		draw down				eastimated Transmittivity			storativity
			slop	intercept	at t=10	at t=100	to	$\Delta s$	design document	un corrected data	correct data	
1	TK1	75	0.517	19.06	20.24	21.03	9.34E-17	1.18	457.3	307	369	9E-15
2	PK1	55	0.456	15.4	16.88	17.23	3.67E-17	1.048	280	267	829	9E-7
3	PK2	70	1.288	0.606	3.56	6.53	6.24E-01	2.96	341	367	428	NA
4	PK3	70	0.18	2.63	3.03	3.44	0.00E+00	0.41	1172.5	1737	2766	1.7E-5
5	PK4	60	1.92	22.02	26.6	31.18	1.56E-05	4.58	1126.5	159	185	3.8E-2
6	PK5	30	1.025	10.32	26.67	15.025	4.19E-05	2.25	55.2	90	201	>1
7	PK6	40	0.478	8.34	9.43	10.53	2.59E-08	10.99	198	453	551	>1
8	PK7	40	0.536	10.01	11.3	12.59	1.95E-08	1.29	198	194	577.72	>1
9	PK8	50	1.101	3	5.53	8.06	5.60E-02	2.53	168	193	280	5.67E-6
10	PK9	50	0.219	2.053	2.556	3.0604	8.40E-05	0.5	768.5			
11	PHG1	50	0.277	1.869	2.5061	3.14	1.00E-03	0.63	1245	1210	1210	0.1228
12	PHG2	45	0.29	6.33	7.006	7.673	3.00E-08	0.667	3145	651	1133	3.6e-8
13	PHG3	50	0.449	2.996	4.0017	5.03	1.00E-03	4.3	513.5	483	765	1.48E-8
14	PHG4	45	0.158	3.783	4.4164	4.509	3.98E-11	0.36	1411.5	1294	1958	0.49
15	TWJ2	15	5.03	11.08	11.35	35.25	9.00E-02	22.9	51.9	20	25	0.2
16	TWJ3	60	0.947	4.166	6.34	8.52	1.00E-02	2.17	624	435	435	0.021
17	TWJ4	60	1.692	3.895	7.78	11.67	9.00E-02	3.89	475.5	183	243	>1

Table 3 summery of hydraulic parameters by using cooper-Jacob

According to the pumping test data in the study area the equation obtained and the plot are as shown in the following figure 8(a-m)

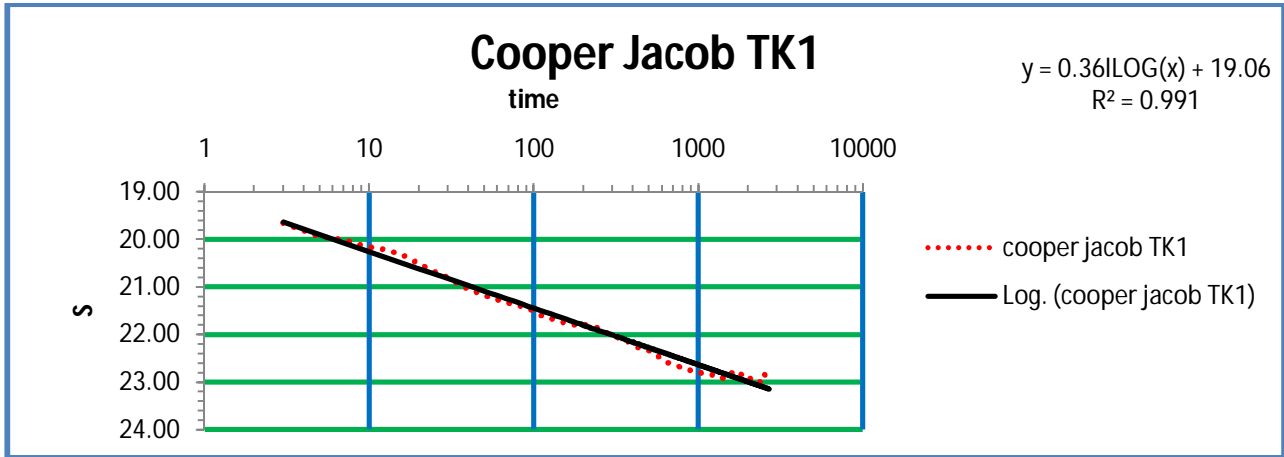


Figure 10 (a) Time versus drawdown cooper-Jacob graph of well ID TK1

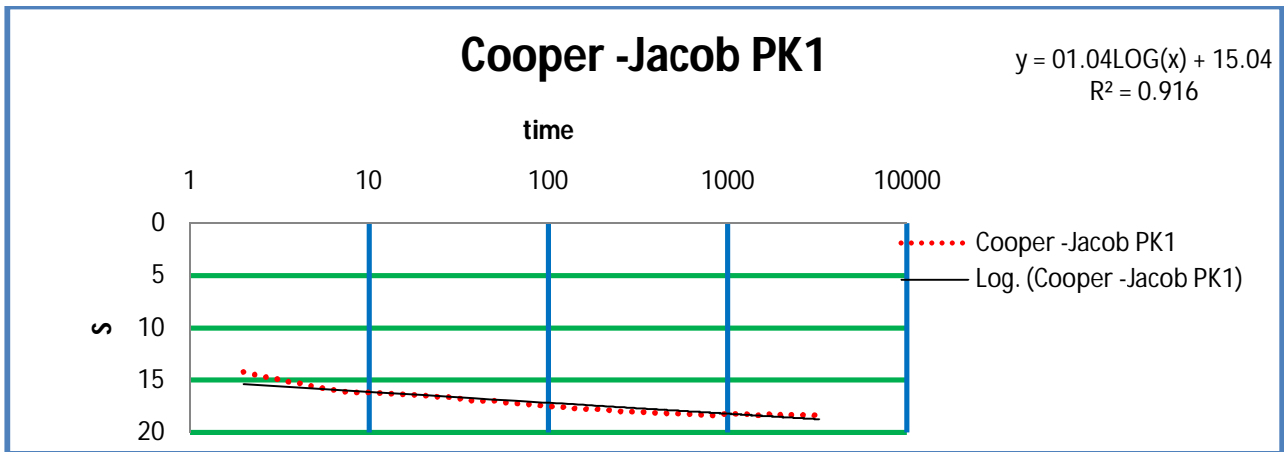


Figure 10 (b) Time versus drawdown cooper-Jacob graph of well ID PK1

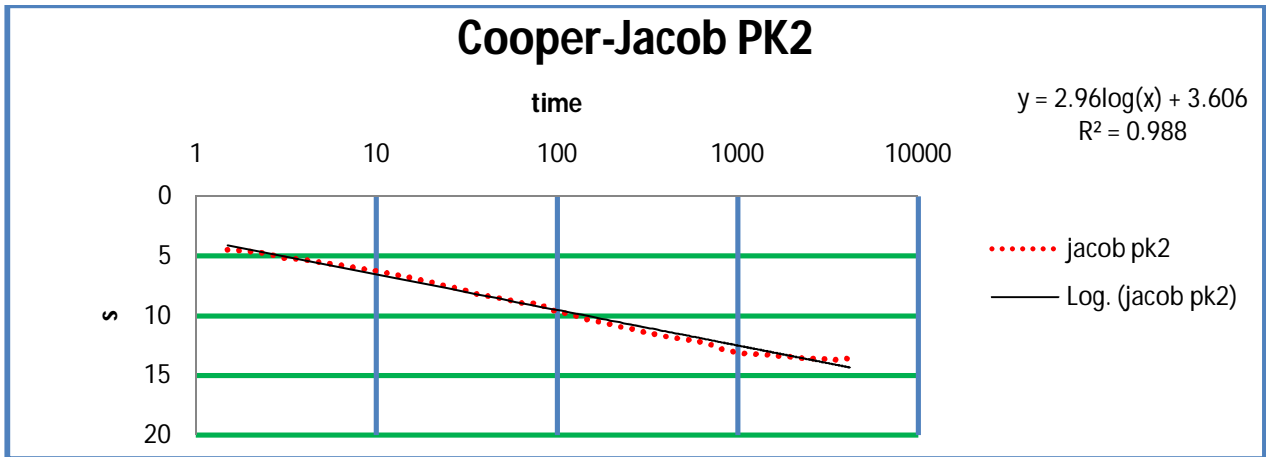


Figure 10 (c) Time versus drawdown cooper-Jacob graph of well ID PK2

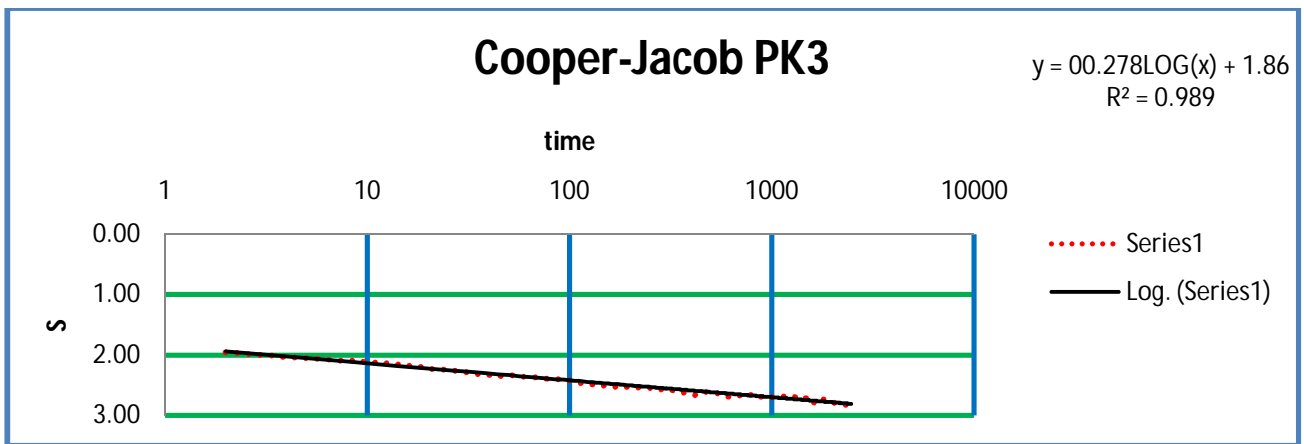


Figure 10 (d) Time versus drawdown cooper-Jacob graph of well ID PK3

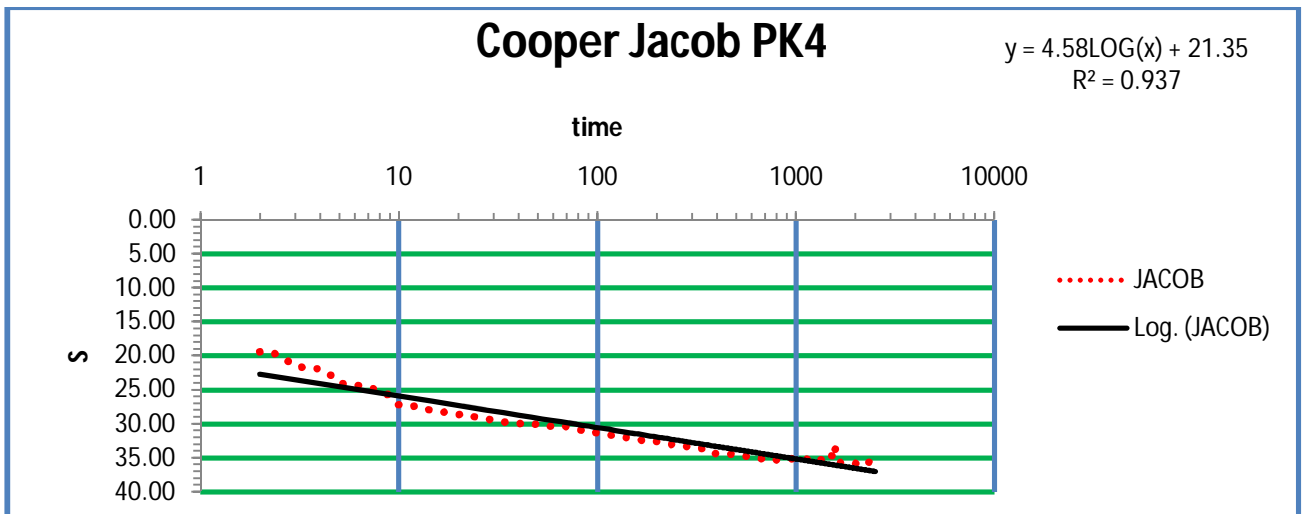


Figure 10 (e) Time versus drawdown cooper-Jacob graph of well ID PK4

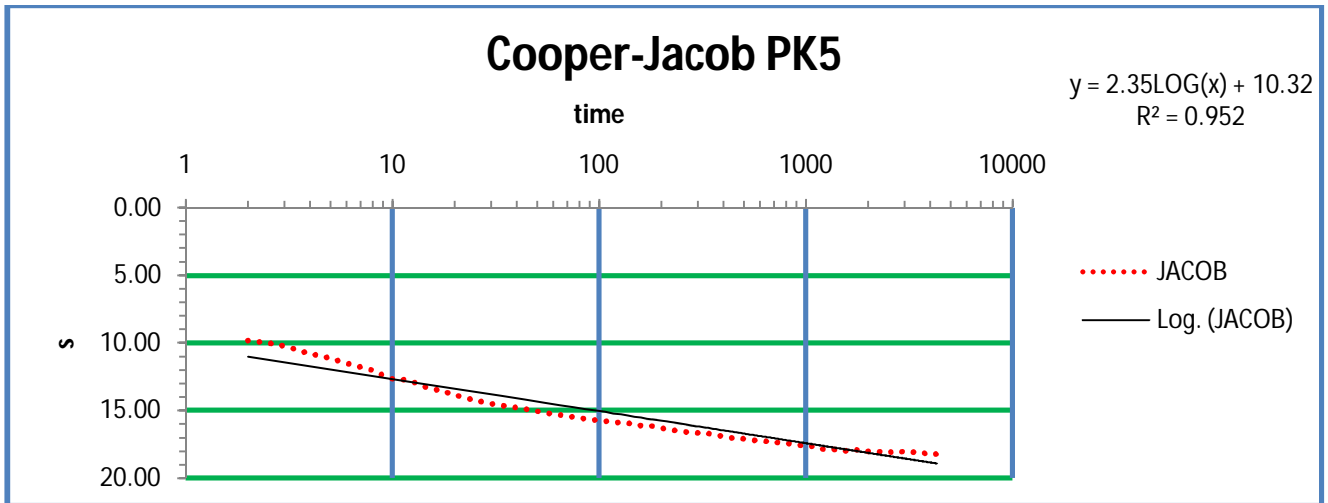


Figure 10 (f) Time versus drawdown cooper-Jacob graph of well ID PK5

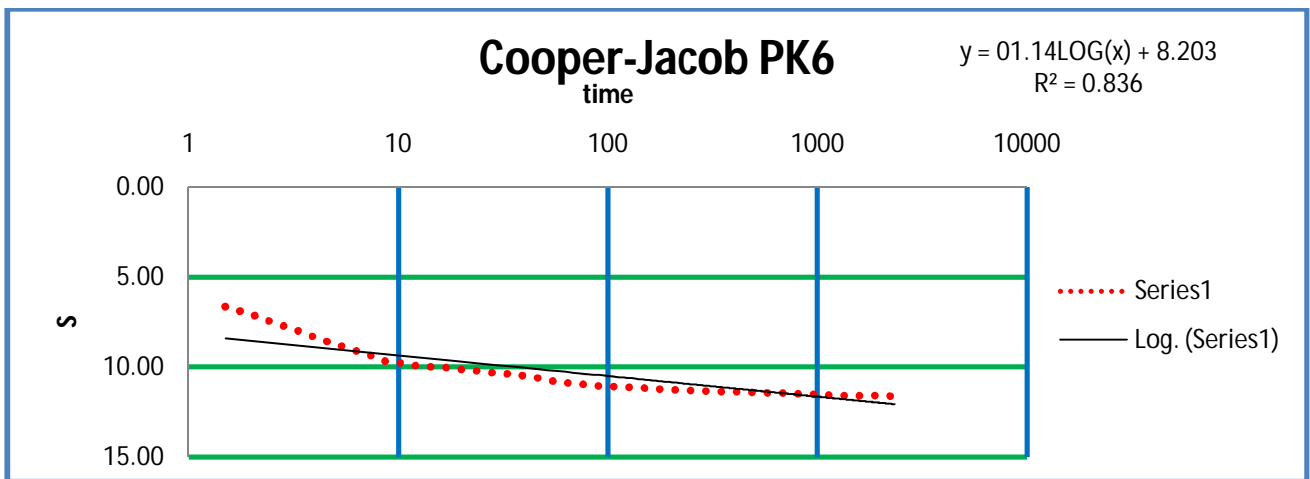


Figure 10(g) Time versus drawdown cooper-Jacob graph of well ID PK6

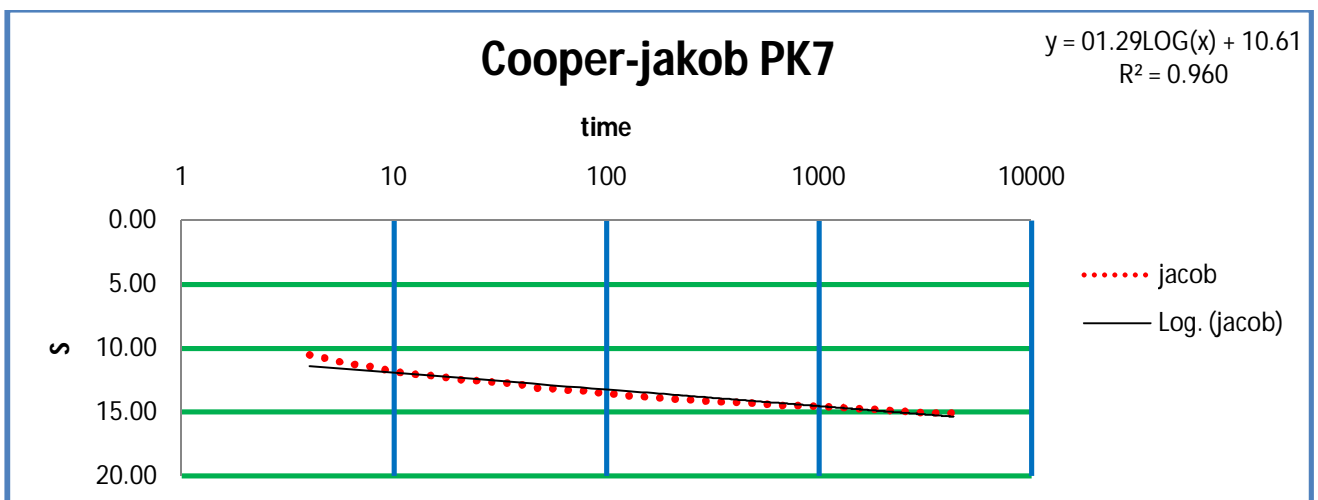


Figure 10(h) Time versus drawdown cooper-Jacob graph of well ID PK7

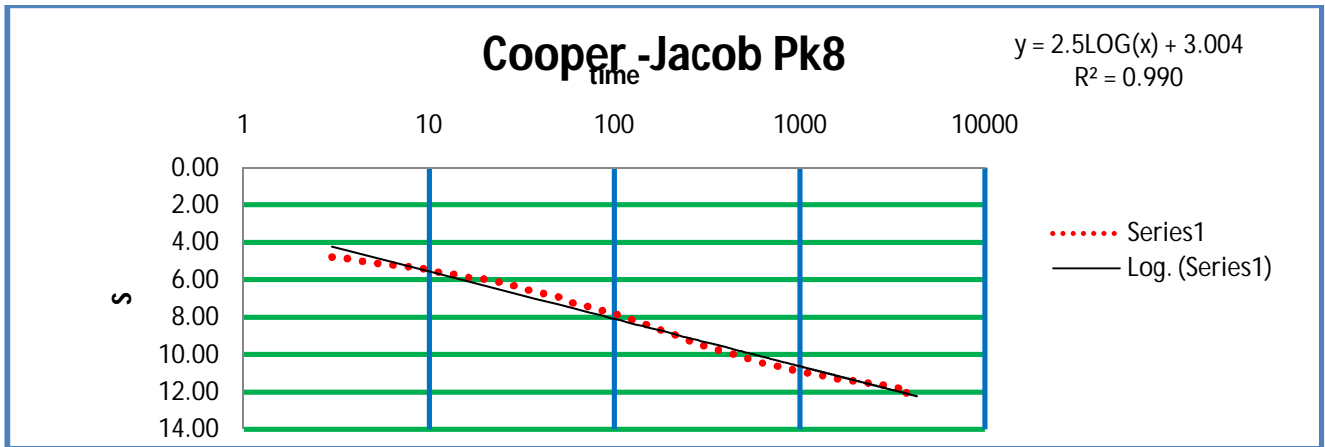


Figure 10(i) Time versus drawdown cooper-Jacob graph of well ID PK8

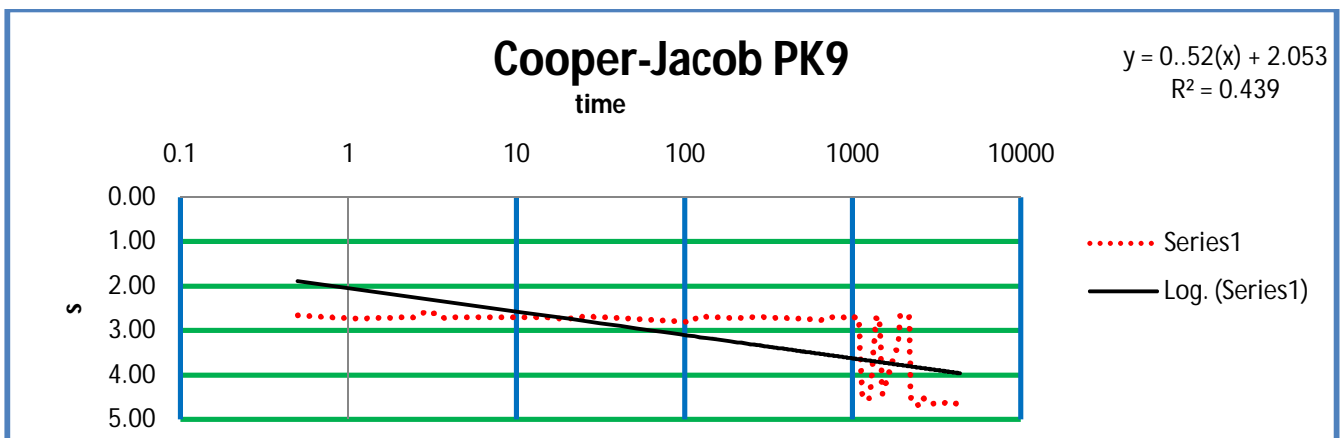


Figure 10(j) Time versus drawdown cooper-Jacob graph of well ID PK9

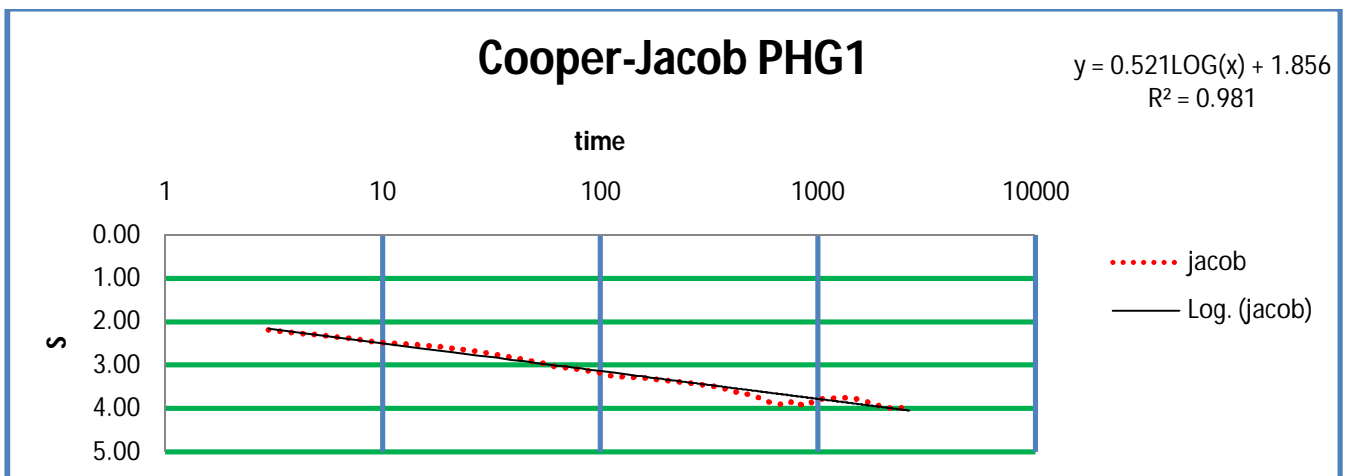


Figure 10(k) Time versus drawdown cooper-Jacob graph of well ID PHG2

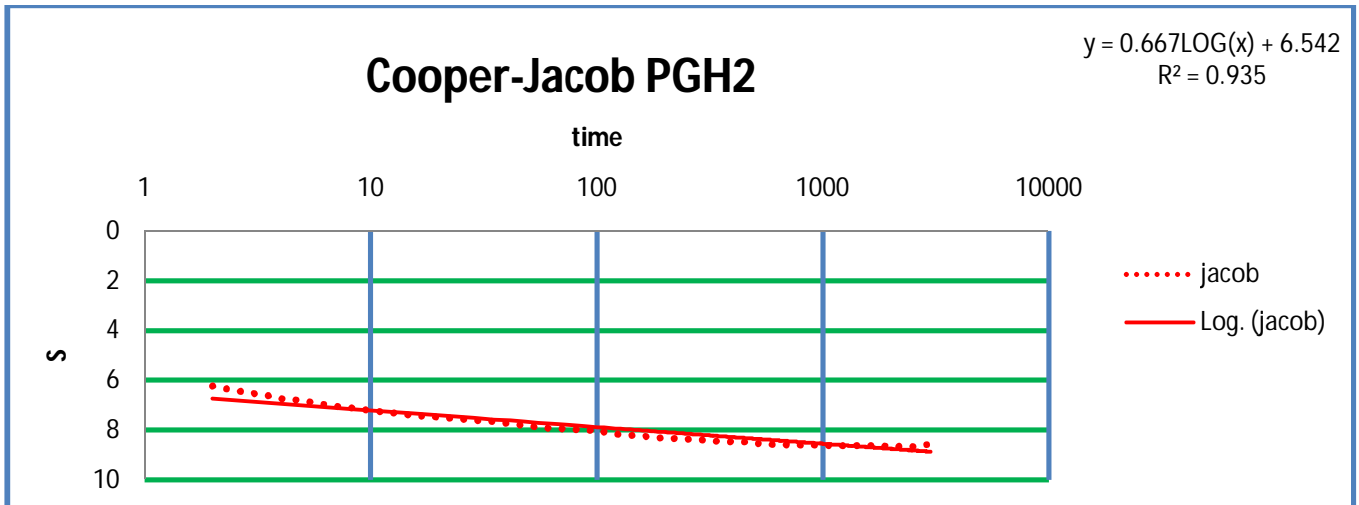


Figure 10 (l) Time versus drawdown cooper-Jacob graph of well ID PHG2

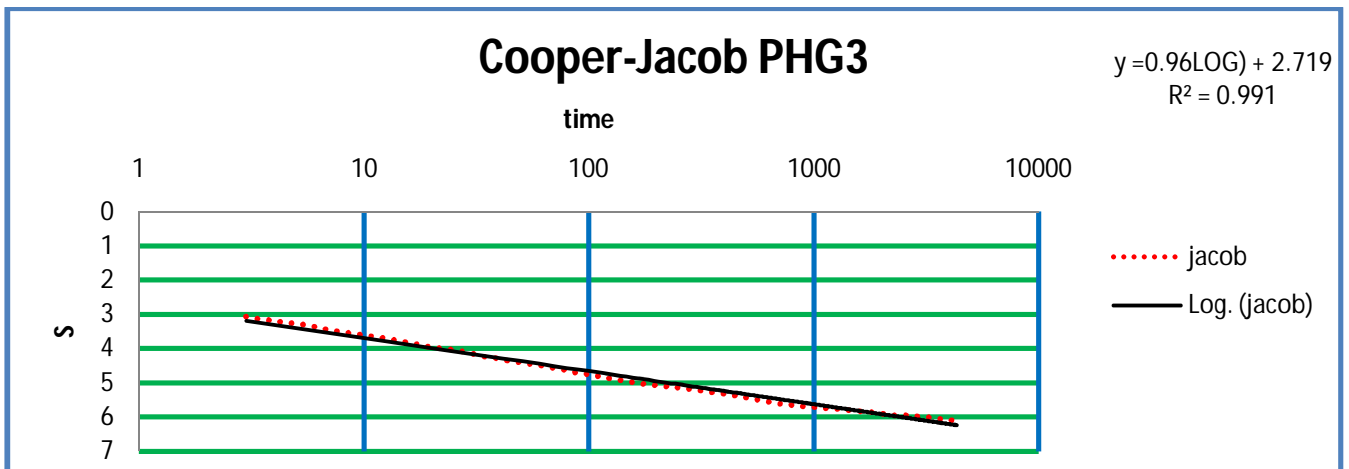


Figure 10(m) Time versus drawdown cooper-Jacob graph of well ID PHG3

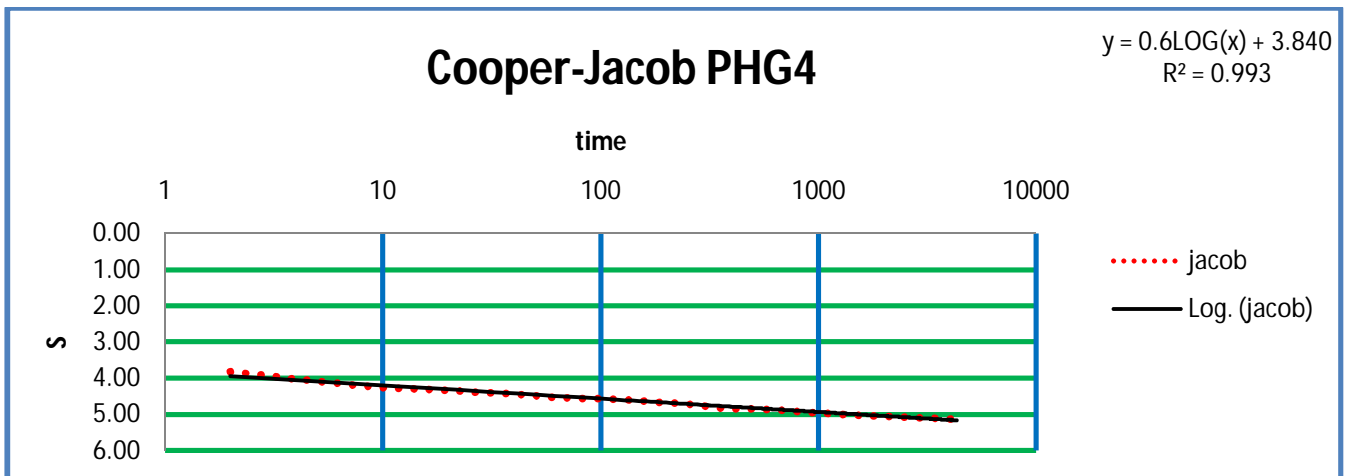


Figure 10 (n) Time versus drawdown cooper-Jacob graph of well ID PHG4

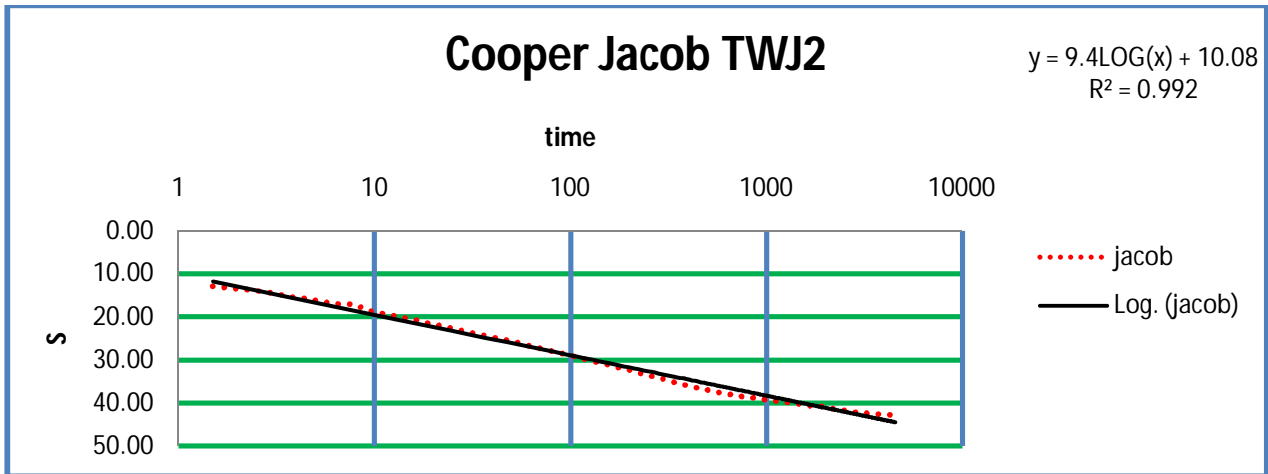


Figure 10 (o) Time versus drawdown cooper-Jacob graph of well ID TWJ2

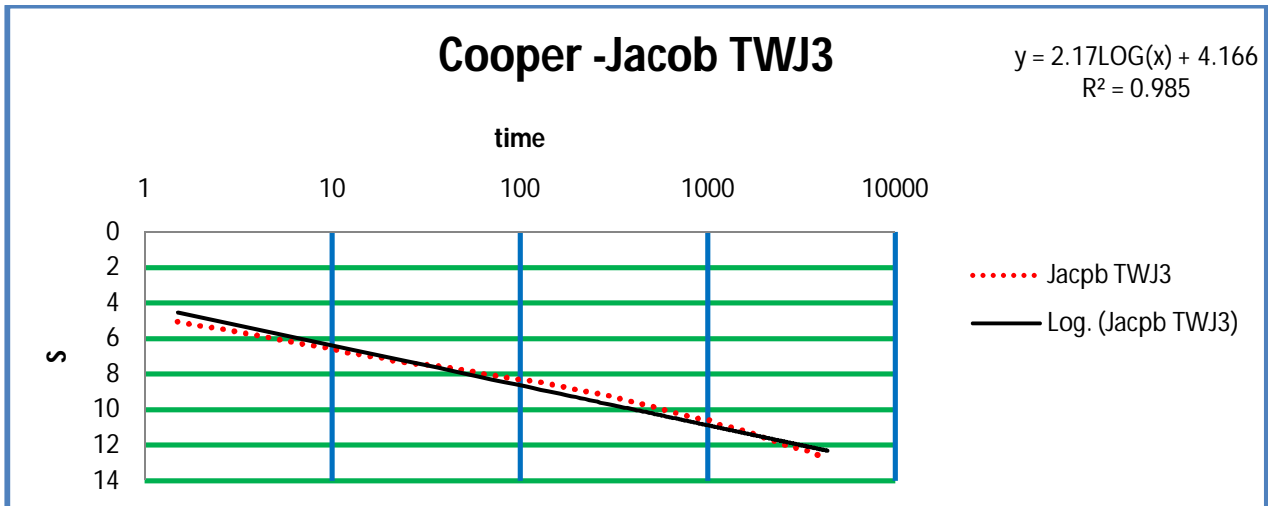


Figure 10 (p) Time versus drawdown cooper-Jacob graph of well ID TWJ3

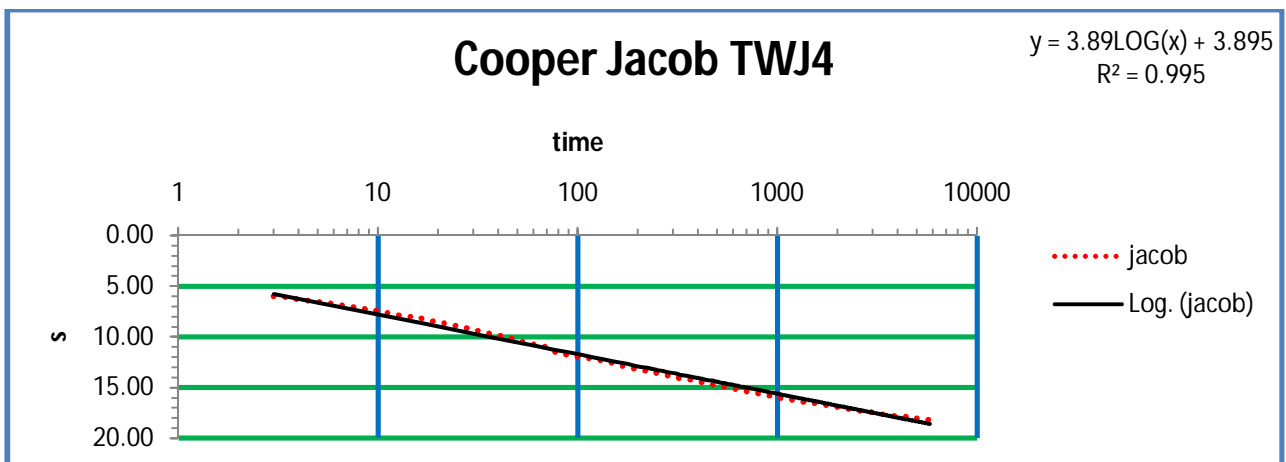


Figure 10 (q) Time versus drawdown cooper-Jacob graph of well ID TWJ4

#### 4.4.2 Theis curve much

Theis method is one of the widely applied methods in groundwater hydrology to determine S and T. However, this method requires curve matching of a type-curve and time drawdown data from a pumping well test. Typically, this is done using a type-curve ( $W(u)$  Vs  $u$ ) plotted on a logarithmic graph paper and the drawdown(s) data curve plotted on another transparent logarithmic graph paper ( $s$  Vs  $\frac{r^2}{t}$ ) with the same scale, and superimposing and sliding the transparent one over the other to get the best possible match while keeping the coordinate axes of two plots parallel.

$$T = \frac{Q}{4\pi T} W(u) \quad 4.2$$

Transmitivity values obtained by using this curve much could be seen from table 1 in the same table the values used in the design of kobo irrigation is also give

No	well ID	Q	w(U)	s	estimated transmitivity			Storativity
					design document	un corrected data	corrected data	
1	TK1	75	1	0.9	457.3	200	997	1E-5
2	PK1	55	1	0.9	280	200	420	9E-7
3	PK2	70	1	1.1	341	410	447	0.5.2E-4
4	PK3	70	1	0.14	1172.5	1718	2716	0.28
5	PK4	60	1	1.3	1126.5	137	200	3.8E-2
6	PK5	30	1	2	55.2	73	105	0.05
7	PK6	40	1	1.05	198	152	275	>1
8	PK7	40	1	0.7	198	261	592.88	2.5E-3
9	PK8	50	1	0.85	168	261	321	>1
10	PK9	50	1	0.1	768.5			>1
11	PHG1	50	1	0.25	1245	1259	1259	1E-8
12	PHG2	45	1	0.3	3145	745	949	0.047
13	PHG3	50	1	0.55	513.5	543	776	>1
14	PHG4	45	1	0.28	1411.5	1031	1104	2.9E-8
15	TWJ2	15	1	6	51.9	47	71	0.33
16	TWJ3	60	1	0.8	624	515	515	0.053
17	TWJ4	60	1	2	475.5	165	206	0.13

Table 4 summary by Theis curve much method estimation result

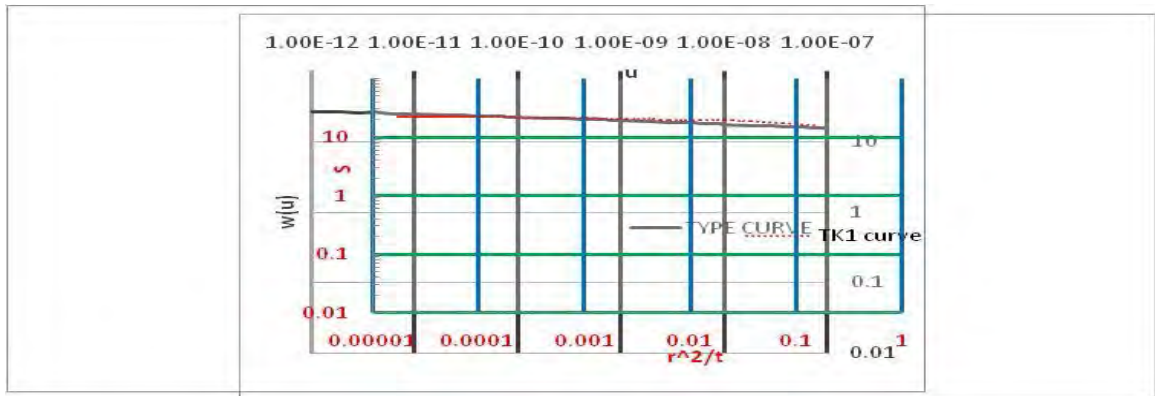


Figure 11(a) Time versus drawdown This curve much method graph of well IDTK1

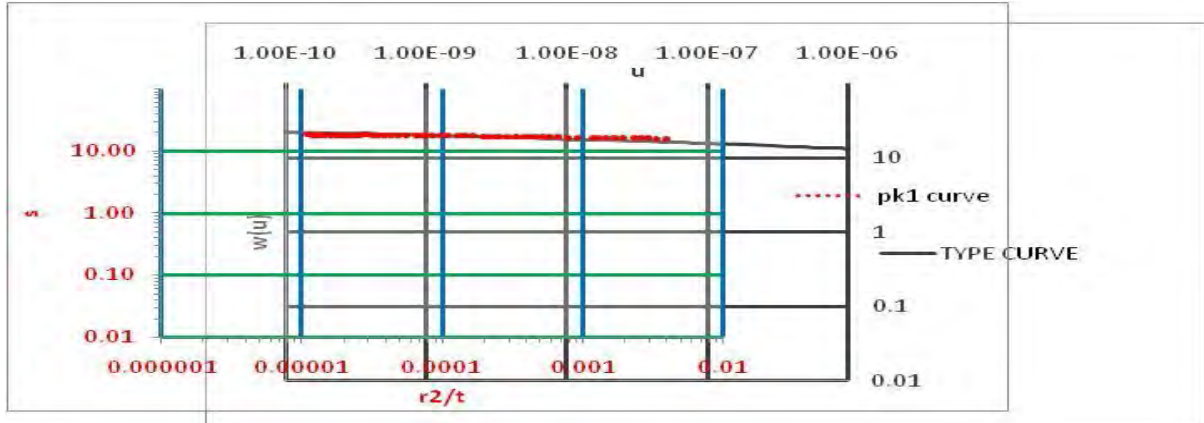


Figure 11(b) Time versus drawdown This curve much method graph of well IDPK1

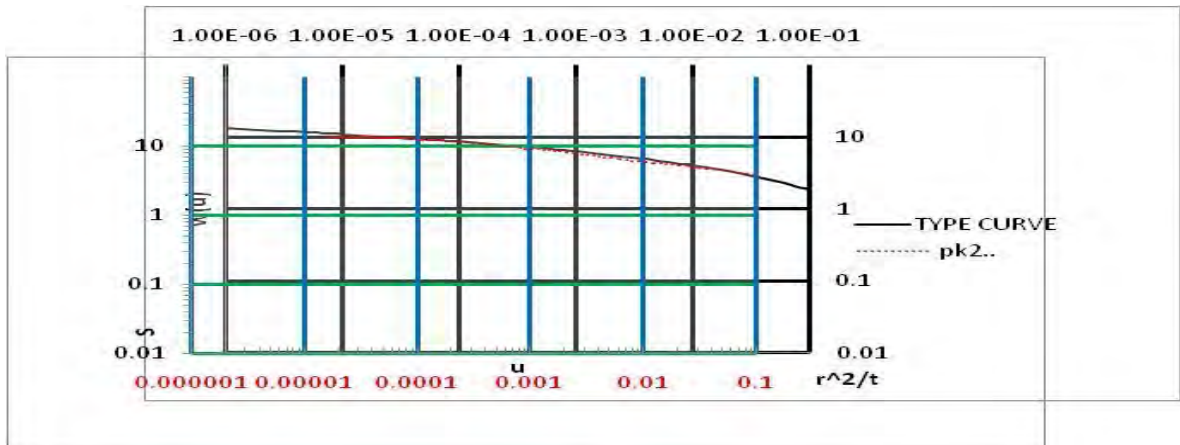


Figure 11(c) Time versus drawdown This curve much method graph of well IDPK2

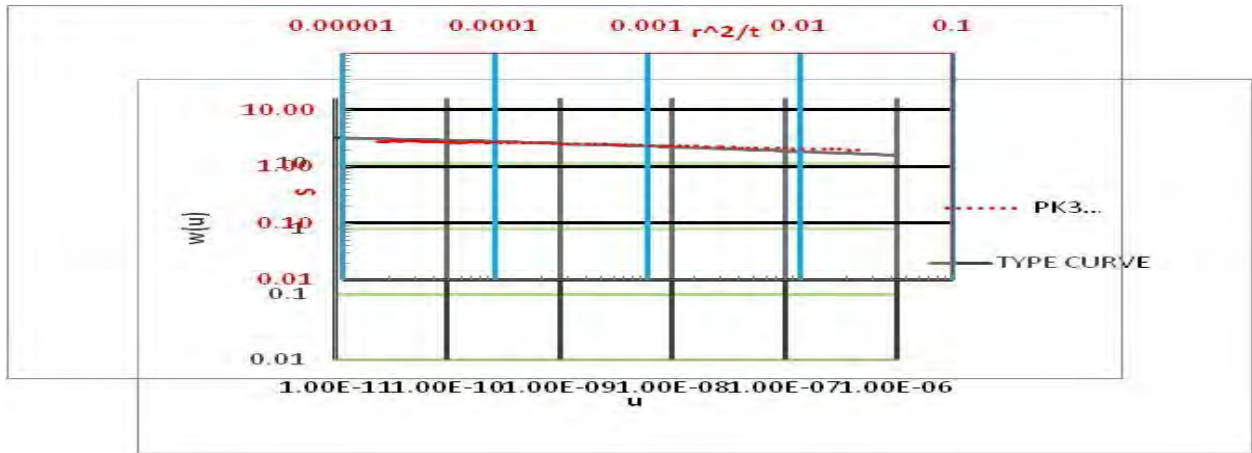


Figure 11 (d) Time versus drawdown This curve much method graph of well ID PK3

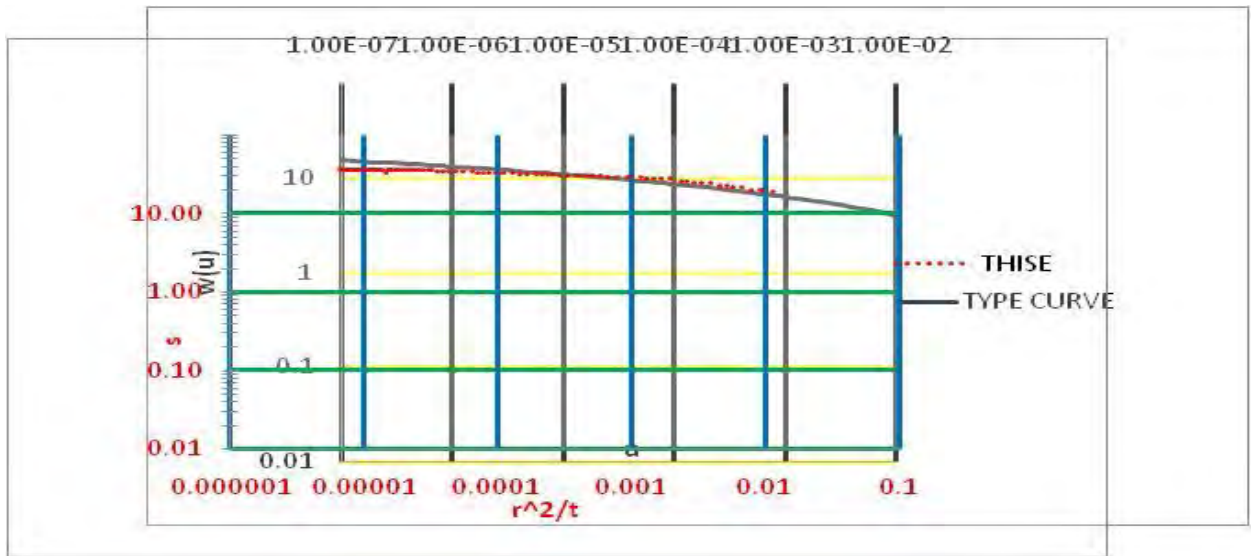


Figure 11 (e) Time versus drawdown This curve much method graph of well ID PK4

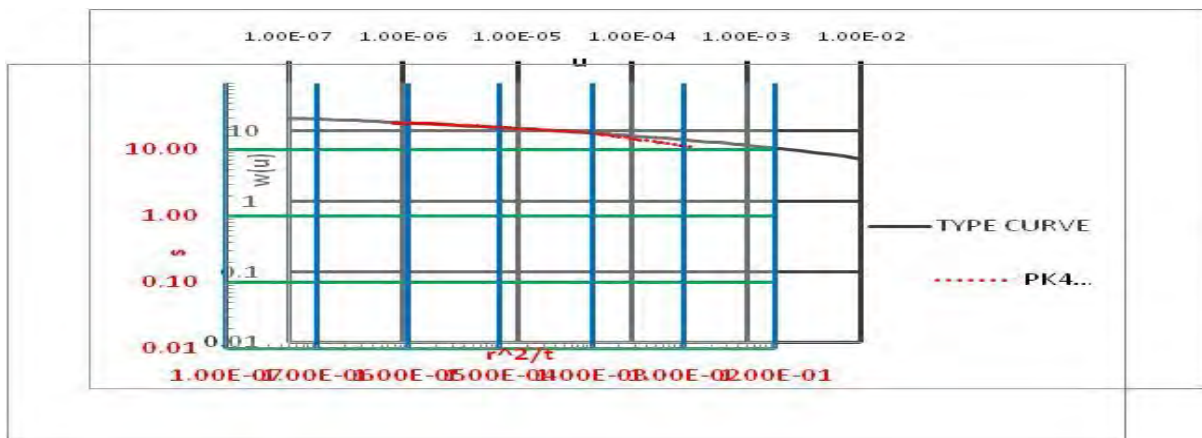


Figure 11 (f) Time versus drawdown This curve much method graph of well IDPK5

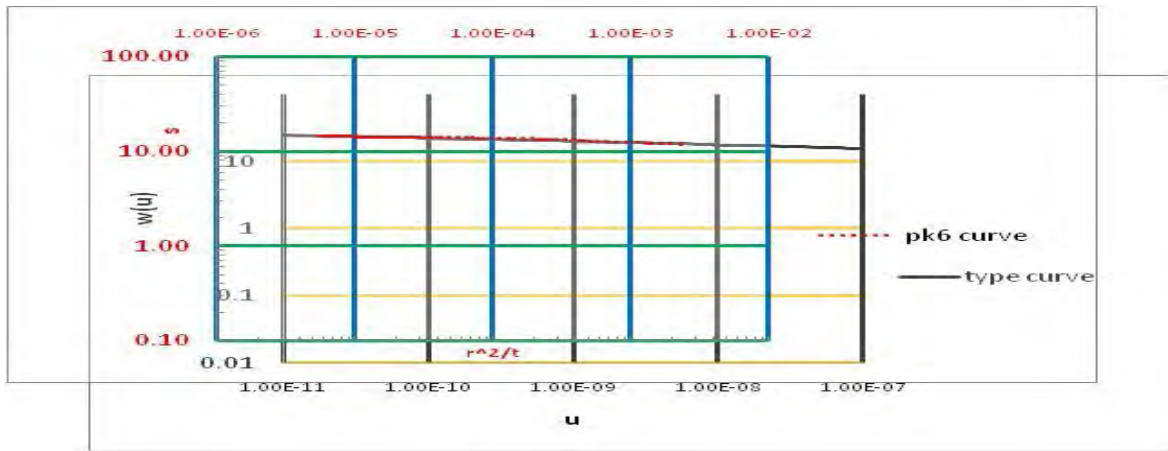


Figure 11 (g) Time versus drawdown This curve much method graph of well IDPK6

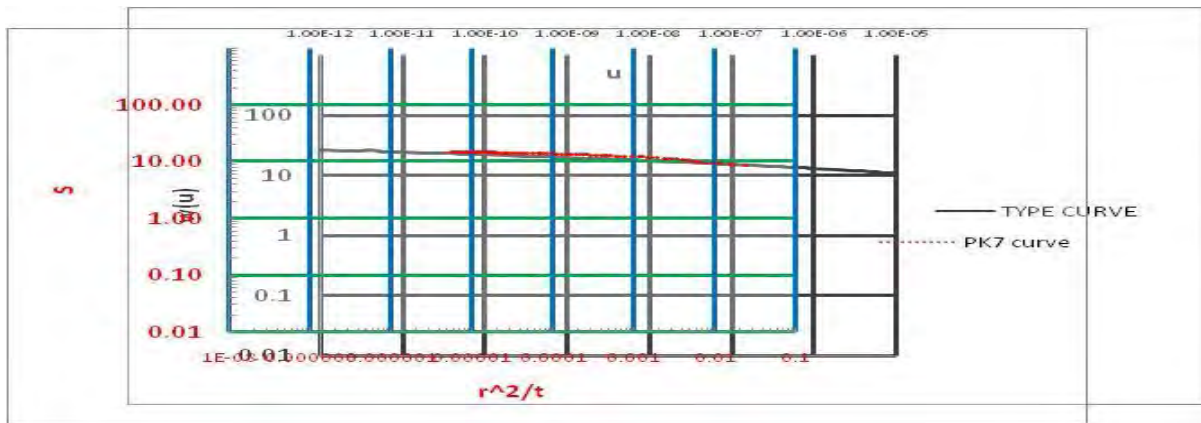


Figure 11 (h) Time versus drawdown This curve much method graph of well IDPK7

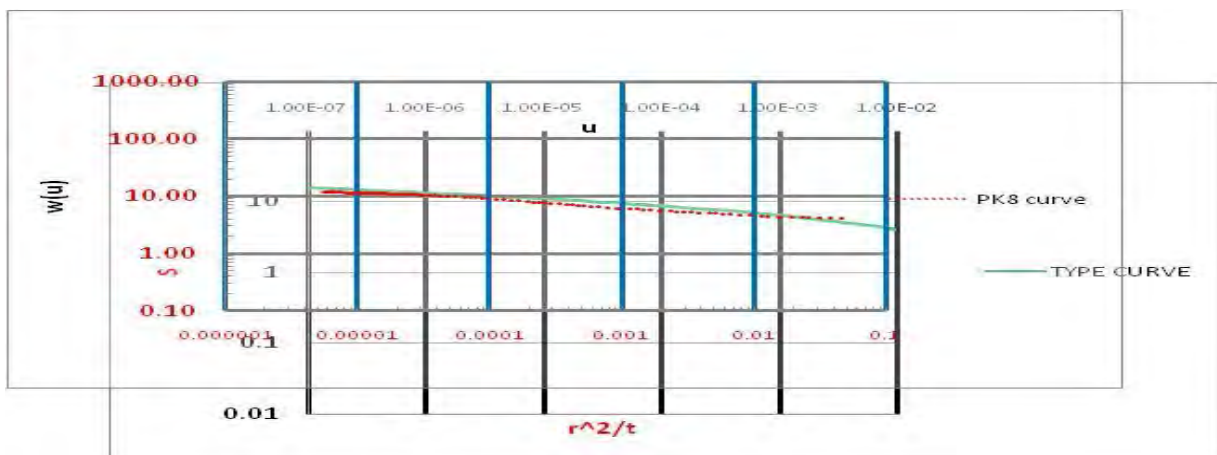


Figure 11 (i) Time versus drawdown This curve much method graph of well ID PK8

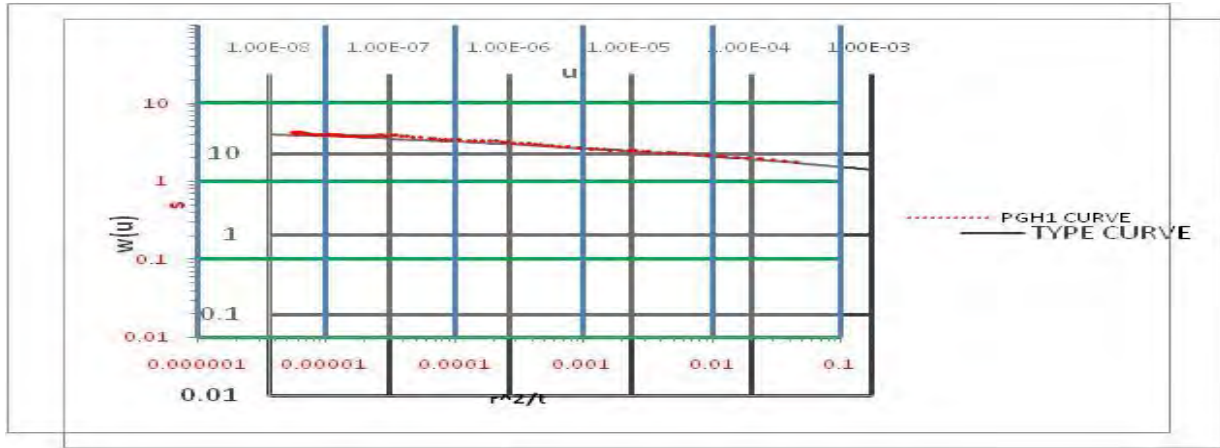


Figure 11 (j) Time versus drawdown This curve much method graph of well ID PHG1

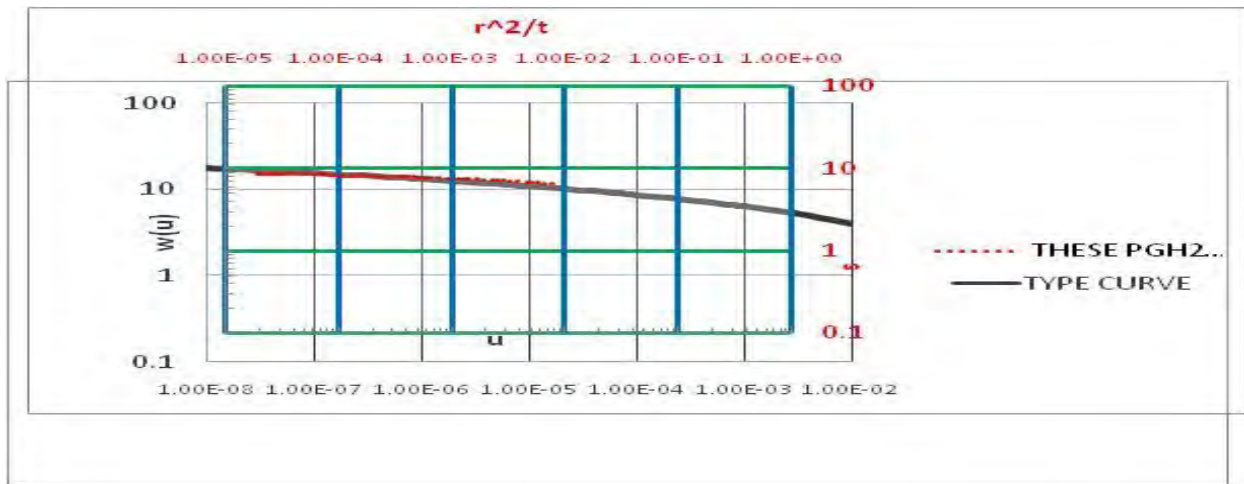


Figure 11(k) Time versus drawdown This curve much method graph of well ID PHG2

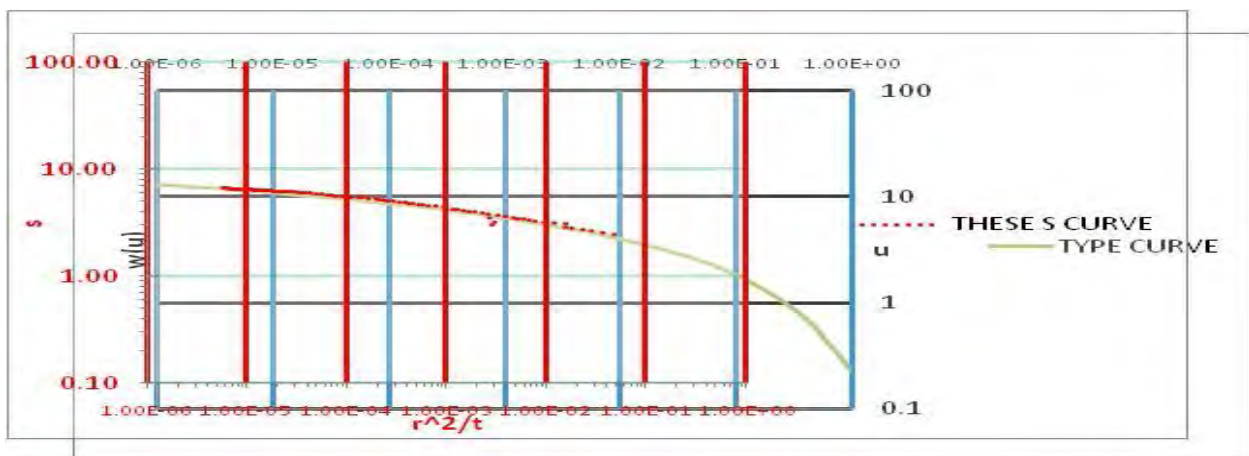


Figure 11(l) Time versus drawdown This curve much method graph of well ID PHG3

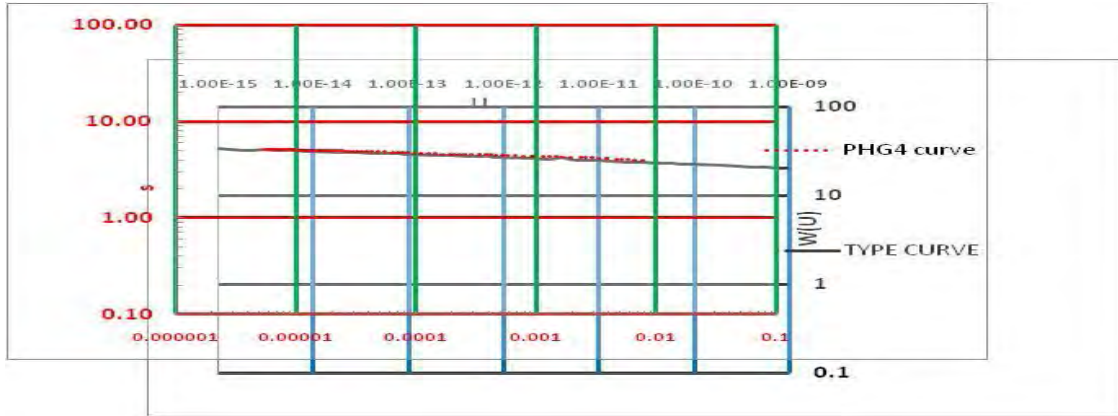


Figure 11 (m) Time versus drawdown Theis curve much method graph of well ID PHG4

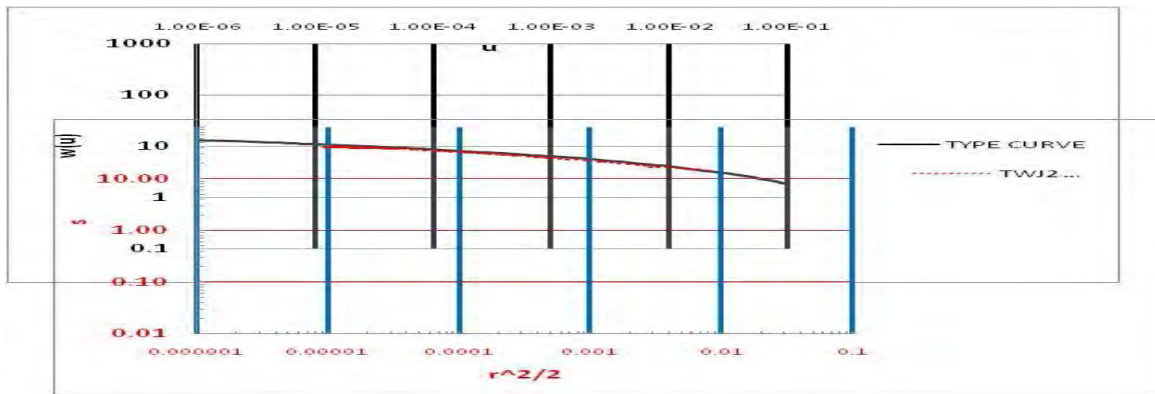


Figure 11 (n) Time versus drawdown Theis curve much method graph of well ID TWJ2

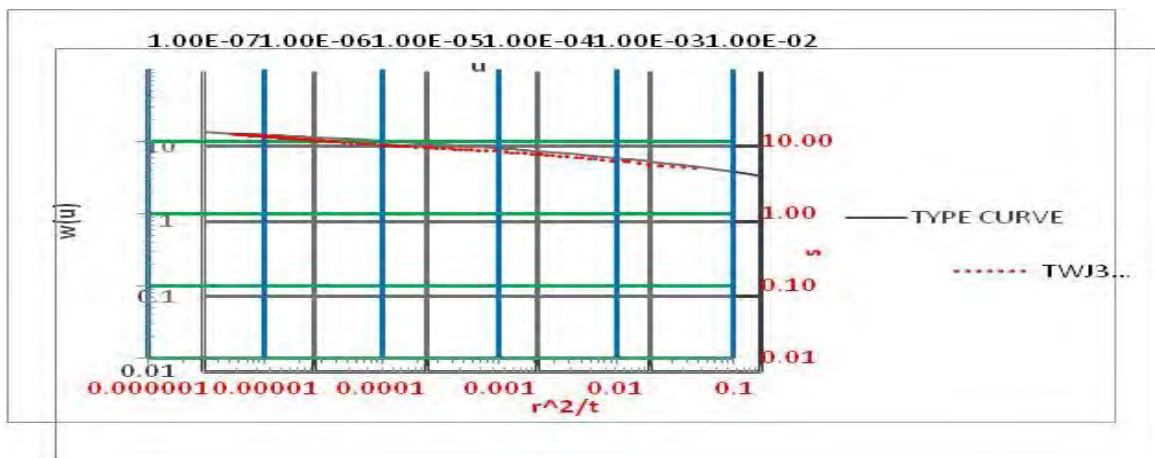


Figure 11 (o) Time versus drawdown Theis curve much method graph of well ID TWJ3



NO	well ID	Q	Best Fit		draw down				Transmitvity			remark
			slop	intercept	at t=10	at t=100	To	$\Delta s$	design document	un corrected data	estimated by correct data	
1	TK1	75	1.934	19.06	22.26	25.47	1.14E-06	3.2	457.3	261	229	
2	PK1	55	1.412	-3.632	10.12	3.24	7.60E-02	3.24	280	240.85	267	
3	PK2	70	1.283	0.139	3.18	6.14	2.95E+00	2.95	341	406	427	
4	PK3	70	0.174	0.305	0.7	1.1	4.00E-01	0.17	1172.5	1718	2701	
5	PK4	60	2.26	-6.894	-1.69	3.5	5.19E+01	21	1126.5	137	207	
6	PK5	30	1.83	-4	0.33	4.66	8.38E+00	4.33	55.2	71	109	
7	PK6	40	1.379	-1.919	2.74	0.42	7.34E+01	3.17	198	162	261	
8	PK7	40	0.476	0.761	1.85	2.95	2.00E-01	1.09	198	348	488.49	
9	PK8	50	1.226	-1.72	1.09	3.91	4.07E+00	2.8	168	186	321	
10	PK9	50	0.366	-0.088	0.75	1.59	1.27E+00	0.84	768.5	761	939	
11	PHG1	50	0.171	0.15	0.54	0.93	4.10E-01	0.39	1245	1272	1270	
12	PHG2	45	0.251	-1.138	-1.71	-2.29	1.00E-02	0.57	3145	998	1188	
13	PHG3	50	0.54	0.858	2.1	3.34	2.00E-01	1.24	513.5	534	636	
14	PHG4	45	0.09	-0.133	0.08	0.29	4.17E+00	0.241	1411.5	1195	1655	
15	TWJ2	15	4.162	0.13	9.7	12.27	9.60E-01	9.57	51.9	20	24	
16	TWJ3	60	0.817	10.57	3.23	5.11	1.80E-01	1.87	624	505	505	
17	TWJ4	60	1.79	0.357	4.47	8.59	8.10E-01	4.117	475.5	173	230	

Table 5 summary of This recovery res

According to the results obtained from the well study area as shown figure 10(a-m)

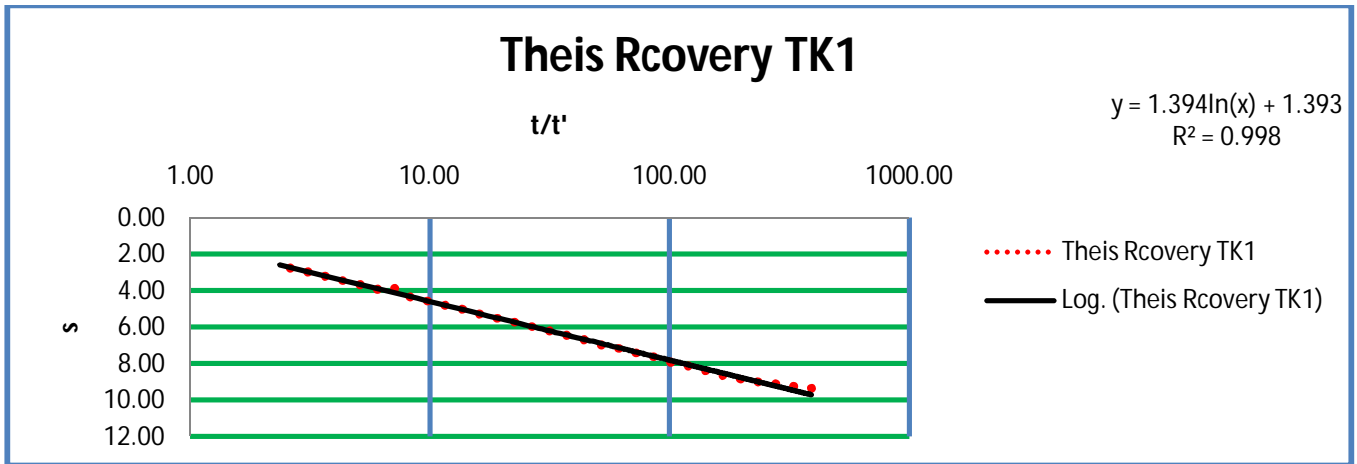


Figure 12(a) Theis recovery graph TK1

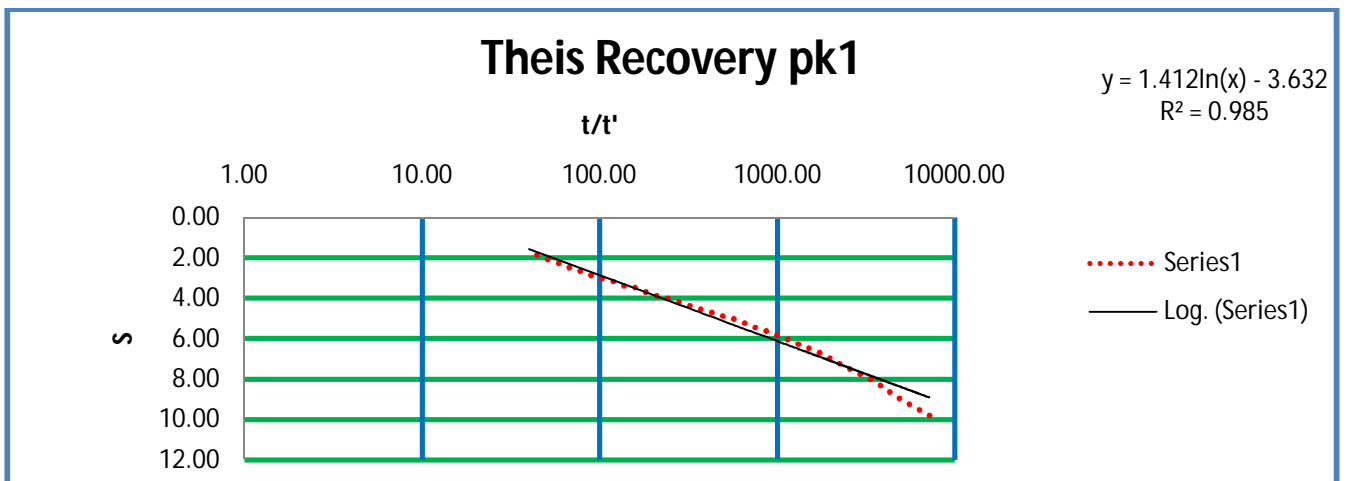


Figure 12 (b) Theis recovery graph PK1

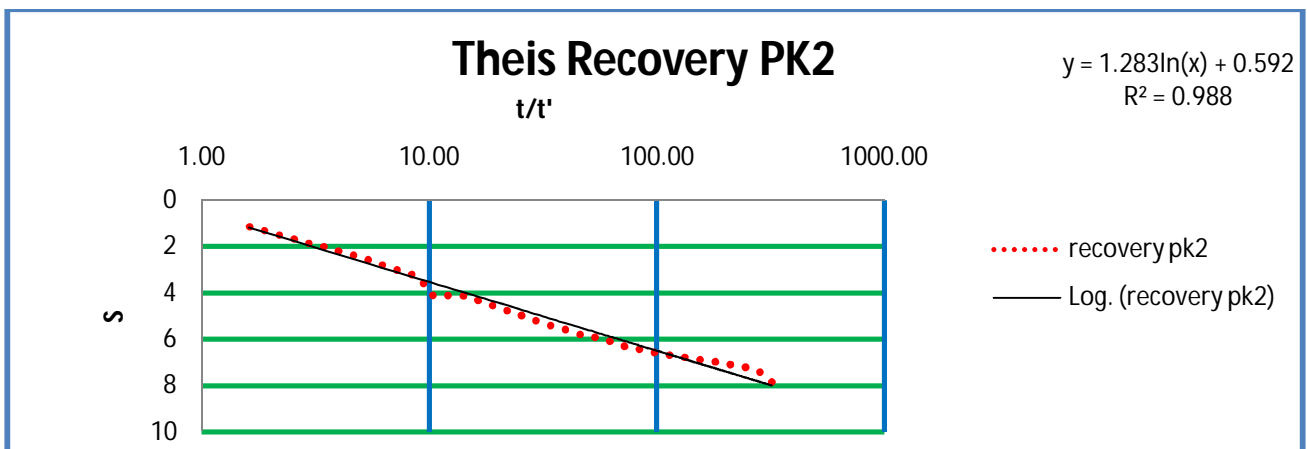


Figure 12 (c) Theis recovery graph PK3

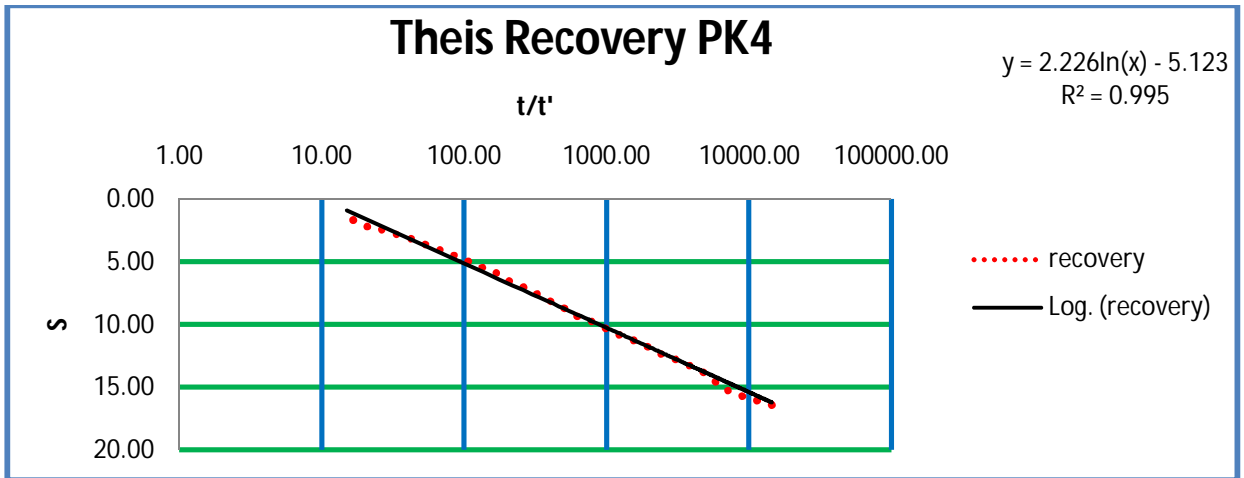


Figure 12 (d) Theis recovery graph PK4

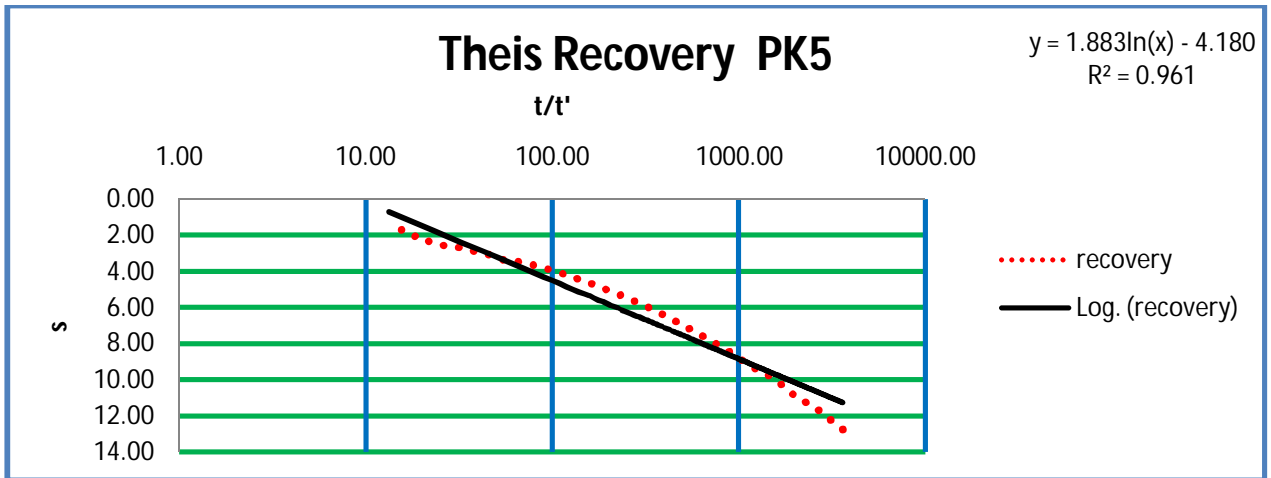


Figure 12 (e) Theis recovery graph PK5

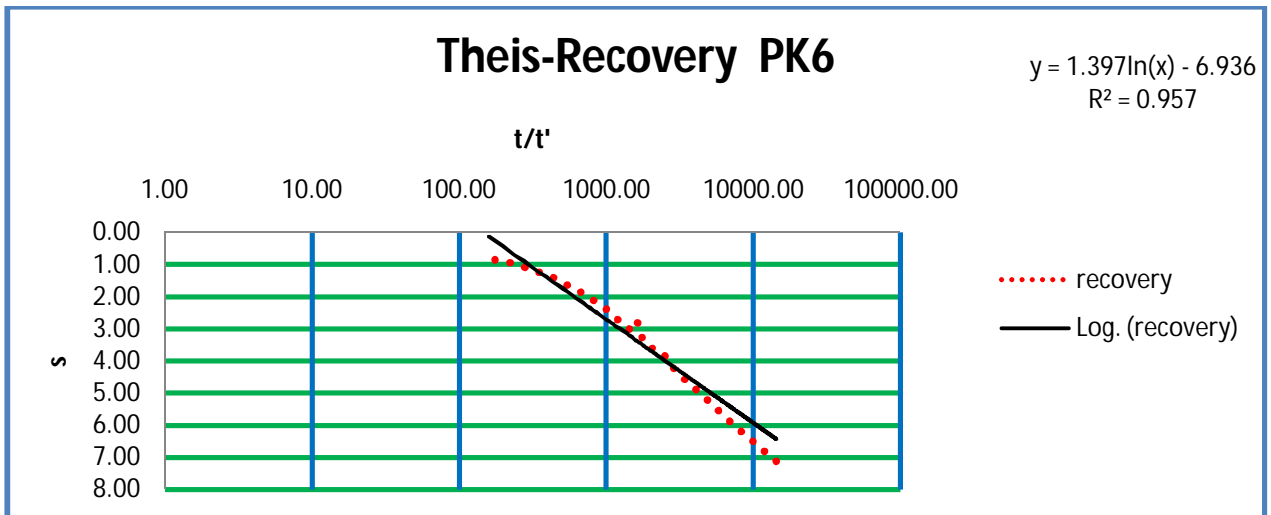


Figure 12 (f) Theis recovery graph PK6

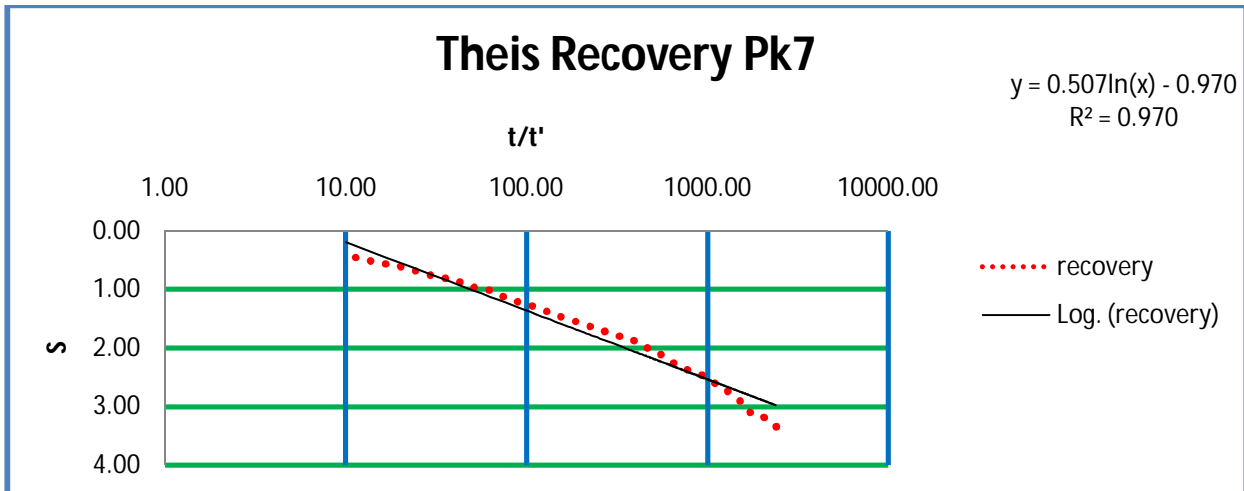


Figure 12 (g) Theis recovery graph PK7

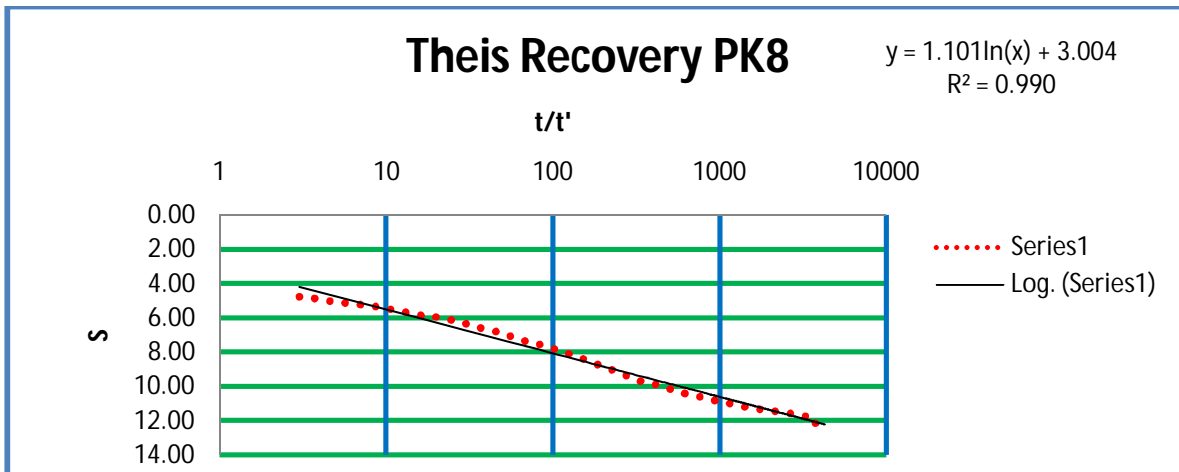


Figure 12 (h) Theis recovery graph PK8

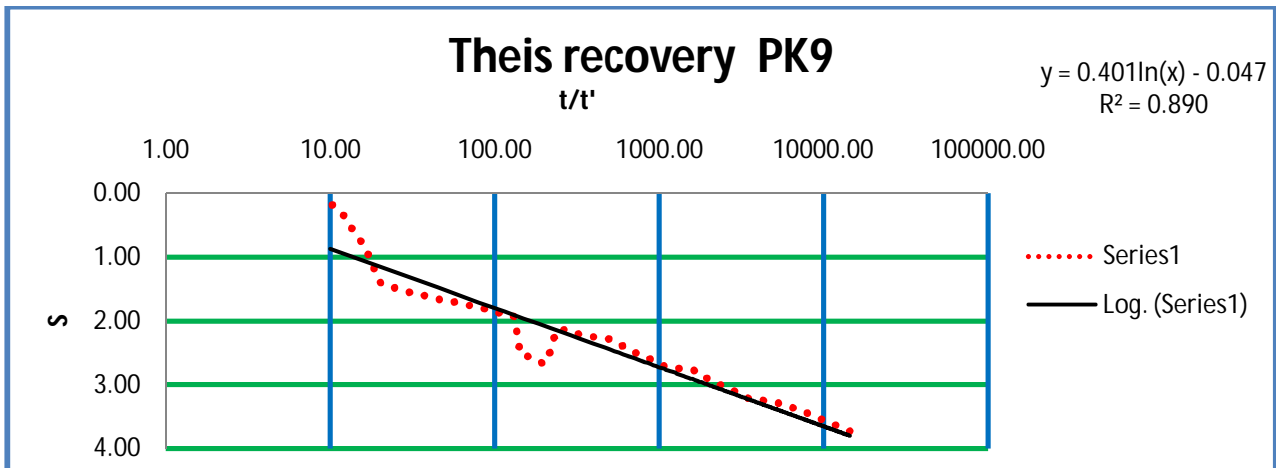


Figure 12 (h) Theis recovery graph PK9

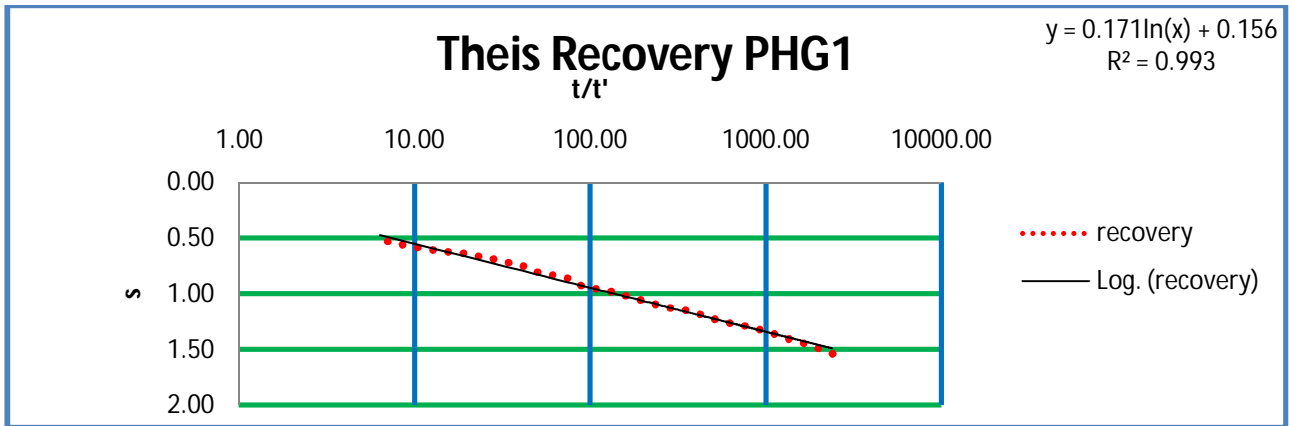


Figure 12 (h) Theis recovery graph PHG1

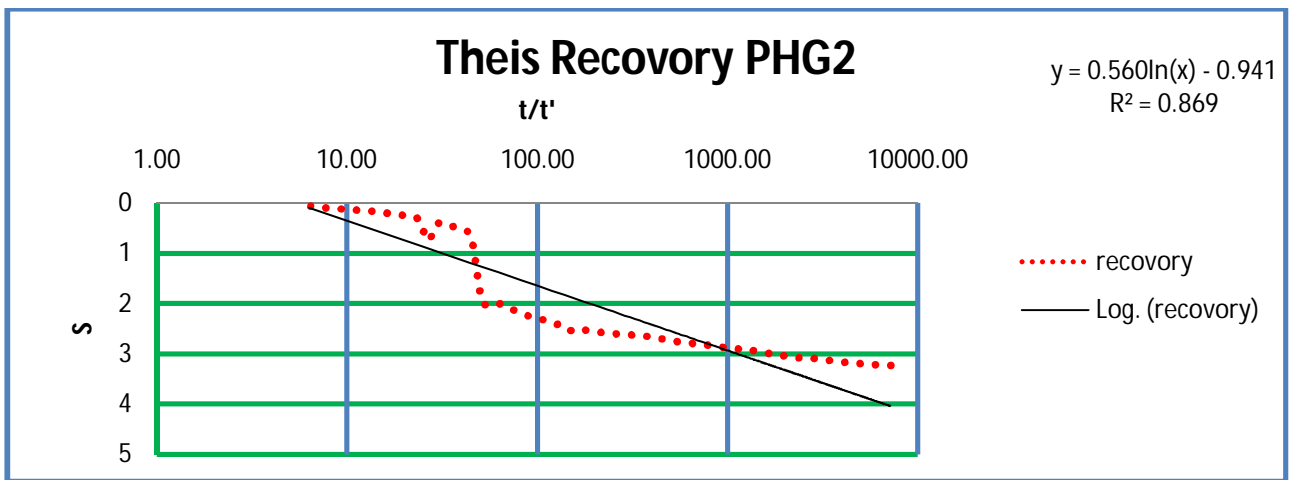


Figure 10 (j) Theis recovery graph PHG2

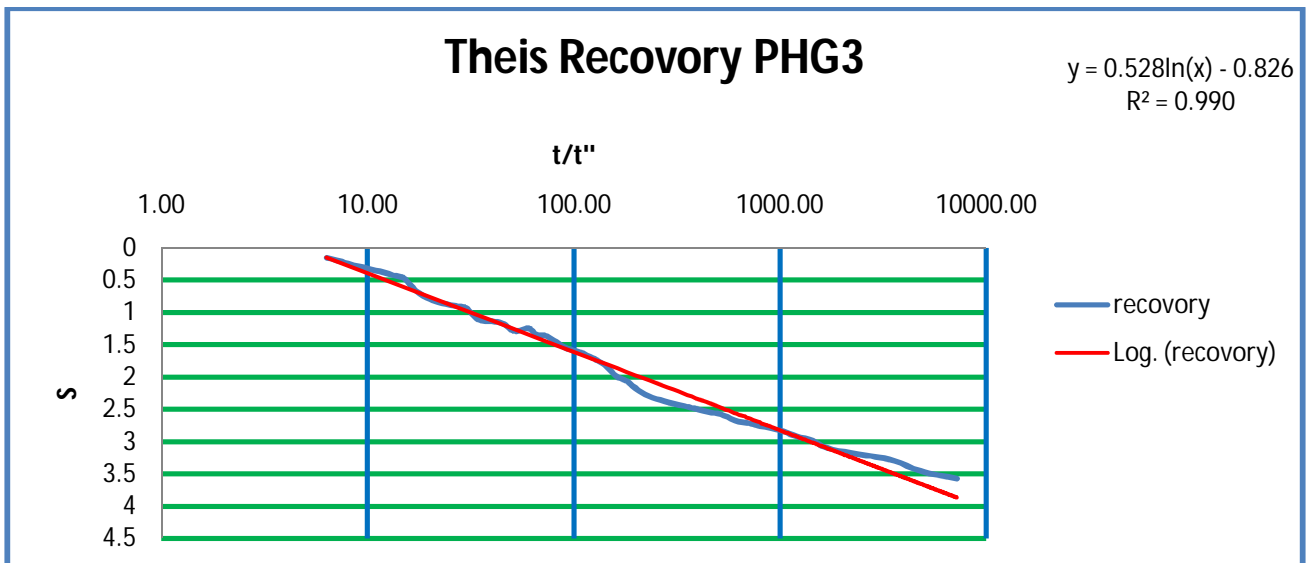


Figure 12 (k) this recovery graph of well ID PHG3

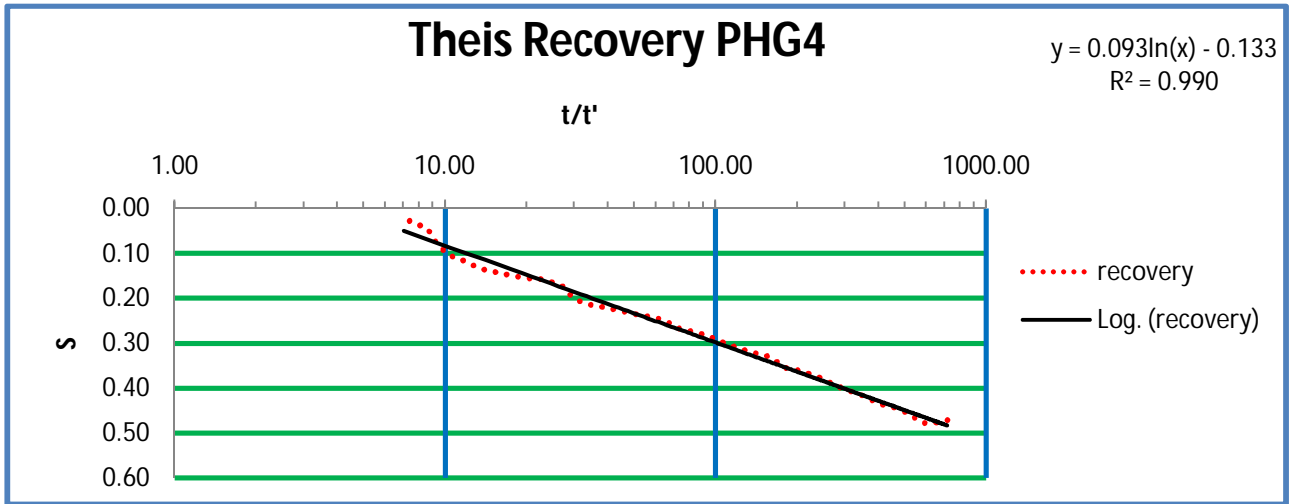


Figure 12 (l) This recovery early time data graph PHG4 early time data

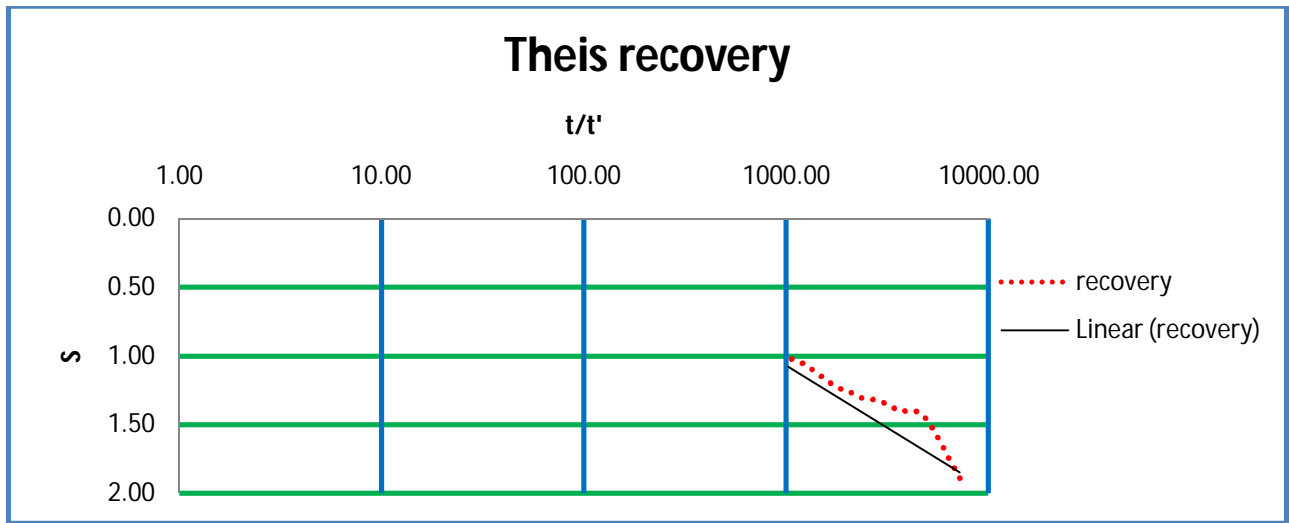


Figure 12 (m) This recovery early time data graph PHG4 early time data

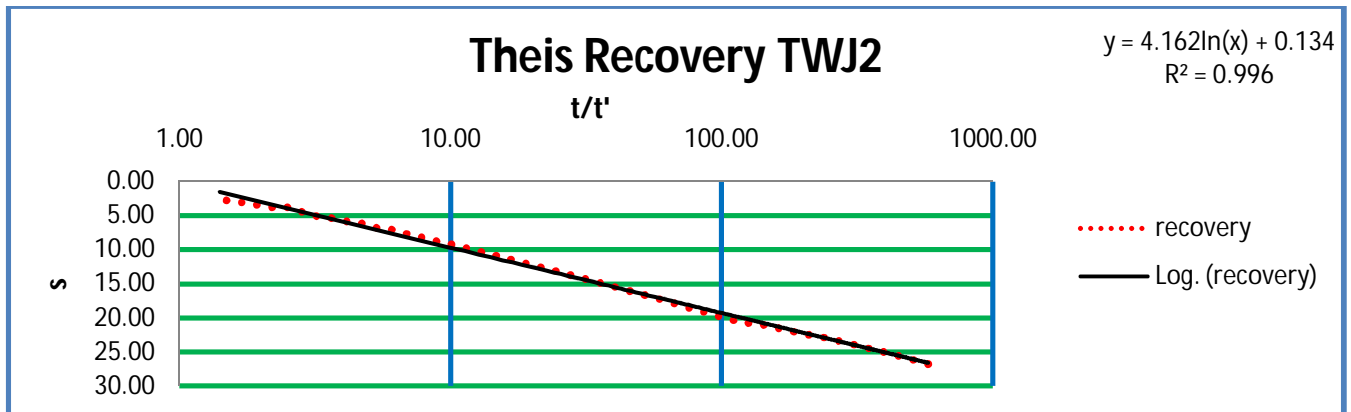


Figure 12 (n) This recovery graph TWJ2

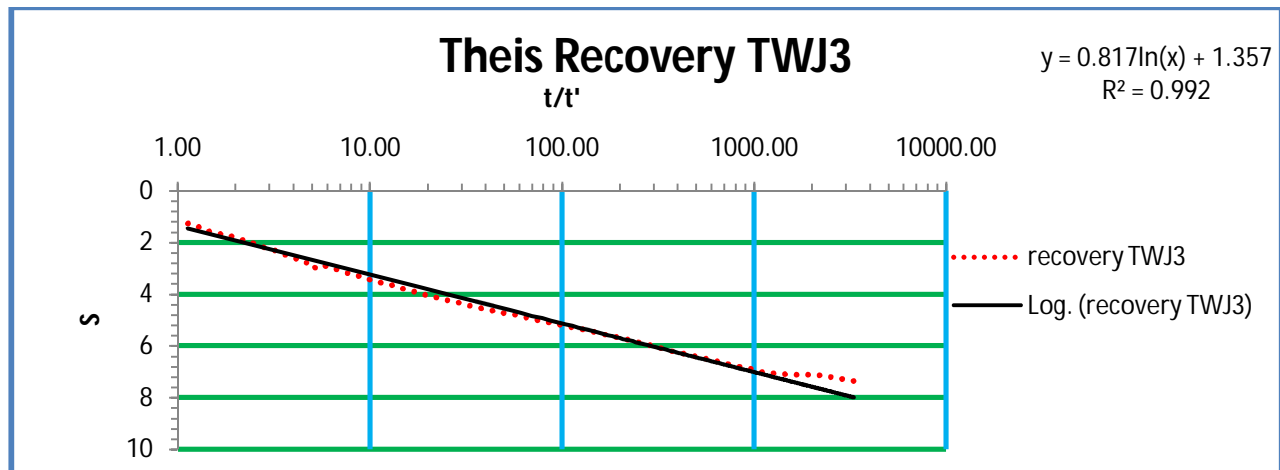


Figure 12(o)Theis recovery graph TWJ2

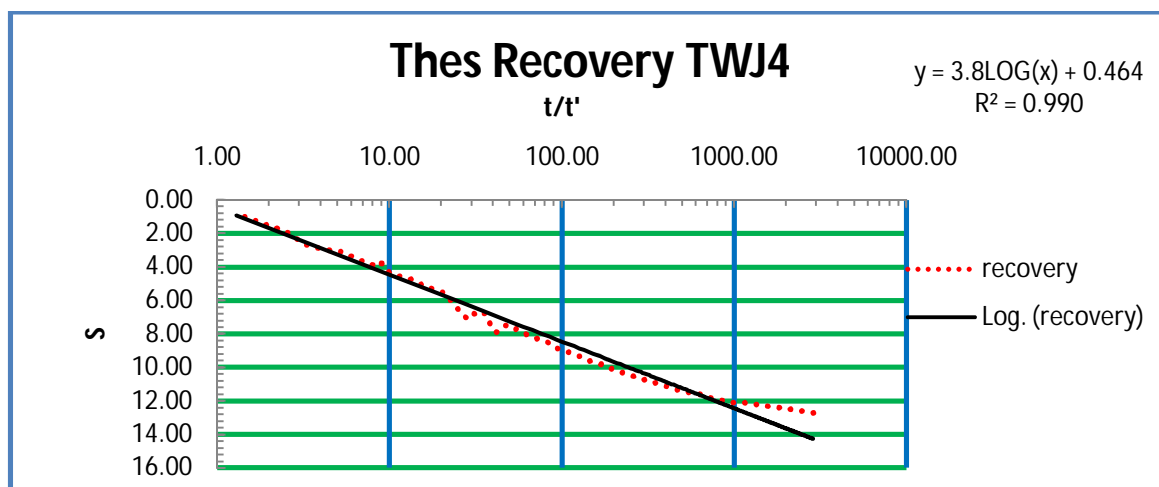


Figure 12 (o) Theis recovery graph of well ID TWJ2

## 2.6 Summary of result and discussion

All above three method results such as cooper-Jacob method. This curve much method and Theis recovery results analyze by using geometric mean of uncorrected and corrected data transmissivity values summarized for the purpose of comparison with kobo irrigation project design document values. All well summarized transmissivity value of kobo irrigation wells are listed in the table 5 below

<b>N O</b>	<b>WELL ID</b>	<b>X</b>	<b>Y</b>	<b>Z</b>	<b>Desig n docm ent value</b>	<b>METHOD</b>	<b>Un corrected data</b>	<b>Geomat ric mean</b>	<b>Correct ed data</b>	<b>Geoma tric mean</b>	<b>Aquitest 3.5 softwear</b>	<b>Geomatic mean</b>	<b>Percentag e increas</b>
1	TK1	570275	1355009	1418	457.3	Theis over lap	200	252	997	438	500	368	4.136974
						cooper jacob	307		369		199		
						Theis recovery	261		229		500		
2	PK1	568066	1340931	1491	280	Theis over lap	270	259	420	453	409	466	-61.7883
						cooper jacob	267		829		847		
						Theis recovery	240.85		267		293		
3	PK2	568476	1341101	1488	341	Theis over lap	410	397	447	434	1160	1153	-27.2444
						cooper jacob	376		428		1040		
						Theis recovery	406		427		1270		
4	PK3	568204	1350350	1440	1172. 5	Theis over lap	1718	1724	2719	2729	2860	2790	-132.71
						cooper jacob	1737		2766		2770		
						Theis recovery	1718		2701		2740		
5	PK4	568000	1353000	1436	1126. 5	Theis over lap	137	144	200	197	174	191	82.50182
						cooper jacob	159		185		219		
						Theis recovery	137		207		182		
6	PK5	568427	1351843	1428	55.2	Theis over lap	73	78	103	131	168	148	-137.619
						cooper jacob	90		201		196		
						theis recovery	71		109		98.5		
7	PK6	569299	1341849	1481	198	Theis over lap	152	223	275	310	360	377	-56.4041
						cooper jacob	453		551		531		
						Theis recovery	162		196		280		
8	PK7	569892	1341651	1474	198	Theis over lap	261	259	592.88	551	382	422	-178.301
						cooper jacob	194		577.72		501		
						Theis recovery	345		488.49		394		
9	PK8	569814	1341065	1469	168	Theis over lap	261	211	321	307	336	323	-82.5633
						cooper jacob	193		280		310		
						Theis recovery	186		321		323		

10	PK9	569485	1341610	1475	768.5	Theis over lap							31.9453
						cooper jacob							
						Theis recovery	907	907	1014	1014	719	719	
11	PHG1	567688	1338578	1475	1245	Theis over lap	1259		1259		1290		-0.08498
						cooper jacob	1210		1210		1250		
						Theis recovery	1272	1247	1270	1246	1275	1272	
12	PHG2	567801	1337977	1479	3145	Theis over lap	745		949		910		62.21271
						cooper jacob	651		1133		1090		
						Theis recovery	998	785	1561	1188	1120	1036	
13	PHG3	568356	1337982	1473	513.5	Theis over lap	543		776		721		-40.7515
						cooper jacob	483		765		758		
						Theis recovery	534	519	636	723	621	698	
14	PHG4	566857	1339244	1507	1411.5	Theis over lap	1031		1104		1240		-8.35419
						cooper jacob	1294		1958		1940		
						Theis recovery	1195	1168	1655	1529	1150	1404	
15	TWJ2	573465	1339244	1398	51.9	Theis over lap	47		71		29		32.70711
						cooper jacob	20		25		25		
						Theis recovery	20	27	24	35	23	26	
16	TWJ3	569491	1357769	1428	624	Theis over lap	515		515		491		22.49233
						cooper jacob	435		435		426		
						theis recovery	505	484	505	484	462	459	
17	TWJ4	868854	1352624	1425	475.5	Theis over lap	165		206		247		52.51207
						cooper jacob	183		243		243		
						Theis recovery	173	174	230	226	229	240	

Table 5 summary of hydraulic parameters by using the Theis curve much, cooper-Jacob, Theis recovery method and aqui test 3.5 software by using uncorrected drawdown data and correct draw down data estimation

Summarize all calculated transmissivity values results dividing two groups depend on percentage of overestimate or percentage of underestimate.

The first group is over estimate transmissivity value such as well ID TK1, PK4, PHG2, TWJ2 and TWJ3

The second group is under estimate transmissivity value such as well ID PK1, PK2, PK5, PK6, PK7, PK8, PK9, PHG3 and well ID PHG4

#### **4.6.1 Summary results for overestimate transmissivity**

For Well ID TK1 using above the three method calculating transmissivity by geometric mean is  $445\text{m}^2/\text{day}$  by 90 percent well efficiency. In the design document of average arithmetic uncorrected calculated transmissivity is  $475.5\text{m}^2/\text{day}$ . this is due to use of average arithmetic uncorrected pumping test data and recovery test data. the difference in transmissivity values come from use of uncorrected average pumping test and recovery test data instead of corrected geometric mean value and magnitude of overestimate transmissivity is 4 percent.

Well ID PK4 using the above three method of calculating transmissivity is by geometric mean is  $191\text{m}^2/\text{day}$  by 90 percent well efficiency and uncorrected data average geometric mean transmissivity is  $78\text{m}^2/\text{day}$ . From kobo irrigation design document calculated average transmissivity value is  $1128\text{m}^2/\text{day}$  and design document transmissivity over estimate by 82 percent. For this paper used to compute hydraulic parameter of well ID PK4 using both pumping test and recovery test data .

For Well ID PHG2 average calculated transmissivity value by above three methods using geometric mean  $1188\text{m}^2/\text{day}$  and uncorrected data transmissivity value is  $758\text{m}^2/\text{day}$ . design document transmissivity value is  $3145\text{m}^2/\text{day}$  using aqui test 3.5 software. from pumping test data using cooper Jacob method transmissivity is  $1133\text{m}^2/\text{day}$  and Theis type curve method calculated transmissivity value  $949\text{m}^2/\text{day}$  and by using recovery data calculated transmissivity is  $1561\text{m}^2/\text{day}$ . Average calculated geometric is  $1118\text{m}^2/\text{day}$  . Compare calculated value and design document

value, design document value high as compared with estimated value by using above three methods and magnitude of overestimate transmissivity is 62percent..

For Well ID TWJ2 calculated transmissivity using above three method of calculating transmissivity by geometric mean is  $26.66\text{m}^2/\text{day}$  by 82 percent well efficiency. From the design document calculated transmissivity is  $51.9\text{m}^2/\text{day}$ . Project design document to select average uncorrected pumping and recovery data for computing average transmissivity is  $51.9\text{m}^2/\text{day}$  and 32 percent over estimate transmissivity.

For well ID TWJ3 using above three method of calculating transmissivity by geometric mean is  $484\text{m}^2/\text{day}$  .From the design document calculated transmissivity is  $624.33\text{m}^2/\text{day}$  The value difference comes from contractor over estimate hydraulic parameters both pumping test and recovery test data. By using uncorrected recovery data transmissivity value is  $468\text{m}^2/\text{day}$ . For this thesis used to compute both corrected pumping and recovery data to compute hydraulic parameters and analyze by geometric men of the three method transmissivity value is  $484\text{m}^2/\text{day}$  and magnitude of overestimate transmissivity is 22 percent.

Well ID TWJ4 calculating transmissivity by geometric mean is  $174\text{m}^2/\text{day}$  by using 80 percent well efficiency. From the design document calculated transmissivity is  $475\text{m}^2/\text{day}$ . Difference in transmissivity value comes from over hydraulic parameters using both pumping test and recovery test data. For this thesis used to compute both corrected pumping and recovery data to compute the parameters and analyze by geometric men of the three methods transmissivity value is  $174\text{m}^2/\text{day}$  and magnitude of percentage overestimate transmissivity value is 55 percent.

All above overestimate transmissivity with 8-178% and the wells are not supply the estimated yield and not irrigate recommended estimtmate area.

#### **4.6.2 Summary results for underestimate transmissivity**

For well ID PK1 using above three method of calculating transmissivity value by geometric mean is  $392\text{m}^2/\text{day}$ . From the design document calculated transmissivity is  $198\text{m}^2/\text{day}$  .design document value is under estimate because to select un corrected

pumping test and recovery test data for computing transmissivity . For this thesis used to compute both corrected pumping and recovery data to compute hydraulic parameters and analyze by geometric mean of the transmissivity value and magnitude of percentage underestimate by 61 percent.

Well ID PK2 is partially penetrated well and step drawdown test not done in the design document. Correction of partial penetration applied only if  $L/b < 0.5$  L/b. for well ID PK2 l/b value 0.66 and greater than 0.5,so not applied correction of partially penetration but unconfined correction is applied. Using the above three method of calculating transmissivity by geometric mean is  $443\text{m}^2/\text{day}$ . From the design document calculated transmissivity is  $341\text{m}^2/\text{day}$  and design so document select uncorrected pumping test and recovery data for computing transmissivity and by using uncorrected data calculated transmissivity using above three methods is  $341\text{m}^2/\text{day}$ . The difference comes from design document use only use uncorrected pumping test and recovery test data and magnitude of percentage underestimate transmissivity value is 28 percent.

Well ID PK3 is partial penetration well and correct drawdown by using kozy 1933 partial penetration correction formula .calculating transmissivity value using above three methods geometric mean is  $2729\text{ m}^2/\text{day}$ . From the design document calculated transmissivity is  $1172\text{ m}^2/\text{day}$ . Design document to select uncorrected pumping test , recovery test and average transmissivity values. Magnitude of percentage underestimate transmissivity value is 133 percent.

For Well ID PK5 calculating transmissivity geometric mean of three methods is  $131\text{m}^2/\text{day}$  and Design document calculated transmissivity is  $55.2\text{m}^2/\text{day}$ . In kobo pressurized irrigation project design document to select average uncorrected pumping test and recovery data for computing transmissivity by UN corrected data calculated transmissivity by using above three method is  $58\text{m}^2/\text{day}$ . The difference come from design document use uncorrected pumping test and recovery test data and magnitude of percentage underestimate transmissivity value is 138percent.

For well ID PK6 using above three method of calculating transmissivity by geometric mean is  $307\text{m}^2/\text{day}$  by 90 percent well efficiency. From the design document calculated

transmissivity is  $198\text{m}^2$ . design document to select pumping test and recovery test data for computing transmissivity and percentage increase under estimate transmissivity value is 56 percent.

The quality of data for well ID PK9 graph is very low seen figure 4 (j). For example  $R^2$  on semi log graph value is below 0.5 and not fit straight line. Pumping test data disturbed with increasing time. Draw down data from 0 minutes to 0.5 minute drawdown rapidly drop 0 to 2.67m. for a time of 0.5 minute up to 4320 minute the water level in the well rise and drop Because of the above reason for this paper not using pumping test data of PK9 for estimation of hydraulic parameter.

The Calculated value of transmissivity well ID PK9 using recovery test data is  $939\text{m}^2/\text{day}$  by 70 percent well efficiency and design document estimated value of transmissivity is  $768\text{m}^2/\text{day}$ . the transmissivity value difference come due to not use correction for recovery data. using un correct recovery data calculated transmissivity is  $768\text{m}^2/\text{day}$  and using pumping test data calculate transmissivity is  $2500\text{m}^2/\text{day}$  this is not realistic because pumping test data quality is very low and Percentage of increase under estimate transmissivity by using recovery test data is 56 percent.

For well ID PHG1 By using the above three method of calculating transmissivity by geometric mean is  $1245\text{m}^2/\text{day}$  and design document calculated transmissivity is  $1246\text{m}^2/\text{day}$

Well ID PHG3 using above three method of calculating transmissivity using geometric mean  $723\text{m}^2/\text{day}$  by 77 percent well efficiency. From the design document calculated transmissivity is  $514\text{m}^2/\text{day}$ . In kobo pressurized irrigation project design document to select average uncorrected pumping and recovery data for computing transmissivity. For this thesis used to compute both pumping and recovery data to compute the parameters and analyze by geometric mean of the three methods by using correcting draw down and recovery data and percentage increase under estimate transmissivity value is 62 percent.

To calculate hydraulic parameter from Theis recovery graph PGH4 is difficult because the graph data is highly disturbed or not fit straight line. Because of the above reason

separate time versus corrected drawdown in to two .the first figure see figure 6(l) is draw by early time data up to middle time data and the second graph figure 6(m) draw by using late time data up to late time data. After draw the two graphs Calculated transmit by using middle time to late time draw dawn data is 3323.278 m<sup>2</sup>/day. From the figure 6(l) and 6(m) graph calculate transmissivity by using geometric mean of the two graph transmissivity value, so calculated transmissivity from two graphs by using geometric mean is 1655.7m<sup>2</sup>/day.

For well ID PHG4 estimated transmissivity using above three methods calculated value of transmissivity geometric mean is 1529 m<sup>2</sup>/day by 75 percent well efficiency. Design document transmissivity is 1411.5m<sup>2</sup>/day and geometric mean uncorrected value of transmissivity is 1168m<sup>2</sup>/day. This difference come from due to absence of correction draw dawn data using direct field data to calculating hydraulic parameters. In this paper used to calculate hydraulic parameters used by geometric mean of corrected pumping and recovery test and 8 percentage increase of under estimate transmissivity.

For each 17 well three transmissivity value were estimated the geometric mean value estimated ranges from a minimum of 26m<sup>2</sup>/day to 2790m<sup>2</sup>/day. For the same wells the range of transmissivity value used in the design of the kobo irrigation scheme was 55.2m<sup>2</sup>/day to 3145m<sup>2</sup>/day. Among the 17 wells 11 wells were found to under estimate transmissivity obtain in this research 4- 82% but one are found to overestimate the transmissivity with 8-178%.given the fact that both this research and the design document uses the same well test data.

All above underestimate transmissivity obtain in this research 4- 82% for the well with under estimated transmissivity values the well yield could have been more yield and irrigable areas.

## 5 Conclusion and recommendation

Single-well aquifer tests provide data in many situations in which aquifer pumping-test data from multiple wells would be a luxury for the ground-water analyst. The primary factor limiting the performance of multi-well aquifer tests is cost, particularly in areas with large depth to water (Belcher et al, 2001). For example, irrigation wells are installed far apart to minimize interference. This separation causes adjacent wells to be poor observation wells.

The ground-water analyst faces many problems and challenges where hydraulic testing is limited to an isolated well. These problems include well-known and quantifiable effects such as borehole head loss during pumping, as well as much more difficult to quantify factors such as lateral and vertical anisotropy. Many effects could only be quantified with reasonable accuracy using multiple observation wells or flow logs (Hanson and Nishikawa, 1996). An analyst can still derive significant useful information from single-well tests.

Well and aquifer head losses can be better differentiated with improved transmissivity estimates from single-well aquifer tests. Head losses, from poor well completion practice and partial penetration, will be transmissivity has been overestimated.

In the study area 17 single well constant pumping test and recovery test data were collected besides 14 of 17 wells have the step drawdown test data. In this research where conducted to re- analyze the transmissivity value estimated for design. having chalked the data quality for all 17 wells in the kobo well field transmissivity was estimated using Theis and Cooper-Jacob method for the time drawdown data collected and the residual drawdown analysis time residual drawdown data. For each well three transmissivity value were estimated the geometric mean value estimated ranges from a minimum of  $26\text{m}^2/\text{day}$  to  $2790\text{m}^2/\text{day}$ .

For the same wells the range of transmissivity value used in the design of the kobo irrigation scheme was  $55.2\text{m}^2/\text{day}$  to  $3145\text{m}^2/\text{day}$ . Among the 17 wells 11 wells were found to under estimate transmissivity obtain in this research 4- 82% but one are found to overestimate the transmissivity with 8-178%.given the fact that both this research and the design document uses the same well test data, such huge variation in the estimation could only because by data interpretation techniques. Appropriate data correction shall be made test for any well analysis for hydraulic parameter estimations. In well data obtained for single well test such correction is even more vital. For the well with under estimated transmissivity values the well yield could have been larger conversely for over estimated transmissivity values will not supply the estimated yield.

All pumping wells in this thesis are partially penetration wells. The general assumption that the well receives water from horizontal flow is not valid on partially penetration wells.

Draw down of pumping well consist of two components aquifer loss and well loss. They are time dependent and very linearly well with well discharge .because of above reason correct all pumping recovery test data by using partially penetration, aquifer loss and well loss correction factors.

Single well test is rapid and economical calculation of K, and T of the zone of interest at a single location. Single well tests also can determine response criteria for observation wells in multiple well pumping tests. Properly designed and conducted multiple well tests can be used to define the overall hydro geologic regime of the area being investigated, including T, S and/or specific yield of a zone.

From data quality point of view single well pumping test not give accurate data and unrealistic storativity value during pumping test analysis. Multiple well pumping test give accurate data quality than single well pumping test data and give realistic hydraulic parameters estimation on large area.

Excess pumping lead to ground water depletion where ground water extracted at rate faster that it can be replaced. To assure sustainably study must show that hydrological ecological and other impact of ground water are minimal.

Multiple well tests is not economical type of pumping test type but from data quality and evaluation o hydraulic parameters point of view recommended method of pumping test type.

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APPENDIX – A

Aquifer Test 3.5 software Automatic Curve Fitting result

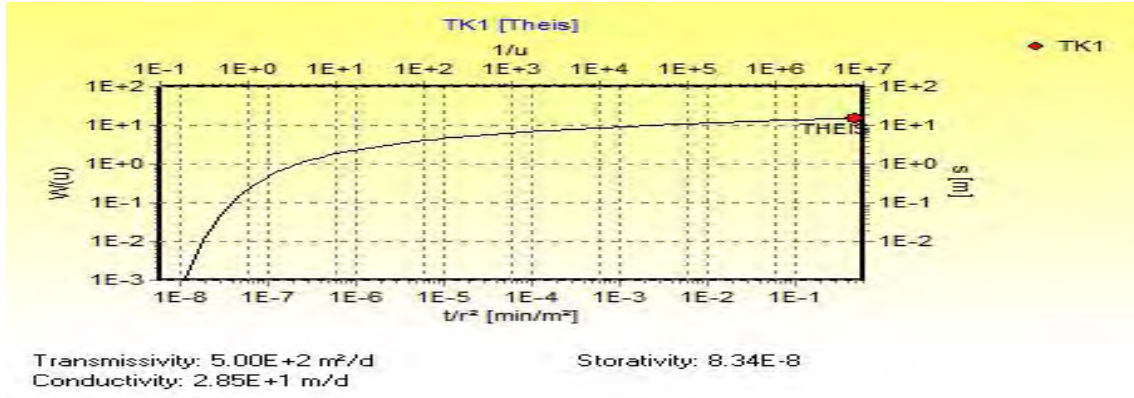


Figure 13(a) Theis's time versus drawdown Curve-Fitting Method graph well ID TK1

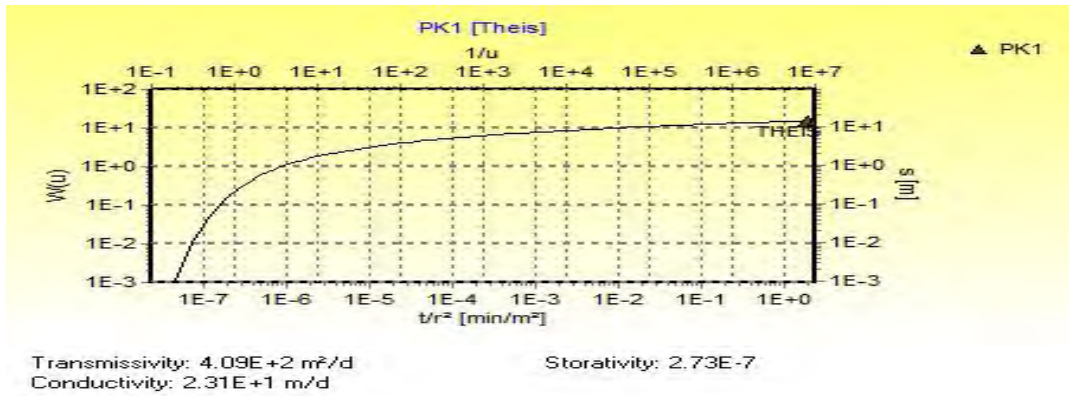


Figure 13(b) Theis's time versus drawdown Curve-Fitting Method graph well ID PK1

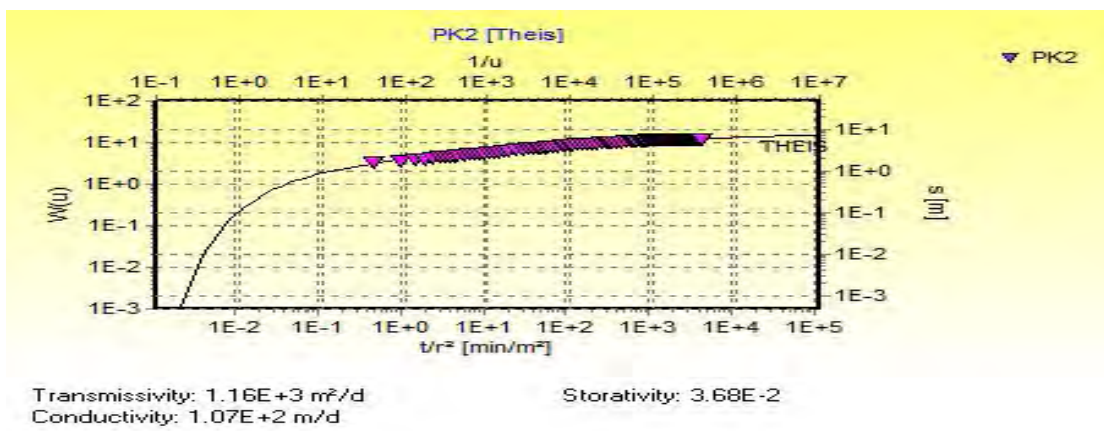


Figure 13(c) Theis's time versus drawdown Curve-Fitting Method graph well ID PK2

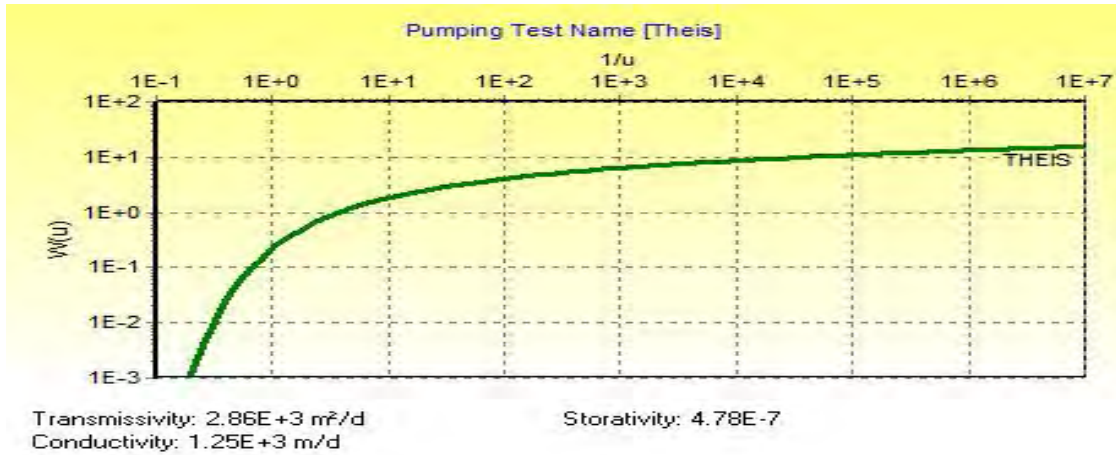


Figure 13(d) *Theis's time versus drawdown Curve-Fitting Method graph well ID PK3*

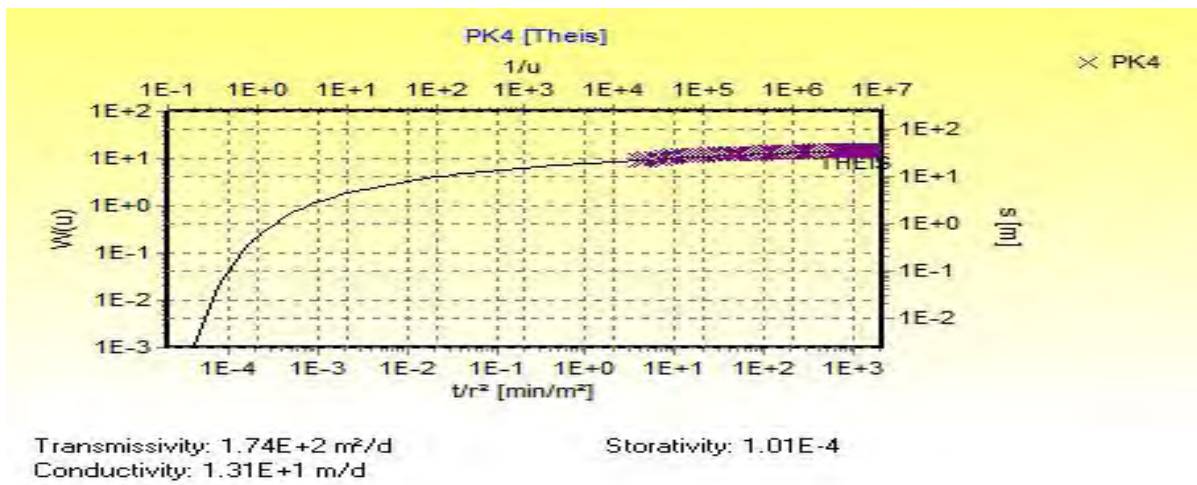


Figure 13(e) *Theis's time versus drawdown Curve-Fitting Method graph well ID PK4*

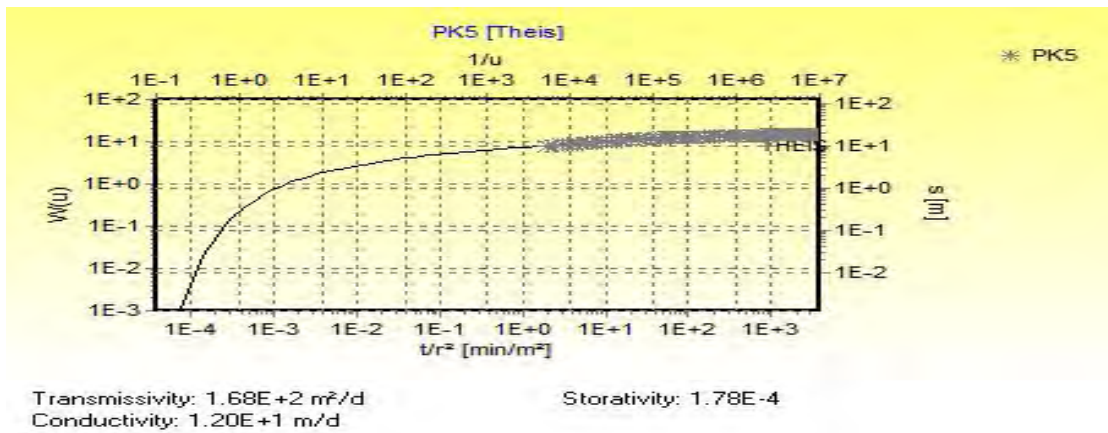


Figure 13(f) *Theis's time versus drawdown Curve-Fitting Method graph well ID PK5*

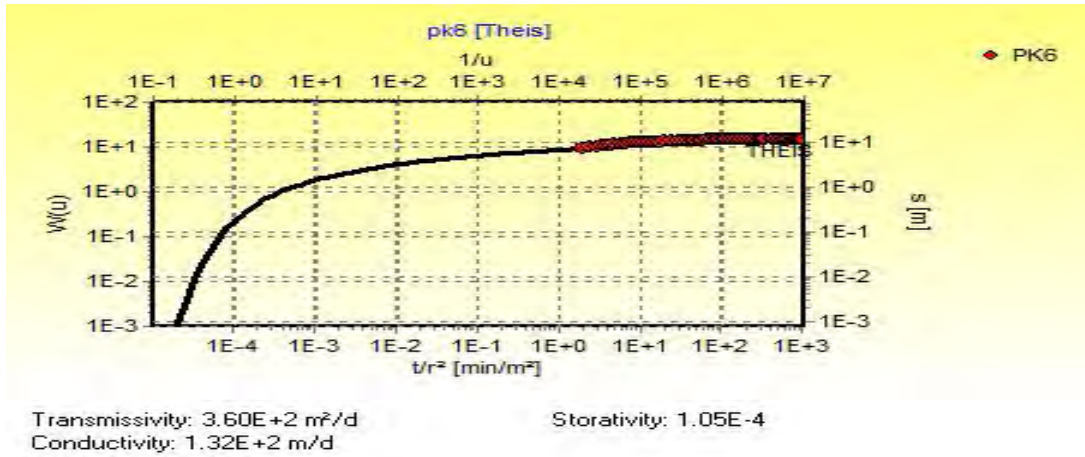


Figure 13(g) Theis's time versus drawdown Curve-Fitting Method graph well ID PK6

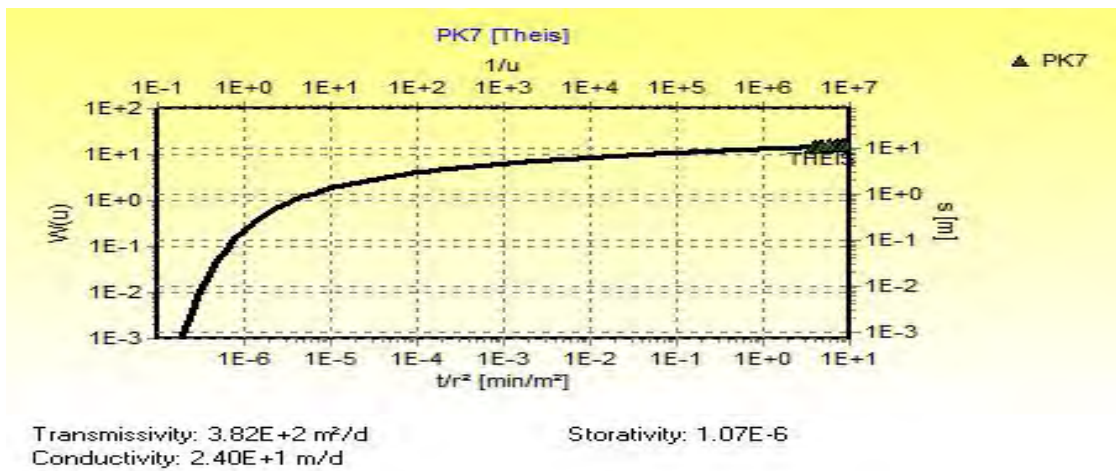


Figure 13(h) Theis's time versus drawdown Curve-Fitting Method graph well ID PK7

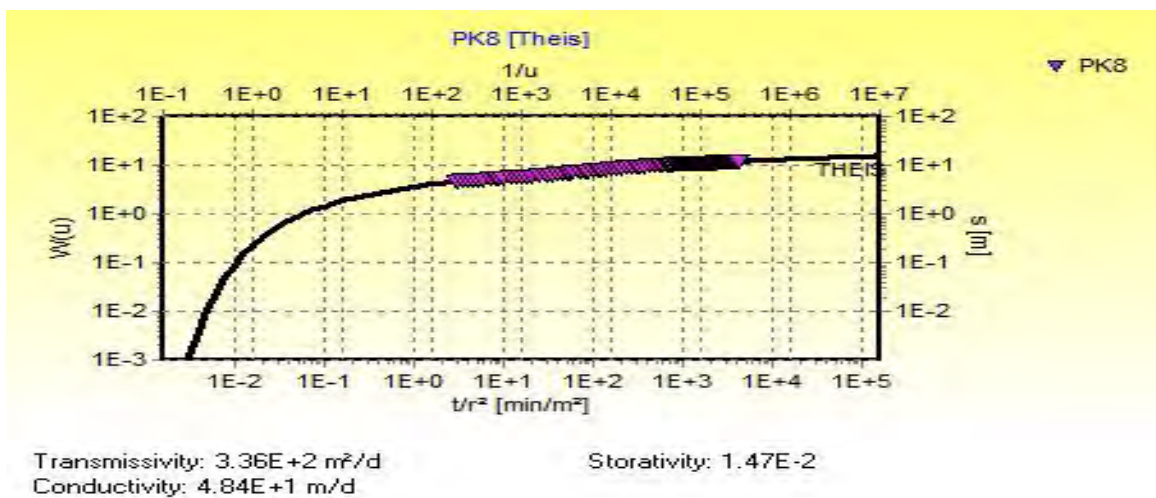


Figure 13(i) Theis's time versus drawdown Curve-Fitting Method graph well ID PK8

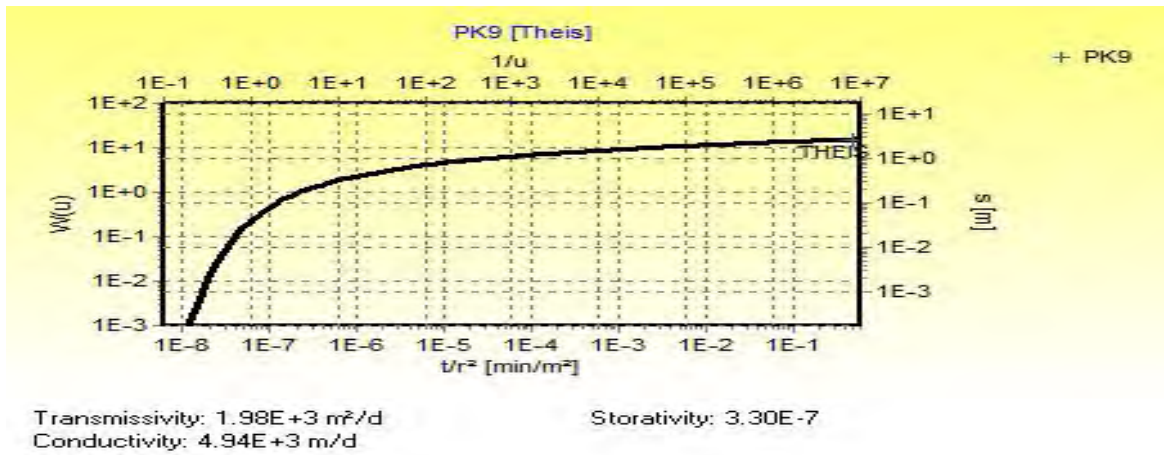


Figure 13(j) Theis's time versus drawdown Curve-Fitting Method graph well ID PK9

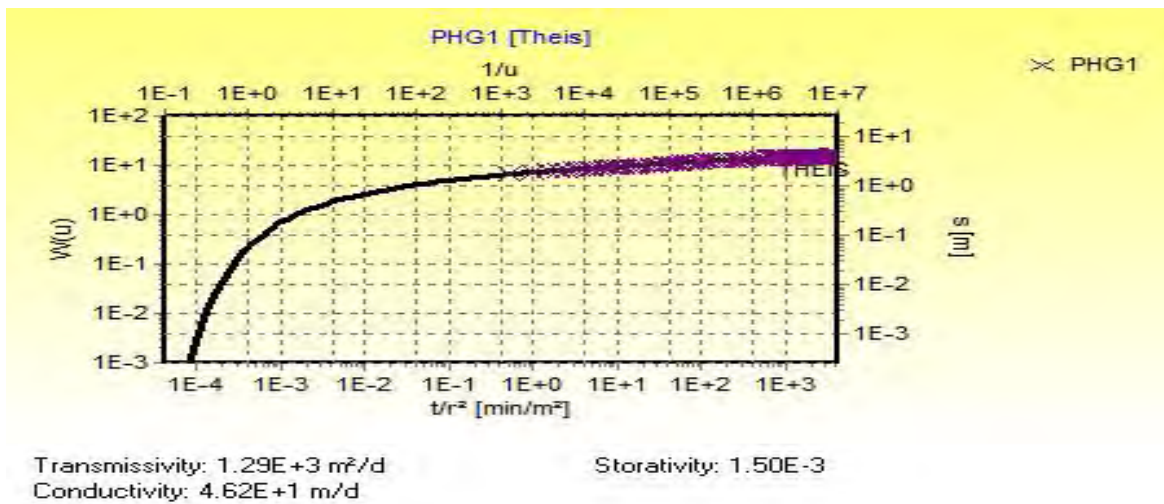


Figure 13(k) Theis's time versus drawdown Curve-Fitting Method graph well ID PHG1

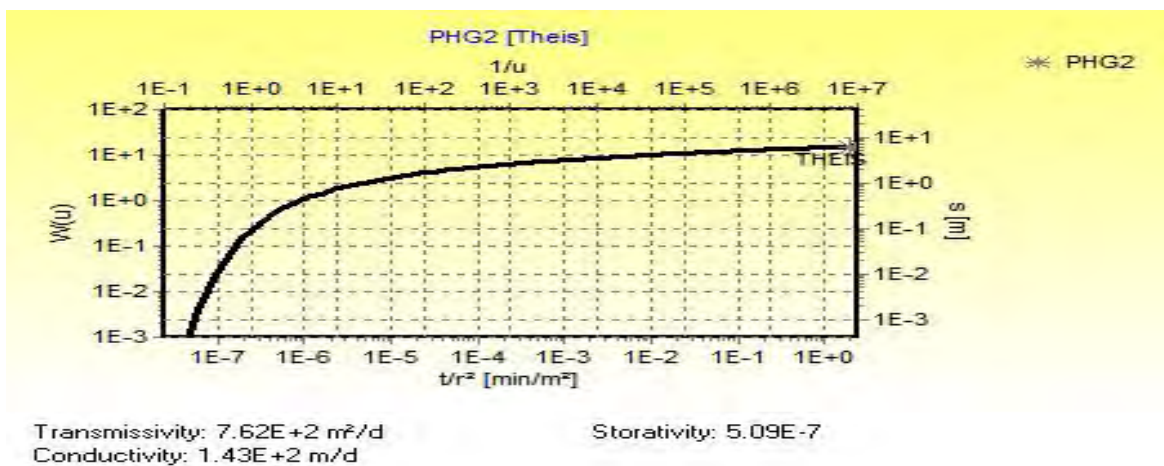


Figure 13(l) Theis's time versus drawdown Curve-Fitting Method graph well ID PHG2

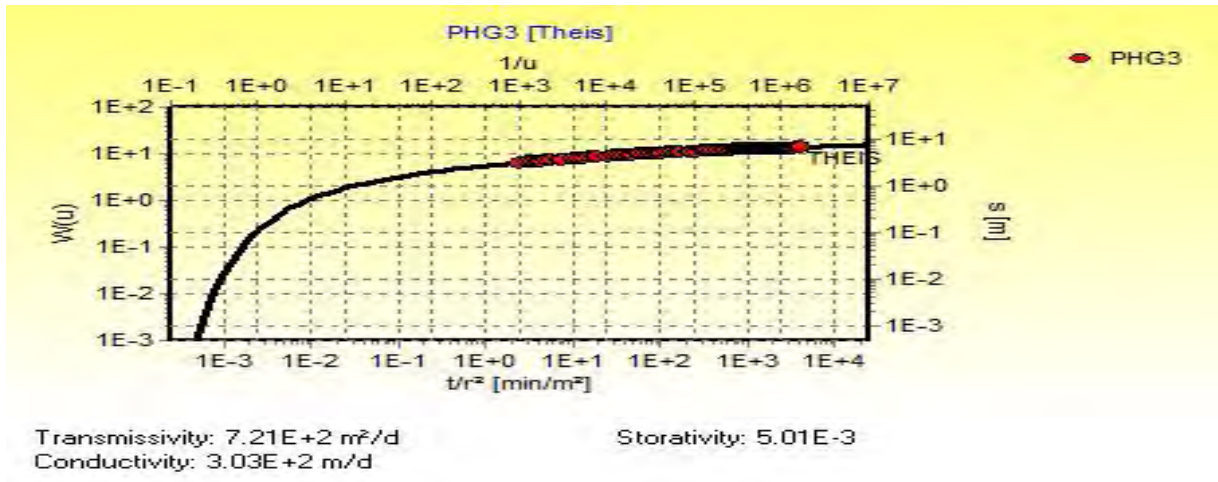


Figure 13(m) *Theis's time versus drawdown Curve-Fitting Method graph well ID PHG3*

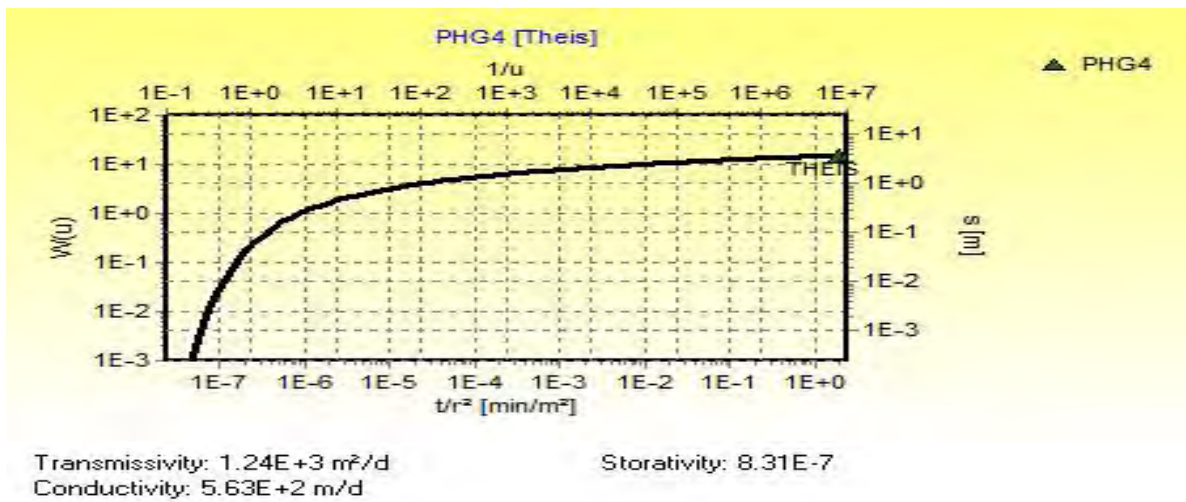


Figure13(n) *Theis's time versus drawdown Curve-Fitting Method graph well ID PHG4*

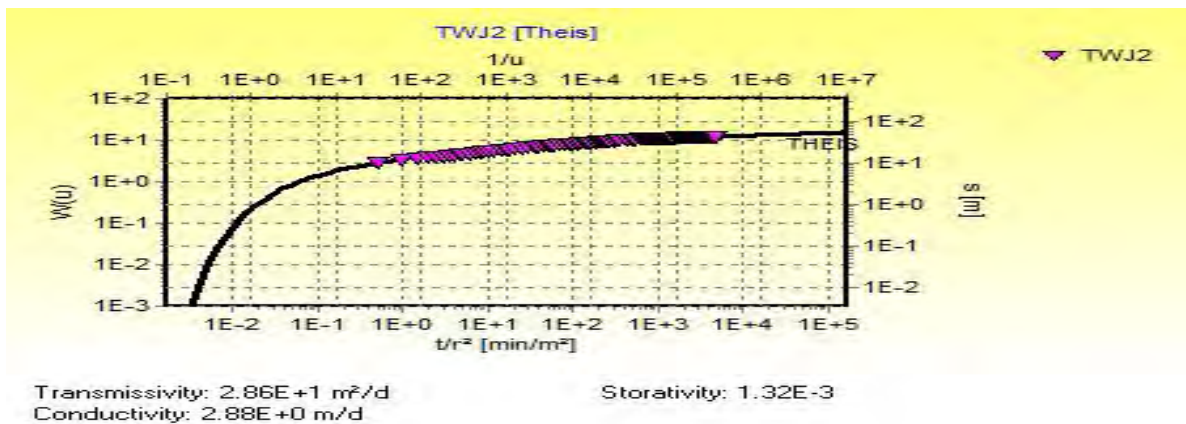


Figure 13(o) *Theis's time versus drawdown Curve-Fitting Method graph well ID TWJ4*

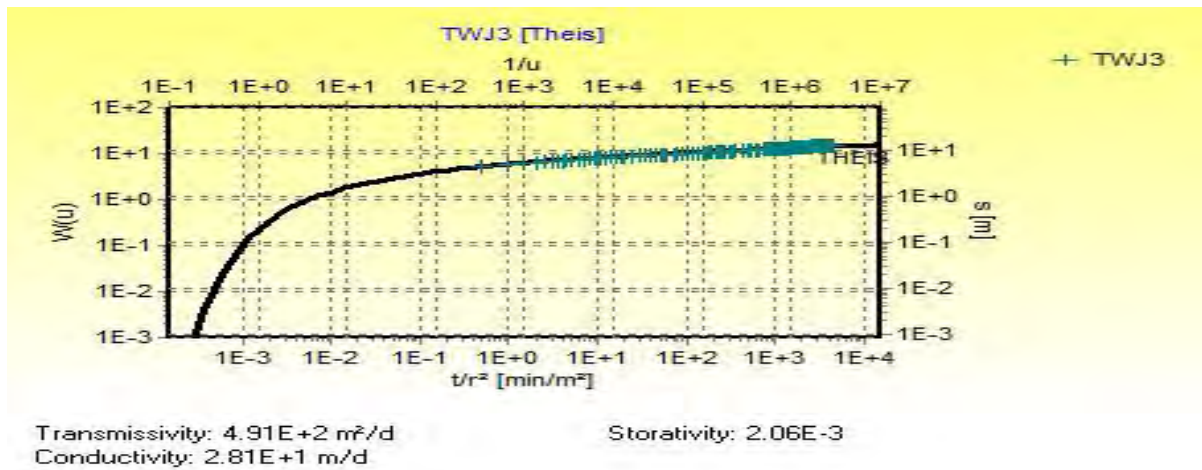


Figure 13(p) Theis's time versus drawdown Curve-Fitting Method graph well ID TWJ3

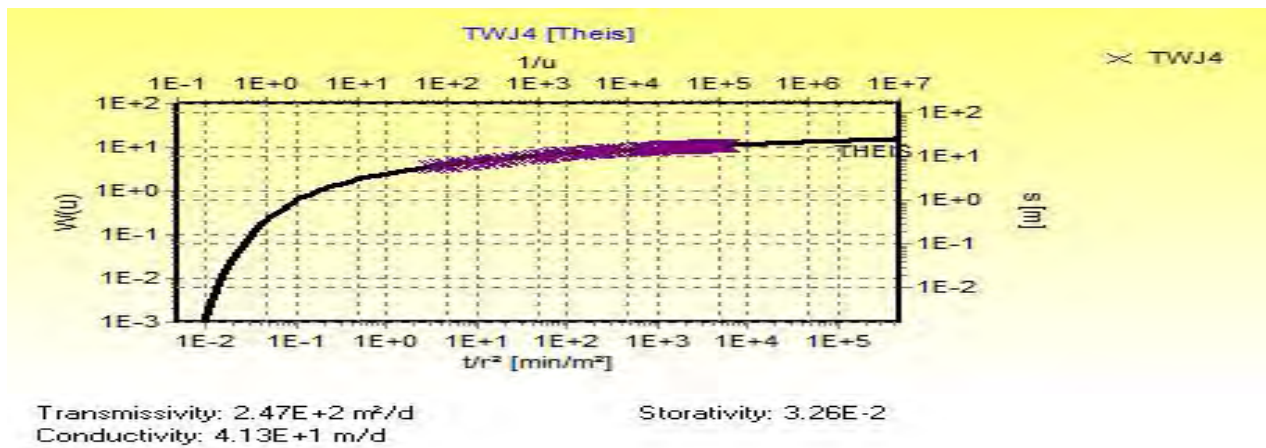


Figure 13(q) Theis's time versus drawdown Curve-Fitting Method graph well ID TWJ4

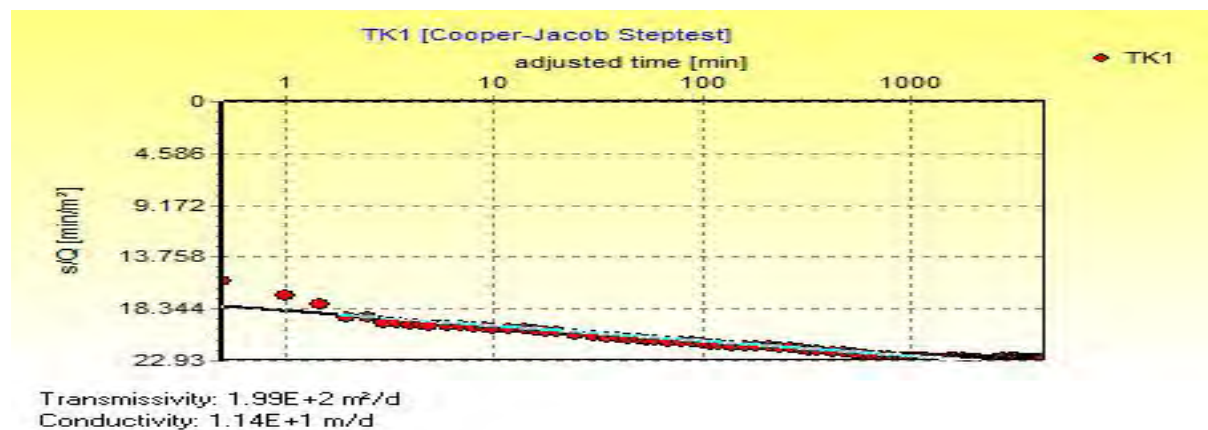


Figure 14(a) Cooper and Jacob Drawdown versus Time Graph of well ID TK1

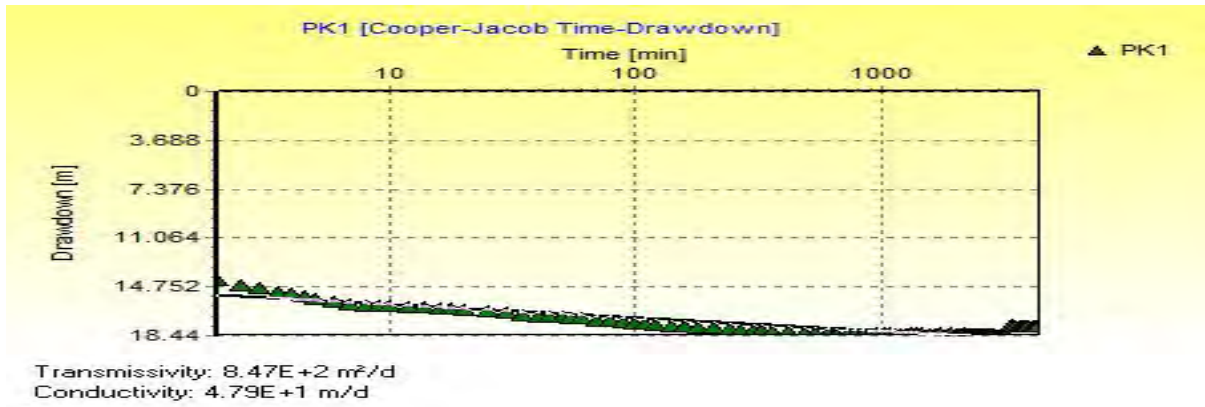


Figure 14(b) Cooper and Jacob Drawdown versus Time Graph of well ID PK1

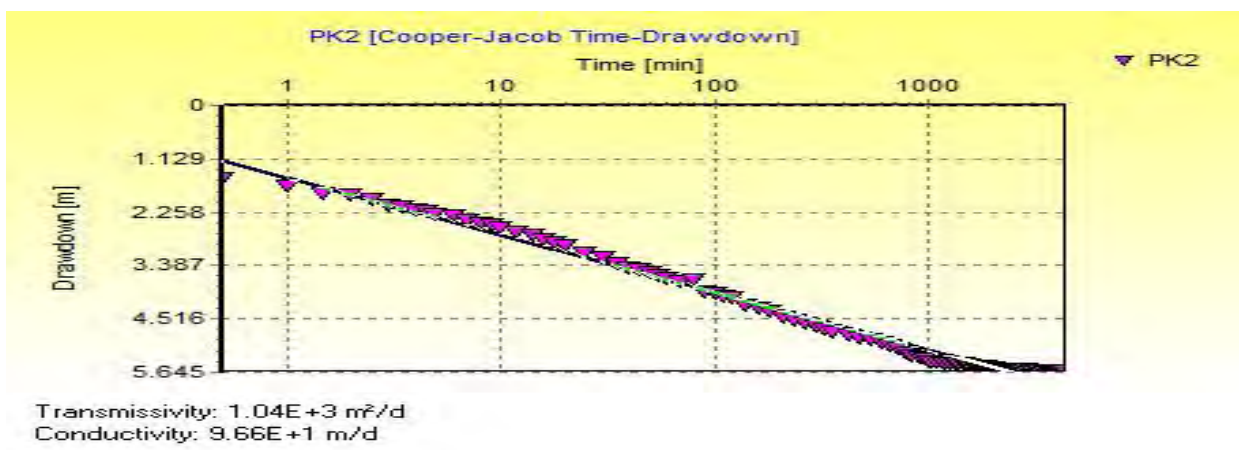


Figure 14(c) Cooper and Jacob Drawdown versus Time Graph of well ID PK2

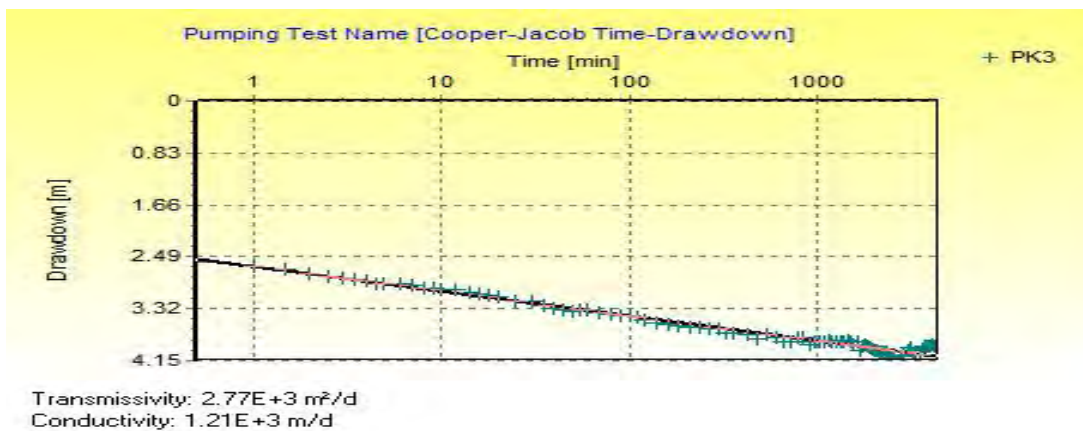


Figure 14(d) Cooper and Jacob Drawdown versus Time Graph of well ID PK3

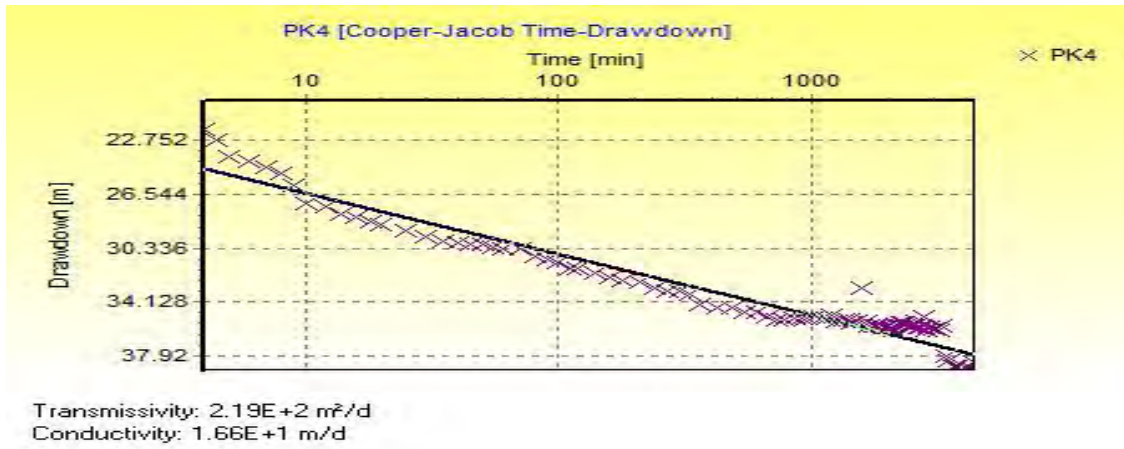


Figure 14(e) Cooper and Jacob Drawdown versus Time Graph of well ID PK4

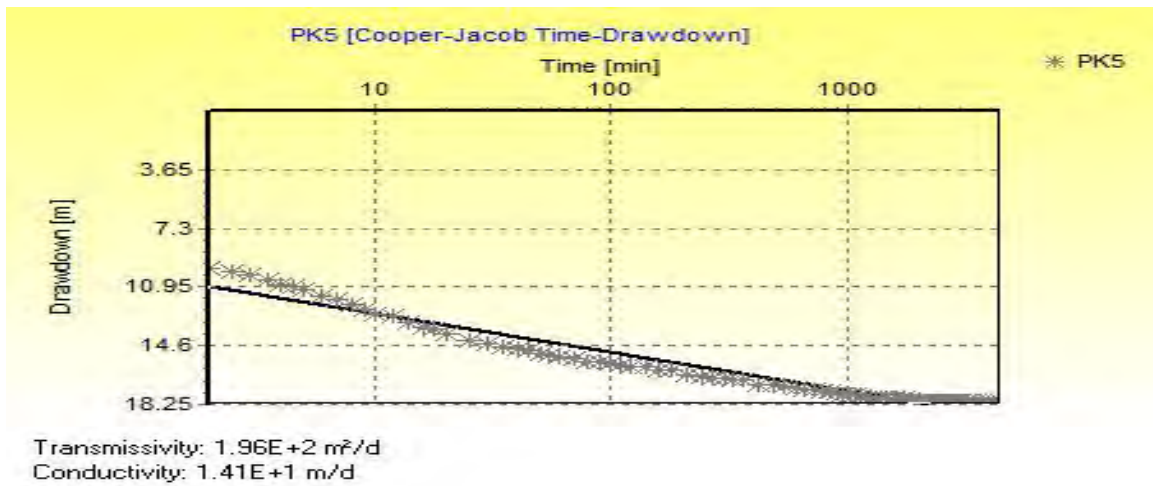


Figure 14(f) Cooper and Jacob Drawdown versus Time Graph of well ID PK5

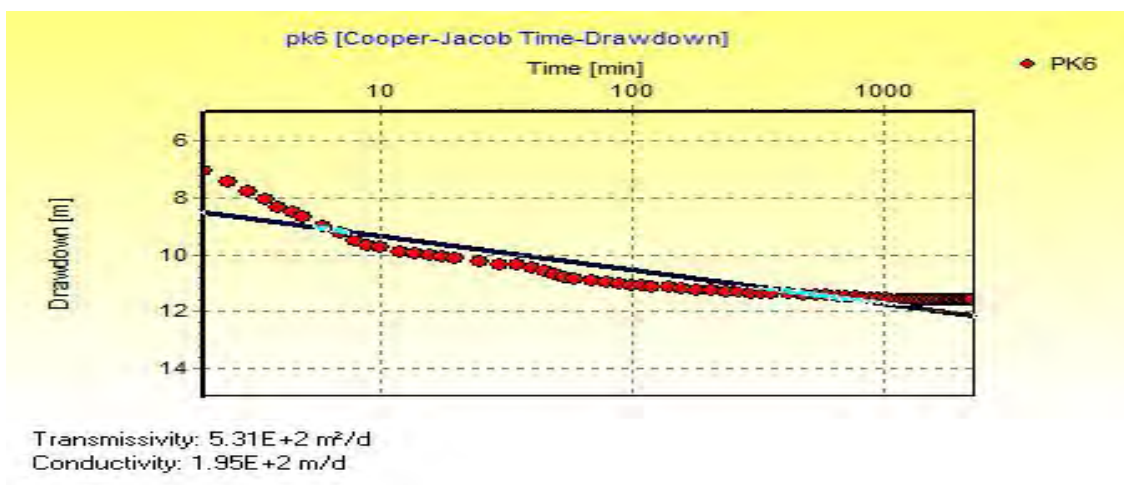


Figure 14(f) Cooper and Jacob Drawdown versus Time Graph of well ID PK6

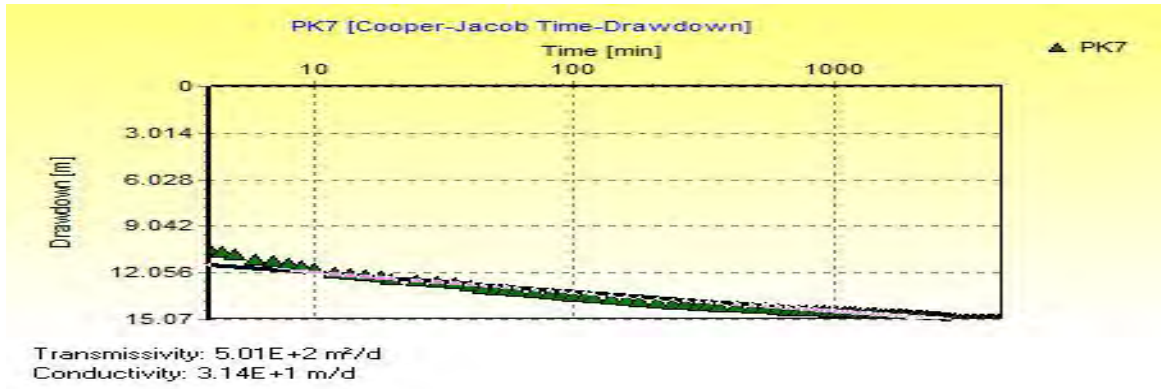


Figure 14(h) Cooper and Jacob Drawdown versus Time Graph of well ID PK7

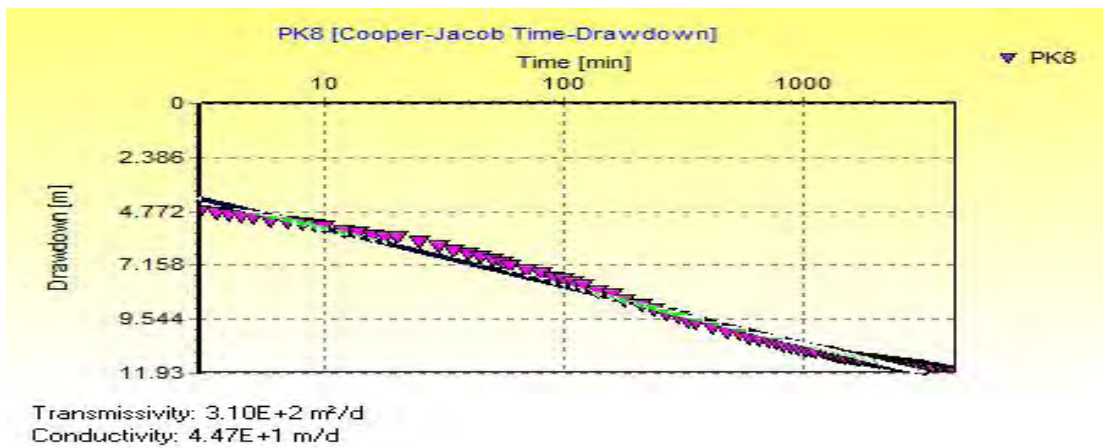


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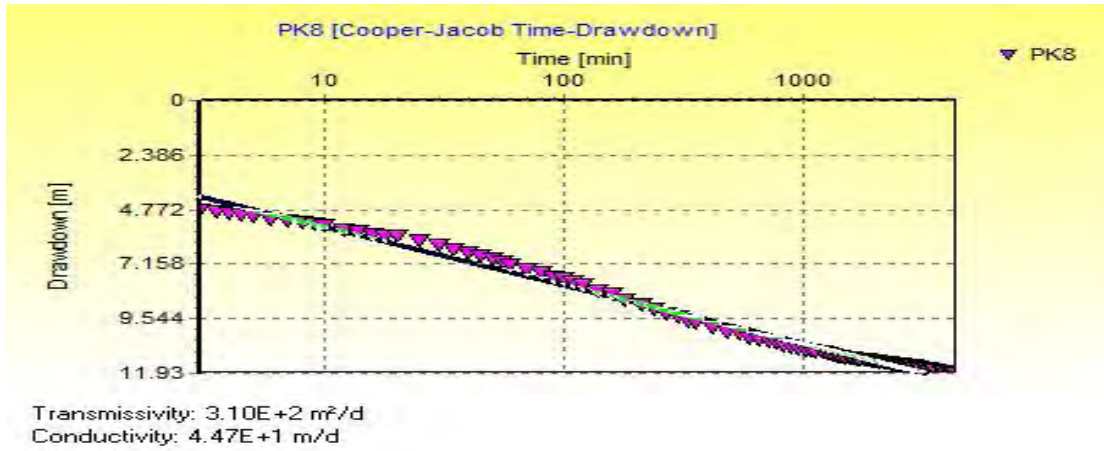


Figure 14(j) Cooper and Jacob Drawdown versus Time Graph of well ID PK8

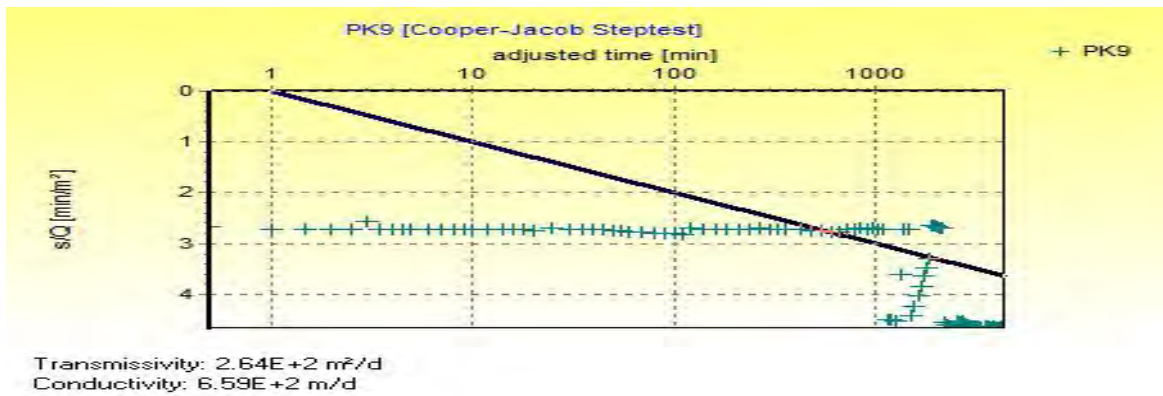


Figure 14(k) Cooper and Jacob Drawdown versus Time Graph of well ID PK9

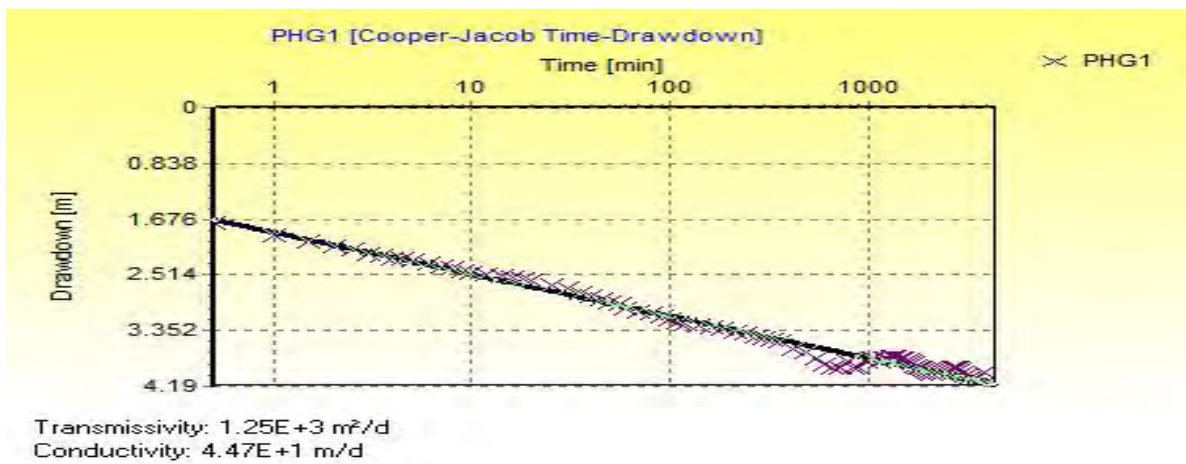


Figure 14(l) Cooper and Jacob Drawdown versus Time Graph of well ID PHG1

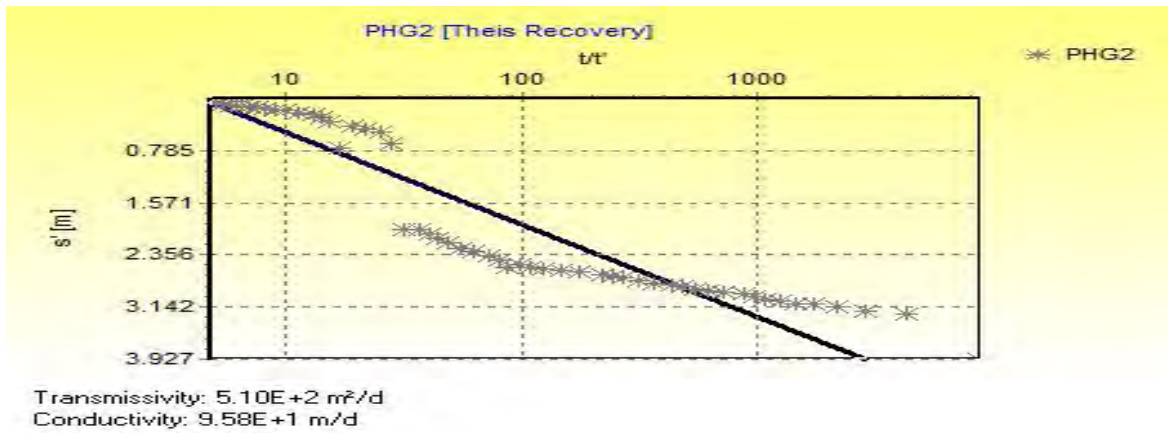


Figure 14 (m) Cooper and Jacob Drawdown versus Time Graph of well ID PHG2

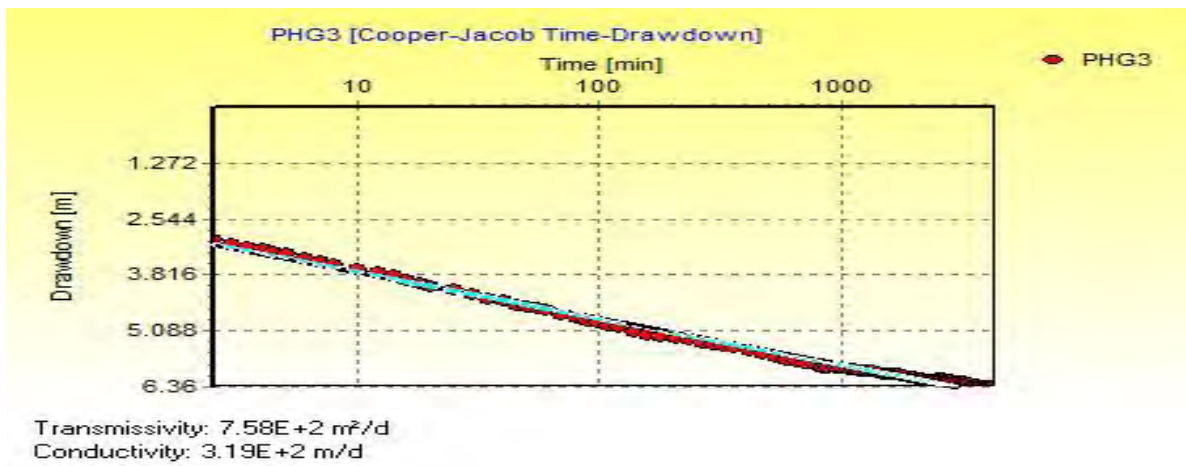


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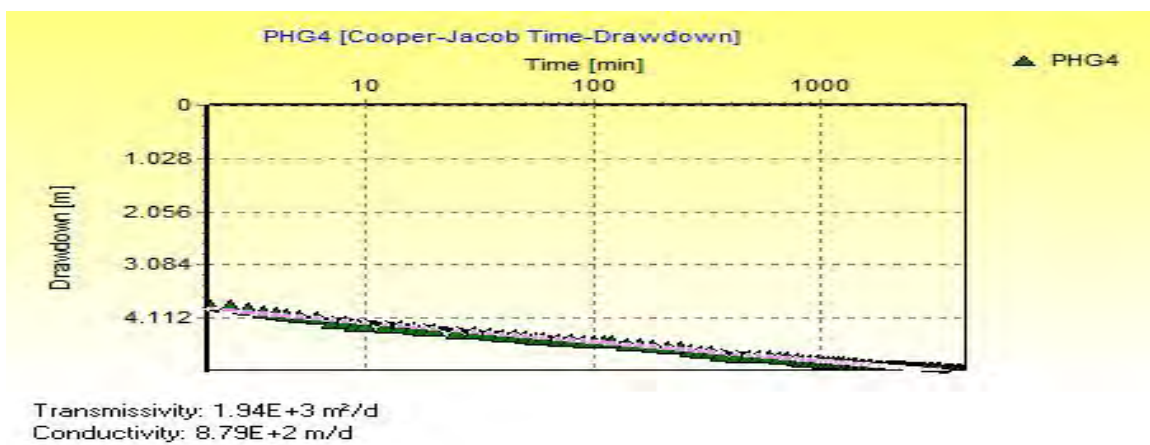


Figure 14(o) Cooper and Jacob Drawdown versus Time Graph of well ID PHG4

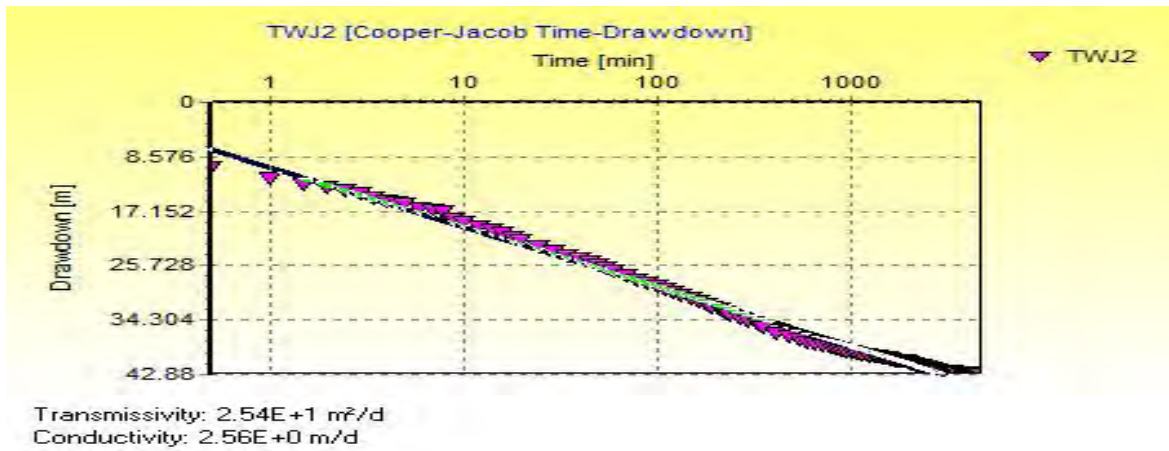


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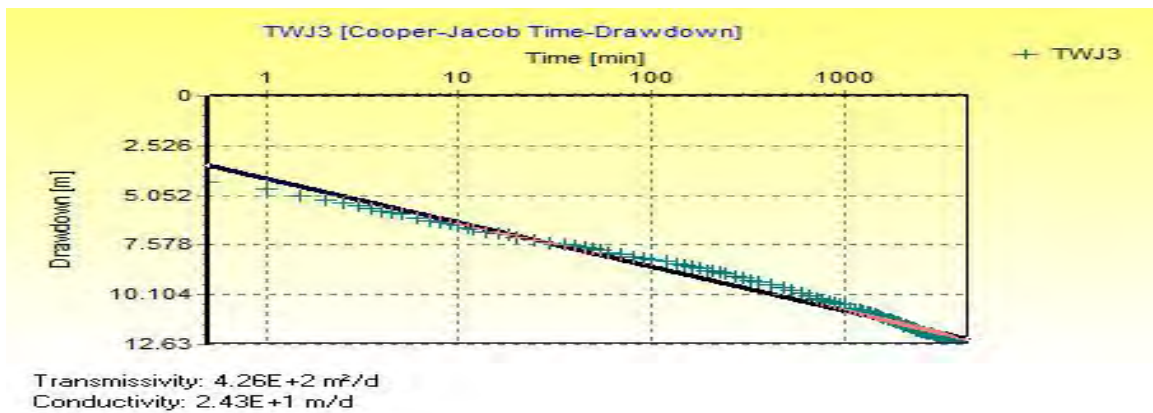


Figure 14(q) Cooper and Jacob Drawdown versus Time Graph of well ID TWJ3

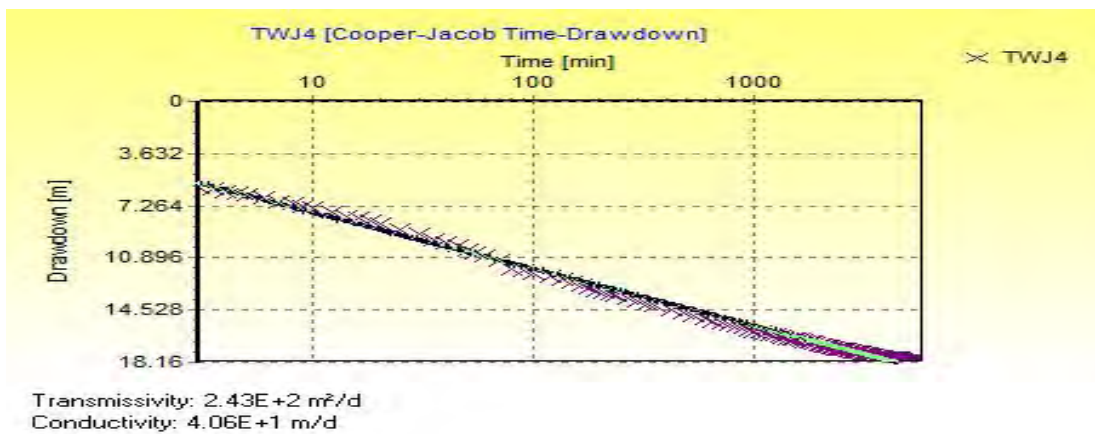


Figure 14(r) Cooper and Jacob Drawdown versus Time Graph of well ID TWJ4

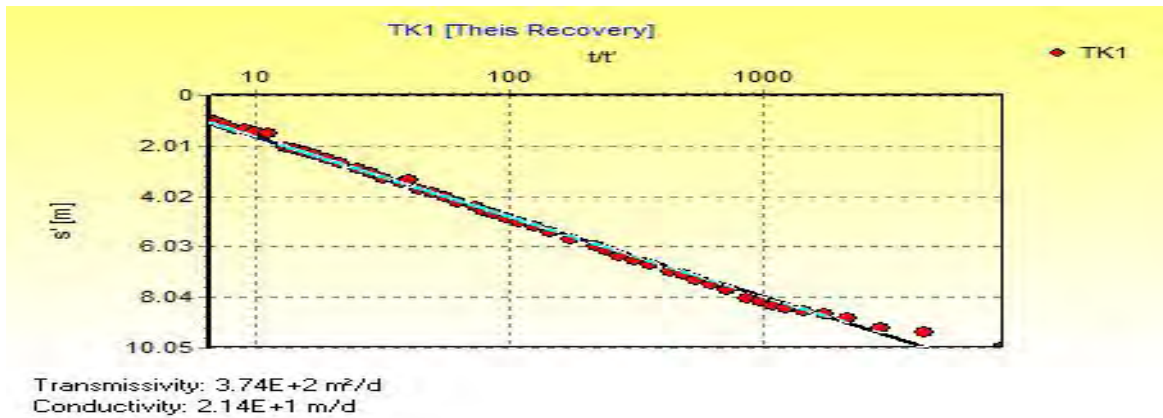


Figure 15(a) Residual Drawdown versus Time Graph well ID TK1

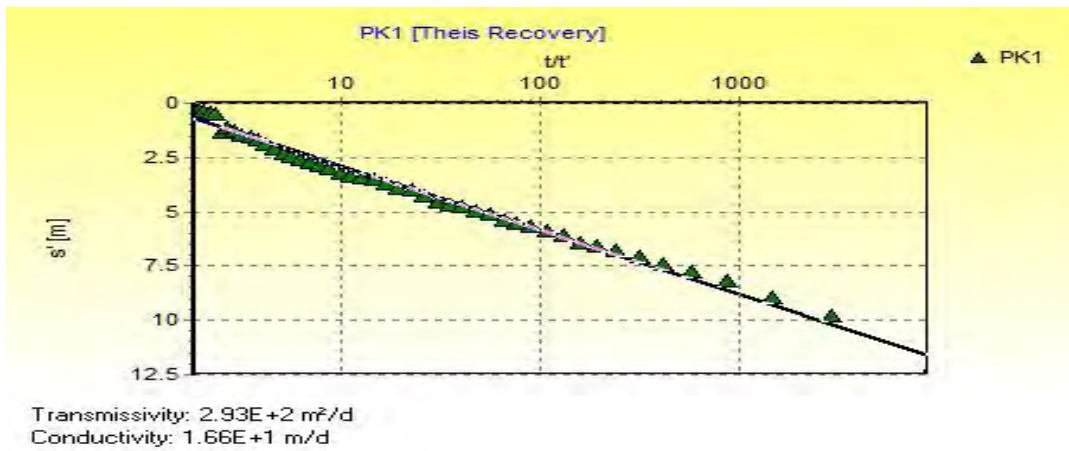


Figure 15(b) Residual Drawdown versus Time Graph well ID PK1

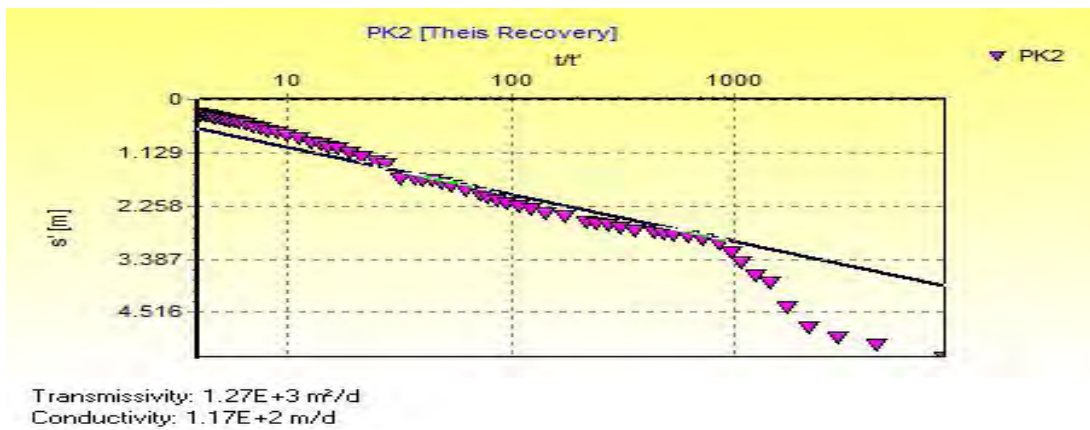


Figure 15(c) Residual Drawdown versus Time Graph well ID PK2

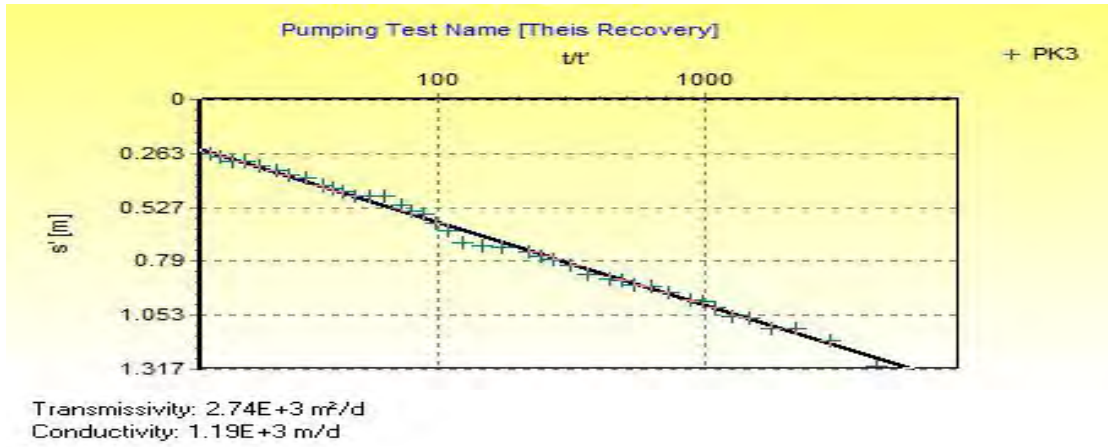


Figure 15(d) Residual Drawdown versus Time Graph well ID PK3

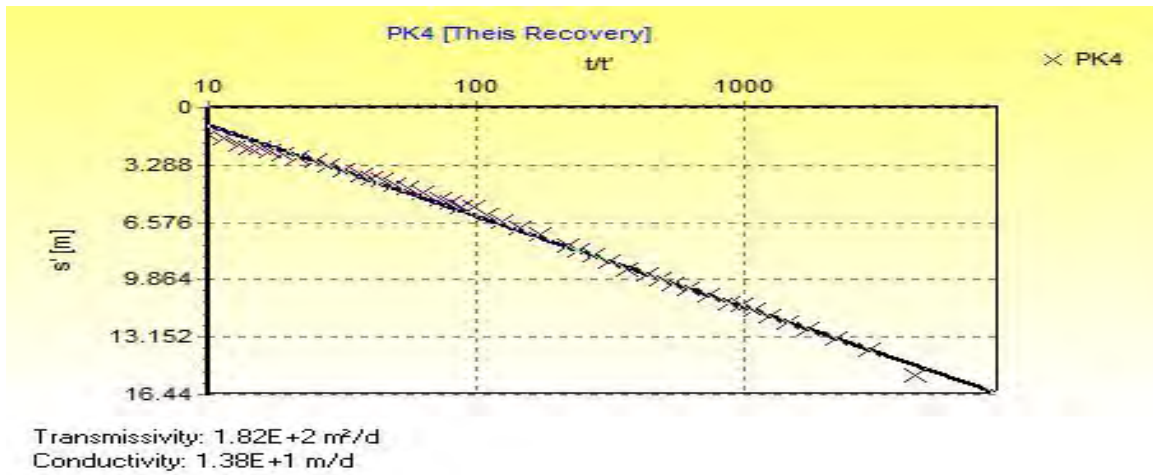


Figure 15(e) Residual Drawdown versus Time Graph well ID PK4

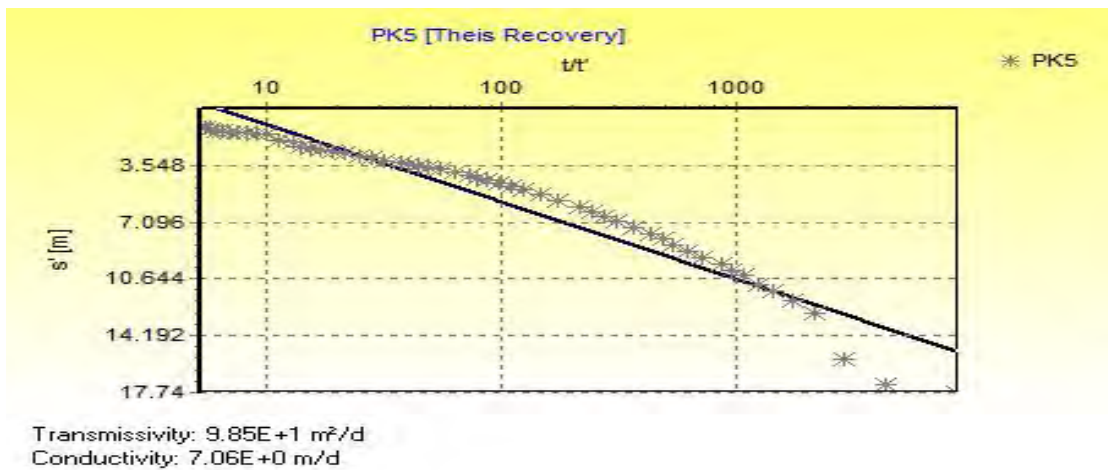


Figure 15(f) Residual Drawdown versus Time Graph well ID PK5

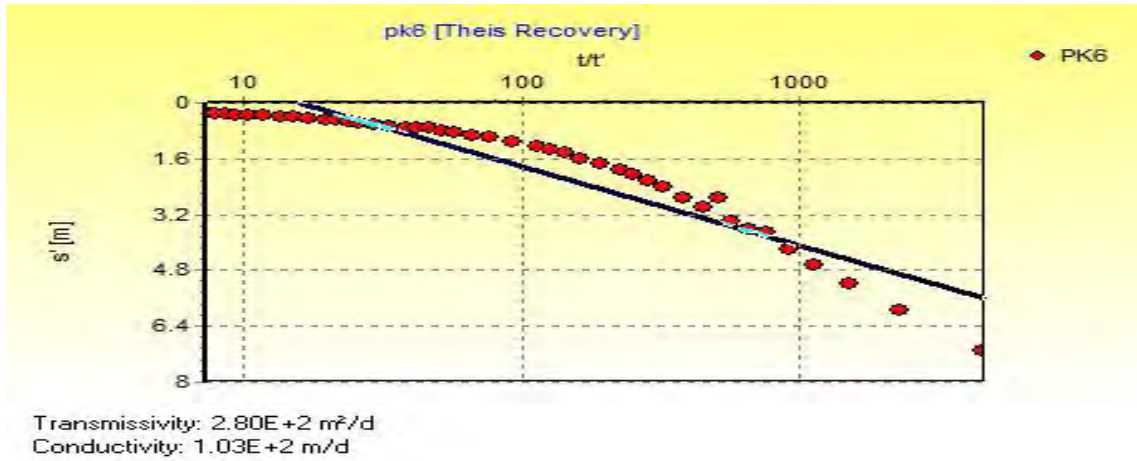


Figure 15(g) Residual Drawdown versus Time Graph well ID PK6

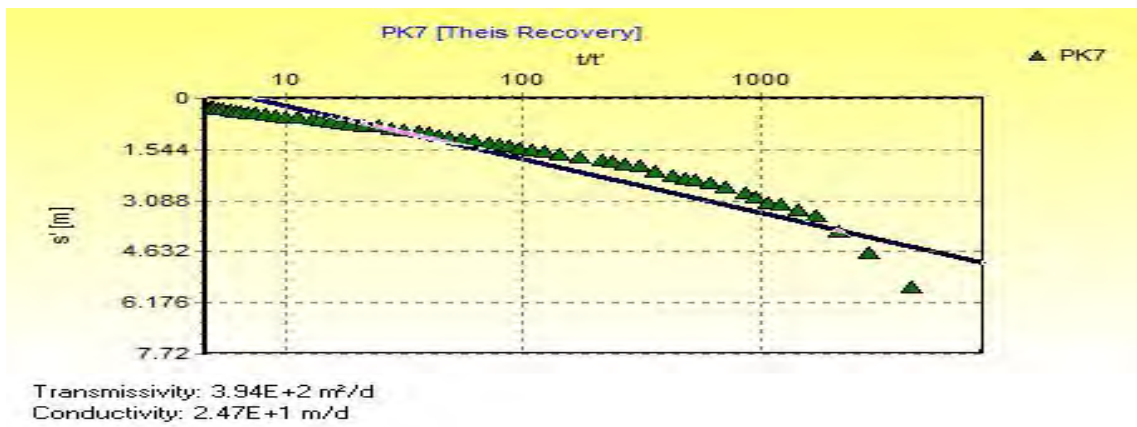


Figure 15(h) Residual Drawdown versus Time Graph well ID PK7

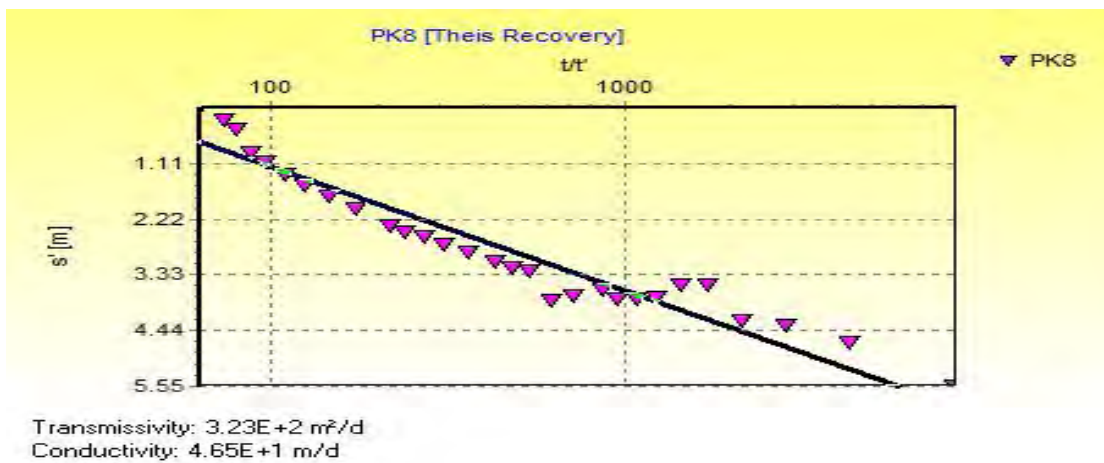


Figure 15(i) Residual Drawdown versus Time Graph well ID PK8

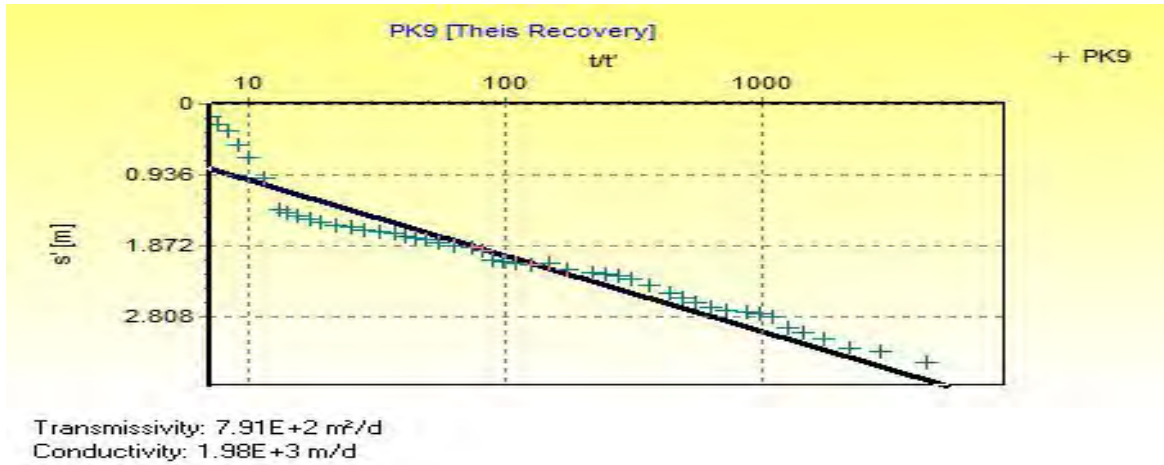


Figure 15(k) Residual Drawdown versus Time Graph well ID PK9

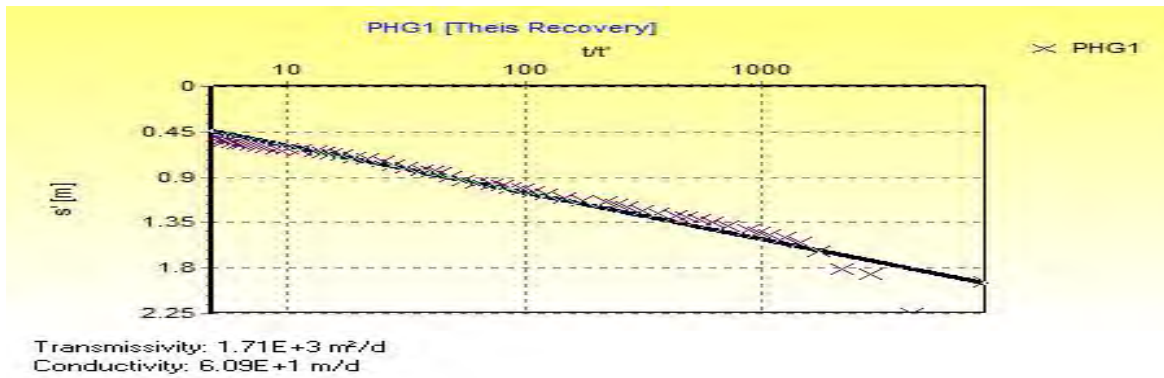


Figure 15(l) Residual Drawdown versus Time Graph well ID PHG1

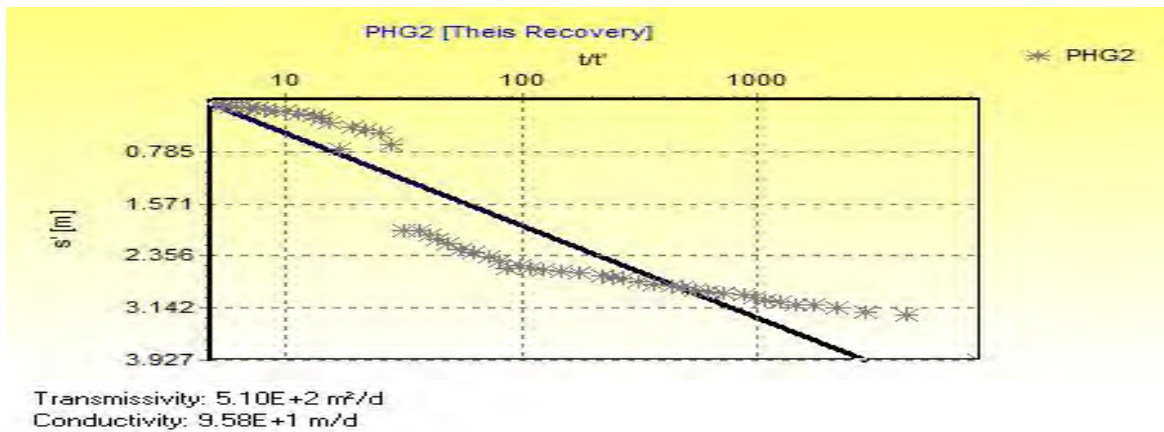


Figure 15(m) Residual Drawdown versus Time Graph well ID PHG2

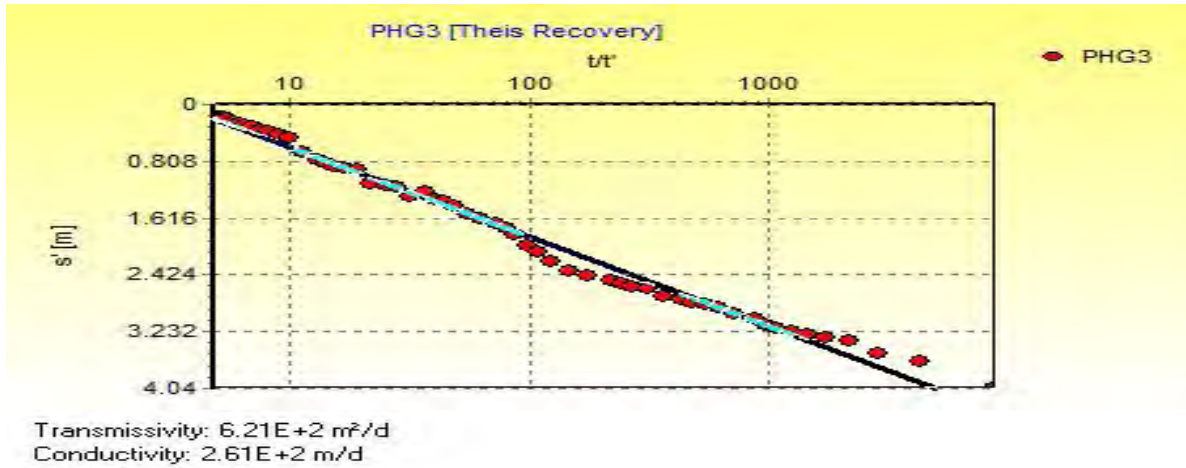


Figure 15(n) Residual Drawdown versus Time Graph well ID PHG3

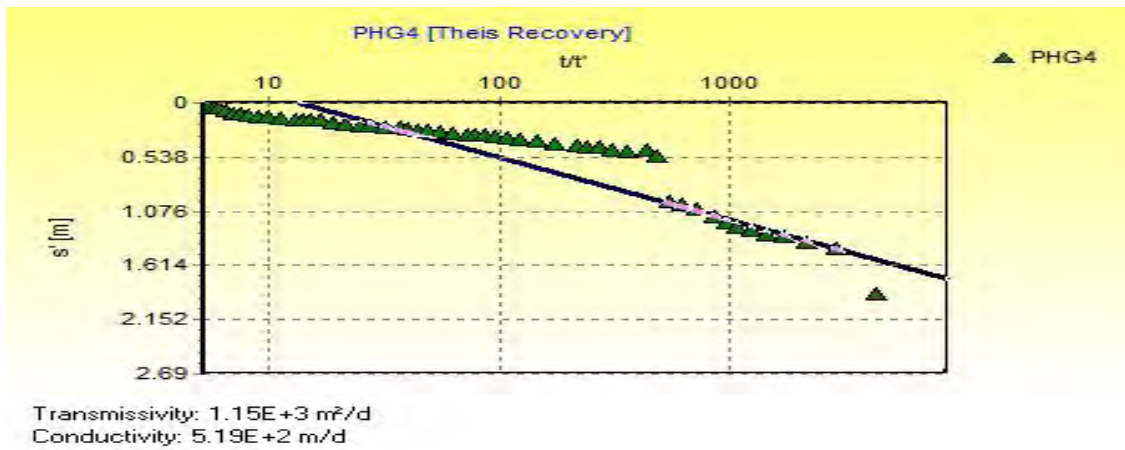


Figure 15(o) Residual Drawdown versus Time Graph well ID PHG4

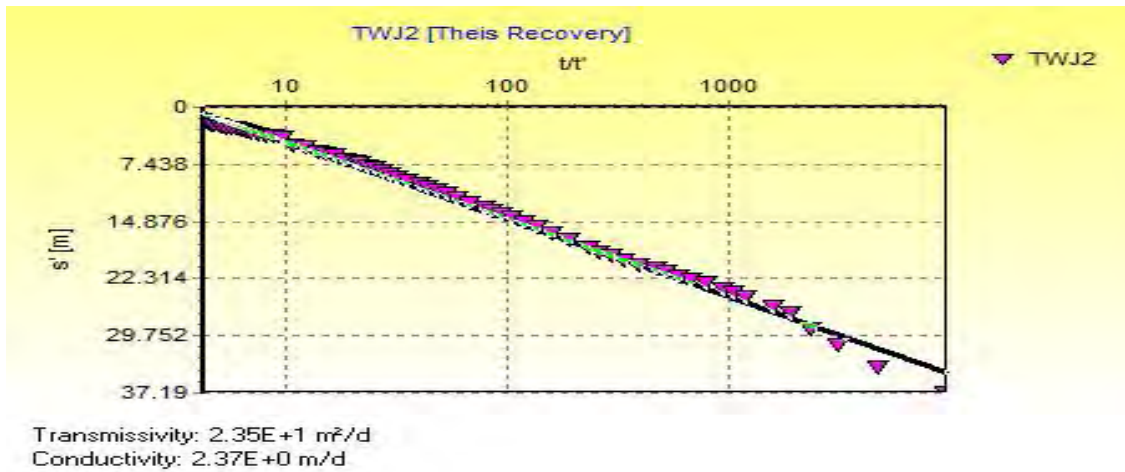


Figure 15(o) Residual Drawdown versus Time Graph well ID TWJ2

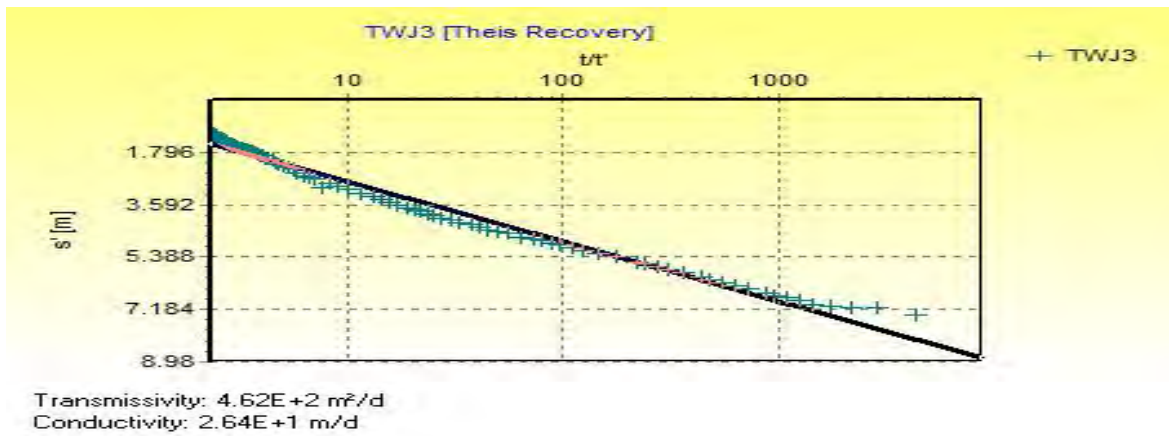


Figure 15(p) Residual Drawdown versus Time Graph well ID TWJ3

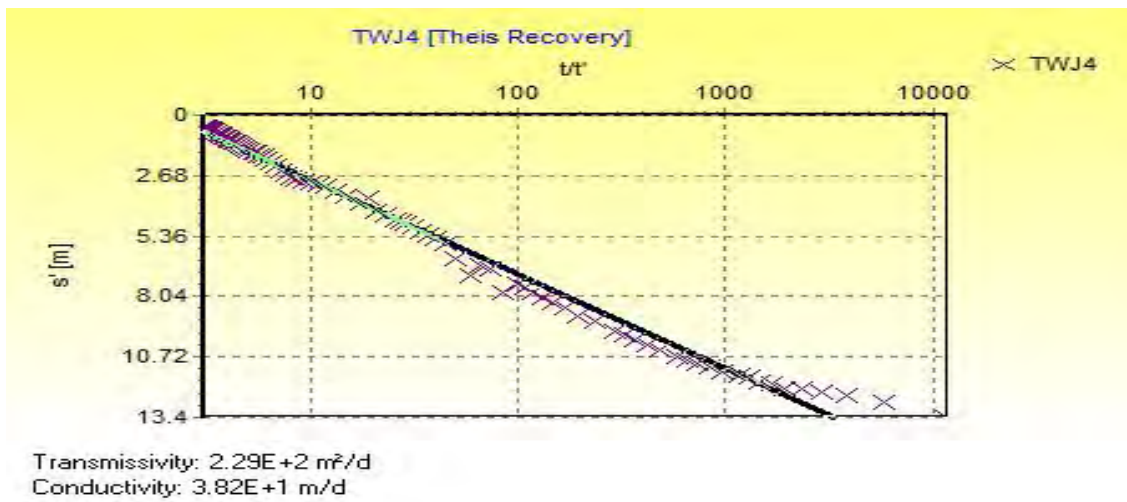


Figure 15(q) Residual Drawdown versus Time Graph well ID TWJ4

# APPENDIX – B

## Summary of step draw down test data all wells

no	well id	Locations			depth	steps	pumping rate (l/s)	measured drawdown	aquifer loss	well loss	efficiency (%)	calculated Sw
		X	Y	Z								
1	TK1	570275	1355009	1481	164	ONE	31	14.79	14.82	0.5	100	15.32
						TWO	45	23.09	21.52	1.06	93.2	22.58
						THREE	60	30.63	28.69	1.89	93.7	30.58
						FOUR	75	38.69	35.86	2.95	92.7	38.81
						20% extrapolated	90	47.28	43.04	4.25	91	47.29
2	PK1	568066	1340931	1491	134	ONE	33	18.9	16.19	2.88	85.6	19.07
						TWO	45	27	22.07	5.35	81.8	27.42
						THREE	52	33.69	25.51	7.14	75.7	32.65
						FOUR	60	38.45	29.43	9.51	76.5	38.94
						20% extrapolated	72	49.01	35.32	13.7	72.1	49.02
3	pk3	568204	1350350	1440	153	ONE	29.5	1.27	1.8	0.05	93	1.23
						TWO	35	1.37	1.4	0.07	100	1.47
						THREE	52	2.34	2.08	0.16	89	2.24
						FOUR	70	3.07	2.8	0.3	91.3	3.1
						20% extrapolated	84	3.79	3.36	0.43	88.7	3.79
4	PK4	568000	1353000	1436	106	ONE	19	11.83	10.5	1.1	8.8	11.6
						TWO	35	22.81	19.35	3.73	84.8	23.08
						THREE	52	37.12	28.74	8.24	77.4	36.98
						FOUR	60	44.1	33.16	10.97	75.2	44.13

						20% extrapolated	72	55.6	39.8	15.8	71.6	55.6
5	PK5	568427	1351843	1428	118	ONE	13	10.82	9.42	1.17	87.1	10.59
						TWO	19.5	16.63	14.14	2.64	85	16.78
						THREE	26	23.4	18.85	4.69	80.5	23.54
						FOUR	32	30.4	23.2	7.1	76.3	30.3
						20% extrapolated	38.4	38.06	27.84	10.22	73.1	38.06
6	TK7	569334	1341467	1475	168	ONE	24	7.04	7.25	0.56	100	7.81
						TWO	31	10.85	9.36	0.93	86.3	10.29
						THREE	40.5	14.22	12.23	1.59	86	13.82
						FOUR	50	17.23	15.1	2.42	87.7	17.52
						20% extrapolated	60	21.61	18.21	3.49	83.9	21.61
7	PK6	569299	1341890	1481	145	ONE	19	6.35	5.84	0.46	86.3	5.94
						TWO	29.5	8.82	8.51	1.11	96.5	9.62
						THREE	33	11.26	9.52	1.39	84.5	10.91
						FOUR	40	13.67	11.54	2.04	84.4	13.58
						20% extrapolated	48	16.78	13.84	2.93	82.5	16.77
8	PK7	569892	1341651	1474	183	ONE	22	9.63	9.84	0.15	100	9.99
						TWO	30	14.36	13.42	0.27	93.5	13.69
						THREE	36	16.09	16.1	0.39	100	16.49
						FOUR	40	18.44	17.89	0.48	97	18.37
						20% extrapolated	48	22.17	21.47	0.7	96.9	22.17
9	PK8	569814	1341065	1469	181	ONE	22	5.35	5.14	0.59	96	5.37
						TWO	29	7.95	6.77	1.03	85.2	7.8
						THREE	39	11.31	9.11	1.87	80.5	10.98

						FOUR	50	14.56	11.68	3.07	80.2	14.75
						20% extrapolated	60	18.43	14.01	4.48	76	18.43
10	PK9	569485	1341610	1475	145	ONE	22	3.59	3.37	0.13	93.9	3.5
						TWO	30	4.89	4.59	0.24	94	4.83
						THREE	38	5.99	5.82	0.38	97.2	6.2
						FOUR	50	8.39	7.66	0.65	91.3	8.31
						20% extrapolated	60	10.13	9.19	0.94	90.7	10.13
11	PGH1	567688	1338579	1478	129	ONE	19	1.01	1.05	0.05	100	1.1
						TWO	29	1.71	1.61	0.13	94	1.74
						THREE	36	2.34	2	0.2	85.3	2.2
						FOUR	50	3.1	2.77	0.38	89.4	3.15
						20% extrapolated	60	3.87	3.33	0.55	85.9	3.88
12	PGH2	567801	1337997	1479	108	ONE	22	5.73	5.38	0.65	94	6.03
						TWO	29	8.29	7.1	1.13	85.6	8.23
						THREE	37	11.3	9.06	1.83	80.1	10.89
						FOUR	45	13.49	11.01	2.71	81.6	13.72
						20% extrapolated	54	17.12	13.22	3.9	77.2	17.12
13	PGH3					ONE	23	3.15	3.62	0.11	100	3.73
						TWO	30	5.28	4.72	0.19	89.4	4.91
						THREE	39	6.78	6.13	0.32	90.5	6.45
						FOUR	50	8.19	7.86	0.53	96	10.21
						20% extrapolated	60	10.2	9.44	0.77	92.5	3.19
14	PGH4	566854	1339244	1507	116	ONE	23	3.12	2.91	0.28	93.1	4.74
						TWO	33	4.85	4.17	0.57	86	5.89
						THREE	40	5.84	5.05	0.84	86.5	6.75
						FOUR	45	6.75	5.69	1.06	84.2	8.35

						20% extrapolated	54	8.35	6.82	1.53	81.7	22.09
15	TWJ2	573465	1355068	1398	121	ONE	10	26.18	18.97	3.12	72.5	35.46
						TWO	15	32.22	28.45	7.01	88.3	50.41
						THREE	20	49.13	37.94	12.47	77.2	66.9
						FOUR	25	68.23	47.42	19.48	69.5	84.95
						20% extrapolated	30	89.96	56.9	28.05	67	7.44
16	TWJ4	568854	1352624	1425	199	ONE	27.5	7.04	6.88	0.56	97.7	11.49
						TWO	41	12	10.25	1.24	85.4	15.99
						THREE	55	15.84	13.75	2.24	86.8	18
						FOUR	61	17.98	15.25	2.75	84.8	2.27
						20% extrapolated	73.2	22.27	18.3	3.97	82.2	

Table 6 step draw down test data summer

## APPENDIX – C

### Partial penetration correction summary

partial penetration correction factor of PK2										
from(m)	to(m)	length(m) (B)	blind length(m)	screen length( m) (L)	2l/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.00	44.00	44	121.2							
44.00	50.00	6		6	94.4882	0.0472	6.980813	0.1028753	0.718153	0.08104
50.00	74.00	24	17.6		0					
74.00	80.00	6		6	94.4882	0.2542	6.449735	0.1028753	0.663519	0.42293
80.00	104.00	24	11.7		0					
104.00	110.00	6	1	17.43	274.488	0.5984	4.131834	0.0603585	0.249391	0.74758
110.00	122.00	12	5.81	12	188.976					
122.00	128.00	6		17.41	274.173	0.7498	2.684832	0.0603931	0.162145	0.87136
128.00	134	6	19.2	6	94.4882					
134	137	3		11.59	182.52	0.3764	5.812762	0.0740193	0.430257	0.53838
									GEO MEAN	0.41303
									Art mean	0.53

Table 6 partial penetration correction of well PK2

partial penetration correction well ID PK3										
from(m)	to(m)	length(m) (B)	blind length(m)	screen length(m) (L)	2l/r	L/B	[7COS(3.1L/2 B)]	SQRT(R/2L)		F
0	27	27	27	0						
27	51.6	24.6	0	24.6	387	0.48	5.13	0.05	0.26	0.60
51.6	63.6	12	12	0	0.00					
63.6	81.6	18	0	18	283	0.60	4.12	0.06	0.24	0.75
81.6	93.6	12	12	0	0.00					
93.6	99.6	6	0	6	94	0.33	6.06	0.10	0.62	0.54
99.6	107.6	8	8	0	0.00					
107.6	127.6	20	0	20	314.	0.71	3.04	0.06	0.17	0.84
127.6	141.6	14	14	0	0.00					
141.6	147.6	6	0	6	94.4	0.30	6.24	0.10	0.64	0.49
147.6	153.6	6	6	0	0.00				Geo mea n	0.63
									Art mea n	0.64

Table 7 partial penetration correction of well PK3

partial penetration correction 0Fwell ID TWJ3										
from(m)	to(m)	length(m) (B)	blind length(m)	screen length(m) (L)	2l/r	L/B	[7COS(3.1L/2 B)]	SQRT(R/2 L)		F
0.00	35.12	35.12	35.12							
35.12	58.96	23.84		23.84	375.43	0.40342	5.636262	0.05161	0.297419	0.52196
58.96	86.76	27.8	17.6		0					
86.76	100.68	13.92		13.92	219.21	0.44624	5.383764	0.067541	0.34596	0.60221
100.68	110.56	9.88	11.7		0					
110.56	130.48	19.92		11.92	187.71	0.50457	4.91541	0.072988	0.33668	0.68571
130.48	142.40	11.92	5.81		0					
142.40	160.28	17.88		17.88	281.57	0.75449	2.634367	0.059594	0.592662	0.873239
160.28	202.00	41.72	19.2		0				F GEO MEAN	0.658665
				66					F ART MEAN	0.67

Table 8 partial penetration correction of well TWJ2

## APPENDIX – D

### Pumping test data and its correction

<b>Well ID:</b> TK1		<b>Depth:</b> 164.00m		
<b>Location:</b> 0570275E, 1355009mN, 1418m				
<b>SWL:</b> 21.08m		<b>Pump position:</b> 78m		
<b>Reference:</b> 1.45m		<b>Date:</b> 04/06/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 75.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confine d sc</b>	<b>Correct drawdown</b>
0	21.08	0.00		
0.5	43.43	22.35	17.81	15.95
1	45.92	24.84	19.23	17.22
1.5	47.60	26.52	20.13	18.02
2	50.35	29.27	21.48	19.24
2.5	50.20	29.12	21.41	19.17
3	51.35	30.27	21.94	19.65
3.5	51.57	30.49	22.04	19.74
4	51.73	30.65	22.11	19.80
4.5	51.96	30.88	22.21	19.89
5	52.02	30.94	22.24	19.91
6	52.20	31.12	22.32	19.98
7	52.22	31.14	22.32	19.99
8	52.42	31.34	22.41	20.07
9	52.55	31.47	22.47	20.12
10	52.64	31.56	22.51	20.15
12	52.75	31.67	22.55	20.20
14	52.92	31.84	22.62	20.26
16	53.08	32.00	22.69	20.32
18	53.37	32.29	22.81	20.43
20	53.56	32.48	22.89	20.50
25	54.05	32.97	23.09	20.68
30	54.40	33.32	23.23	20.80
35	54.80	33.72	23.38	20.94
40	55.10	34.02	23.50	21.04
45	55.29	34.21	23.57	21.11

50	55.48	34.40	23.64	21.17
55	55.62	34.54	23.69	21.22
60	55.75	34.67	23.74	21.26
70	55.97	34.89	23.82	21.33
80	56.13	35.05	23.88	21.39
90	56.24	35.16	23.92	21.42
100	56.53	35.45	24.03	21.51
110	56.76	35.68	24.11	21.59
120	56.95	35.87	24.17	21.65
140	57.09	36.01	24.22	21.69
160	57.37	36.29	24.32	21.78
180	57.42	36.34	24.33	21.79
210	57.44	36.36	24.34	21.80
240	57.60	36.52	24.40	21.85
270	57.93	36.85	24.51	21.94
300	58.13	37.05	24.57	22.00
330	58.38	37.30	24.65	22.08
360	58.50	37.42	24.69	22.11
420	59.03	37.95	24.86	22.26
480	59.23	38.15	24.92	22.31
540	59.50	38.42	25.00	22.39
600	60.00	38.92	25.15	22.52
660	60.30	39.22	25.24	22.60
720	60.47	39.39	25.28	22.64
780	60.64	39.56	25.33	22.69
840	60.88	39.80	25.40	22.75
900	60.90	39.82	25.41	22.75
960	60.95	39.87	25.42	22.76
1020	61.10	40.02	25.46	22.80
1080	61.18	40.10	25.48	22.82
1140	61.20	40.12	25.49	22.82
1200	61.24	40.16	25.50	22.83
1260	61.40	40.32	25.54	22.87
1320	61.35	40.27	25.53	22.86
1380	61.52	40.44	25.57	22.90
1440	61.59	40.51	25.59	22.92
1500	61.37	40.29	25.53	22.86
1560	61.10	40.02	25.46	22.80
1620	61.20	40.12	25.49	22.82
1680	61.33	40.25	25.52	22.86
1740	61.39	40.31	25.54	22.87
1800	61.20	40.12	25.49	22.82
1860	61.50	40.42	25.57	22.90

1920	61.53	40.45	25.58	22.90
1980	61.43	40.35	25.55	22.88
2040	61.60	40.52	25.59	22.92
2100	61.62	40.54	25.60	22.92
2160	61.65	40.57	25.61	22.93
2220	61.83	40.75	25.65	22.97
2280	61.94	40.86	25.68	23.00
2340	62.00	40.92	25.70	23.01
2400	61.80	40.72	25.65	22.97
2460	61.86	40.78	25.66	22.98
2520	61.25	40.17	25.50	22.84
2580	61.90	40.82	25.67	22.99
2640	61.83	40.75	25.65	22.97
2700	61.99	40.91	25.70	23.01
2760	62.09	41.01	25.72	23.03
2820	61.20	40.12	25.49	22.82
2880	61.83	40.75	25.65	22.97
3000	60.86	39.78	25.39	22.74
3120	61.23	40.15	25.50	22.83
3240	61.20	40.12	25.49	22.82
3360	61.37	40.29	25.53	22.86
3480	61.28	40.20	25.51	22.84
3600	61.58	40.50	25.59	22.91
3720	61.52	40.44	25.57	22.90
3840	61.53	40.45	25.58	22.90
3960	61.50	40.42	25.57	22.90
4080	61.78	40.70	25.64	22.96
4200	61.62	40.54	25.60	22.92
4320	61.48	40.40	25.56	22.89

Table 9 pumping test data and its correction for well ID TK1

<b>Well ID: PK1      Depth: 134.00m</b>				
<b>Location: 0568062E, 1340937mN, 1492m</b>				
<b>SWL: 26.44m</b>		<b>Pump position: 78m</b>		
<b>Reference: 0.82m</b>		<b>Date: 28/06/09</b>		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 55.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>unconfined sc</b>	<b>sc</b>

0	26.44	0.00		0
0.5	42.10	15.66	13.47	9.81183676
1	46.04	19.60	16.17	11.778228
1.5	49.98	23.54	18.59	13.5427016
2	51.55	25.11	19.48	14.1895435
2.5	52.55	26.11	20.02	14.5848306
3	53.20	26.76	20.37	14.8347921
3.5	53.95	27.51	20.75	15.1163805
4	54.30	27.86	20.93	15.2452845
4.5	54.80	28.36	21.18	15.4266691
5	55.40	28.96	21.47	15.6400383
6	56.00	29.56	21.76	15.8487249
7	56.58	30.14	22.03	16.0460042
8	56.90	30.46	22.18	16.152975
9	56.95	30.51	22.20	16.1695688
10	56.95	30.51	22.20	16.1695688
12		30.74	22.30	16.2454818
	57.18			
14		30.96	22.40	16.3174503
	57.40			
16	57.45	31.01	22.42	16.333719
18	57.66	31.22	22.52	16.4016924
20	57.90	31.46	22.62	16.4786738
25	58.25	31.81	22.78	16.5895955
30	58.50	32.06	22.88	16.6678497
35	59.20	32.76	23.18	16.8826367
40	59.70	33.26	23.38	17.0321538
45	59.45	33.01	23.28	16.9578017
50	59.50	33.06	23.30	16.9727372
55	60.00	33.56	23.50	17.1203032
60	60.10	33.66	23.54	17.1494262
70	60.56	34.12	23.73	17.2817166
80	60.75	34.31	23.80	17.3355551
90	61.10	34.66	23.93	17.4335022
100	61.40	34.96	24.05	17.5161886
110	61.52	35.08	24.09	17.5489354
120	61.60	35.16	24.12	17.5706625
140	62.08	35.64	24.30	17.6992771
160	62.30	35.86	24.38	17.757224
180	62.40	35.96	24.41	17.7833553
210	62.65	36.21	24.50	17.8481146
240	63.08	36.64	24.65	17.957599
270	63.40	36.96	24.76	18.0375149
300	63.45	37.01	24.78	18.0498814

330	63.43	36.99	24.77	18.0449387
360	63.82	37.38	24.90	18.1403832
420	63.80	37.36	24.90	18.1355367
480	64.10	37.66	25.00	18.2076873
540	64.17	37.73	25.02	18.224354
600	64.26	37.82	25.05	18.245689
660	64.50	38.06	25.13	18.3020672
720	64.61	38.17	25.16	18.3276568
780	64.75	38.31	25.21	18.3599977
840	64.80	38.36	25.22	18.3714863
900	64.50	38.06	25.13	18.3020672
960	64.26	37.82	25.05	18.245689
1020	64.11	37.67	25.00	18.2100722
1080	64.00	37.56	24.96	18.1837672
1140	64.53	38.09	25.14	18.3090617
1200	64.46	38.02	25.11	18.2927228
1260	64.43	37.99	25.10	18.2857009
1320	64.37	37.93	25.08	18.271622
1380	64.26	37.82	25.05	18.245689
1440	64.42	37.98	25.10	18.2833577
1500	65.10	38.66	25.32	18.4397348
1560	64.80	38.36	25.22	18.3714863
1620	64.58	38.14	25.15	18.3206934
1680	64.44	38.00	25.11	18.2880429
1740	64.41	37.97	25.10	18.2810131
1800	64.92	38.48	25.26	18.3989261
1860	64.60	38.16	25.16	18.3253369
1920	64.40	37.96	25.09	18.2786673
1980	64.73	38.29	25.20	18.3553932
2040	64.68	38.24	25.18	18.3438591
2100	64.63	38.19	25.17	18.3322925
2160	64.32	37.88	25.07	18.2598538
2220	64.64	38.20	25.17	18.3346084
2280	64.65	38.21	25.17	18.336923
2340	64.67	38.23	25.18	18.3415484
2400	64.65	38.21	25.17	18.336923
2460	64.75	38.31	25.21	18.3599977
2520	64.61	38.17	25.16	18.3276568
2580	64.63	38.19	25.17	18.3322925
2640	64.73	38.29	25.20	18.3553932
2700	64.79	38.35	25.22	18.3691912
2760	64.85	38.41	25.24	18.3829423
2820	64.87	38.43	25.24	18.3875156
2880	64.90	38.46	25.25	18.3943658
3000	64.90	38.46	25.25	18.3943658

3120	64.45	38.01	25.11	18.2903835
3240	64.75	38.31	25.21	18.3599977
3360	61.76	35.32	24.18	17.613867
3480	62.00	35.56	24.27	17.6780495
3600	62.10	35.66	24.31	17.704571
3720	62.15	35.71	24.32	17.717783
3840	62.11	35.67	24.31	17.707216
3960	62.09	35.65	24.30	17.7019247
4080	62.10	35.66	24.31	17.704571
4200	62.08	35.64	24.30	17.6992771
4320	62.10	35.66	24.31	17.704571

Table 10 pumping test data and its correction for well ID PK1

<b>Well ID: PK2</b>		<b>Depth:</b> 137.00m		
<b>Location:</b> 0568471E, 1341132mN, 1482m				
<b>SWL:</b> 24.31m		<b>Pump position:</b> 84m		
<b>Reference:</b> 0.75m		<b>Date:</b> 03/05/09		1
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 80.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confound corrction</b>	<b>sc for partial penetratio n</b>
0	24.31	0.00		
0.5	28.10	3.79	3.7093028	1.5319421
1	28.50	4.19	4.0913702	1.6897359
1.5	28.90	4.59	4.4716399	1.8467873
2	29.05	4.74	4.6137775	1.9054901
2.5	29.25	4.94	4.8029011	1.9835982
3	29.60	5.29	5.132786	2.1198406
3.5	29.70	5.39	5.226786	2.1586626
4	29.80	5.49	5.3206736	2.1974382
4.5	29.89	5.58	5.4050764	2.2322966
5	30.05	5.74	5.5549011	2.2941742
6	30.19	5.88	5.6857618	2.3482196
7	30.38	6.07	5.8630062	2.4214216
8	30.55	6.24	6.0212494	2.486776

9	30.67	6.36	6.1327551	2.5328278
10	30.79	6.48	6.2440989	2.5788128
12	31.05	6.74	6.4847888	2.6782178
14	31.25	6.94	6.669418	2.7544696
16	31.45	7.14	6.8535978	2.8305359
18	31.65	7.34	7.0373281	2.9064165
20	31.80	7.49	7.1748309	2.9632052
25	32.20	7.89	7.5402691	3.1141311
30	32.48	8.17	7.7950062	3.2193376
35	32.85	8.54	8.1302719	3.3578023
40	33.05	8.74	8.3108562	3.4323836
45	33.17	8.86	8.418991	3.4770433
50	33.35	9.04	8.5808899	3.5439075
55	33.48	9.17	8.6975904	3.5921049
60	33.66	9.35	8.8588624	3.6587102
70	33.80	9.49	8.9840444	3.7104103
80	33.75	9.44	8.9393618	3.6919564
90	34.40	10.09	9.5180444	3.9309523
100	34.48	10.17	9.5889388	3.9602317
110	34.68	10.37	9.7658601	4.0333002
120	34.80	10.49	9.8717972	4.0770522
140	35.20	10.89	10.223752	4.2224097
160	35.40	11.09	10.399056	4.29481
180	35.59	11.28	10.565178	4.3634183
210	35.87	11.56	10.809249	4.46422
240	36.10	11.79	11.009078	4.5467493
270	36.24	11.93	11.130422	4.5968642
300	36.48	12.17	11.337928	4.6825641
330	36.60	12.29	11.441438	4.7253137
360	36.75	12.44	11.570598	4.7786569
420	36.99	12.68	11.776728	4.8637887
480	37.13	12.82	11.896672	4.9133255
540	37.26	12.95	12.007851	4.9592425
600	37.39	13.08	12.11884	5.0050811
660	37.57	13.26	12.272204	5.0684205
720	37.76	13.45	12.433694	5.1351155
780	38.05	13.74	12.679396	5.2365903
840	38.22	13.91	12.822988	5.2958941
900	38.35	14.04	12.932575	5.3411536
960	38.45	14.14	13.016744	5.3759152
1020	38.56	14.25	13.109199	5.4140994

1080	38.60	14.29	13.142786	5.4279706
1140	38.63	14.32	13.167964	5.4383692
1200	38.65	14.34	13.184744	5.4452992
1260	38.67	14.36	13.201519	5.4522274
1320	38.69	14.38	13.21829	5.4591537
1380	38.70	14.39	13.226674	5.4626162
1440	38.72	14.41	13.243438	5.4695397
1500	38.74	14.43	13.260197	5.4764614
1560	38.80	14.49	13.310449	5.4972154
1620	38.83	14.52	13.33556	5.5075861
1680	38.86	14.55	13.36066	5.5179526
1740	38.87	14.56	13.369025	5.5214072
1800	38.88	14.57	13.377388	5.5248613
1860	38.90	14.59	13.394112	5.5317682
1920	38.93	14.62	13.419189	5.542125
1980	38.95	14.64	13.435901	5.5490272
2040	39.00	14.69	13.477662	5.5662746
2100	39.02	14.71	13.494359	5.5731703
2160	39.03	14.72	13.502706	5.5766174
2220	39.05	14.74	13.519396	5.5835103
2280	39.08	14.77	13.544422	5.5938462
2340	39.08	14.77	13.544422	5.5938462
2400	39.08	14.77	13.544422	5.5938462
2460	39.08	14.77	13.544422	5.5938462
2520	39.08	14.77	13.544422	5.5938462
2580	39.08	14.77	13.544422	5.5938462
2640	39.08	14.77	13.544422	5.5938462
2700	39.08	14.77	13.544422	5.5938462
2760	39.10	14.79	13.561101	5.6007345
2820	39.10	14.79	13.561101	5.6007345
2880	39.03	14.72	13.502706	5.5766174
3000	39.13	14.82	13.58611	5.6110635
3120	39.19	14.88	13.636099	5.6317088
3240	39.10	14.79	13.561101	5.6007345
3360	39.18	14.87	13.62777	5.6282691
3480	39.23	14.92	13.669402	5.6454631
3600	39.13	14.82	13.58611	5.6110635
3720	39.10	14.79	13.561101	5.6007345
3840	39.13	14.82	13.58611	5.6110635
3960	39.12	14.81	13.577775	5.607621
4080	39.10	14.79	13.561101	5.6007345

4200	39.13	14.82	13.58611	5.6110635
4320	39.13	14.82	13.58611	5.6110635

Table 11 pumping test data and its correction for well ID PK2

<b>Well ID: PK3</b>		<b>Depth: 153.00m</b>	
<b>Location: 0568203E, 1350350mN, 1437m</b>			
<b>SWL: 31.11m</b>		<b>Pump position: 81m</b>	
<b>Reference: 0.66m</b>		<b>Date: 21/06/09</b>	
<b>CONSTANT DISCHARGE RATE TEST</b>			
<b>Q(l/sec): 70.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>partial penetration Correction</b>
0	31.11	0.00	0
0.5	35.20	4.09	2.58
1	35.30	4.19	2.64
1.5	35.40	4.29	2.70
2	35.50	4.39	2.77
2.5	35.55	4.44	2.80
3	35.60	4.49	2.83
3.5	35.65	4.54	2.86
4	35.68	4.57	2.88
4.5	35.74	4.63	2.92
5	35.75	4.64	2.92
6	35.76	4.65	2.93
7	35.80	4.69	2.95
8	35.85	4.74	2.99
9	35.86	4.75	2.99
10	35.88	4.77	3.01
12	35.91	4.80	3.02
14	35.95	4.84	3.05
16	36.00	4.89	3.08
18	36.05	4.94	3.11

20	36.08	4.97	3.13
25	36.17	5.06	3.19
30	36.21	5.10	3.21
35	36.28	5.17	3.26
40	36.36	5.25	3.31
45	36.40	5.29	3.33
50	36.44	5.33	3.36
55	36.42	5.31	3.35
60	36.42	5.31	3.35
70	36.47	5.36	3.38
80	36.50	5.39	3.40
90	36.56	5.45	3.43
100	36.56	5.45	3.43
110	36.60	5.49	3.46
120	36.68	5.57	3.51
140	36.73	5.62	3.54
160	36.78	5.67	3.57
180	36.82	5.71	3.60
210	36.85	5.74	3.62
240	36.86	5.75	3.62
270	36.88	5.77	3.64
300	36.90	5.79	3.65
330	36.98	5.87	3.70
360	36.98	5.87	3.70
420	37.04	5.93	3.74
480	37.15	6.04	3.81
540	37.03	5.92	3.73
600	37.09	5.98	3.77
660	37.21	6.10	3.84
720	37.22	6.11	3.85
780	37.13	6.02	3.79
840	37.13	6.02	3.79
900	37.28	6.17	3.89
960	37.20	6.09	3.84
1020	37.22	6.11	3.85
1080	37.24	6.13	3.86
1140	37.18	6.07	3.82
1200	37.20	6.09	3.84
1260	37.21	6.10	3.84
1320	37.21	6.10	3.84
1380	37.22	6.11	3.85

1440	37.18	6.07	3.82
1500	37.22	6.11	3.85
1560	37.28	6.17	3.89
1620	37.23	6.12	3.86
1680	37.44	6.33	3.99
1740	37.31	6.20	3.91
1800	37.30	6.19	3.90
1860	37.32	6.21	3.91
1920	37.37	6.26	3.94
1980	37.40	6.29	3.96
2040	37.43	6.32	3.98
2100	37.44	6.33	3.99
2160	37.46	6.35	4.00
2220	37.47	6.36	4.01
2280	37.48	6.37	4.01
2340	37.49	6.38	4.02
2400	37.54	6.43	4.05
2460	37.58	6.47	4.08
2520	37.59	6.48	4.08
2580	37.64	6.53	4.11
2640	37.68	6.57	4.14
2700	37.70	6.59	4.15
2760	37.7	6.59	4.15
2820	37.58	6.47	4.08
2880	37.56	6.45	4.06
3000	37.44	6.33	3.99
3120	37.38	6.27	3.95
3240	37.55	6.44	4.06
3360	37.55	6.44	4.06
3480	37.56	6.45	4.06
3600	37.39	6.28	3.96
3720	37.31	6.20	3.91
3840	37.33	6.22	3.92
3960	37.32	6.21	3.91
4080	37.3	6.19	3.90
4200	37.31	6.20	3.91
4320	37.33	6.22	3.92

Table 12 pumping test data and its correction for well ID PK3

<b>Well ID:</b> PK4		<b>Depth:</b> 106.00m	
<b>Location:</b> 0567992E, 1352995mN, 1446m			
<b>SWL:</b> 9.72m		<b>Pump position:</b> 77m	
<b>Reference:</b> 0.58m		<b>Date:</b> 12/06/09	
<b>CONSTANT DISCHARGE RATE TEST</b>			
<b>Q(l/sec): 60.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>corrct drawdown</b>
0	9.72	0.00	0.00
0.5	32.55	22.83	16.96
1	35.00	25.28	18.79
1.5	35.62	25.90	19.25
2	35.80	26.08	19.38
2.5	36.40	26.68	19.83
3	38.64	28.92	21.49
3.5	38.85	29.13	21.65
4	39.31	29.59	21.99
4.5	40.29	30.57	22.72
5	41.90	32.18	23.91
6	42.30	32.58	24.21
7	42.90	33.18	24.66
8	43.50	33.78	25.10
9	44.50	34.78	25.85
10	46.30	36.58	27.18
12	46.60	36.88	27.41
14	47.25	37.53	27.89
16	47.60	37.88	28.15
18	47.95	38.23	28.41
20	48.23	38.51	28.62
25	48.80	39.08	29.04
30	49.35	39.63	29.45
35	49.80	40.08	29.78
40	50.05	40.33	29.97
45	50.10	40.38	30.01
50	50.20	40.48	30.08
55	50.43	40.71	30.25
60	50.60	40.88	30.38
70	50.62	40.90	30.39
80	51.22	41.50	30.84

90	51.60	41.88	31.12
100	51.90	42.18	31.34
110	52.35	42.63	31.68
120	52.38	42.66	31.70
140	52.80	43.08	32.01
160	53.20	43.48	32.31
180	53.62	43.90	32.62
210	53.64	43.92	32.64
240	54.25	44.53	33.09
270	54.53	44.81	33.30
300	54.56	44.84	33.32
330	54.81	45.09	33.51
360	55.83	46.11	34.26
420	56.05	46.33	34.43
480	56.14	46.42	34.49
540	56.53	46.81	34.78
600	56.57	46.85	34.81
660	56.93	47.21	35.08
720	57.20	47.48	35.28
780	57.29	47.57	35.35
840	57.15	47.43	35.25
900	57.19	47.47	35.27
960	57.05	47.33	35.17
1020	57.03	47.31	35.16
1080	57.10	47.38	35.21
1140	57.11	47.39	35.22
1200	56.85	47.13	35.02
1260	57.45	47.73	35.47
1320	57.21	47.49	35.29
1380	57.33	47.61	35.38
1440	57.50	47.78	35.51
1500	57.45	47.73	35.47
1560	54.32	44.60	33.14
1620	57.35	47.63	35.39
1680	57.80	48.08	35.73
1740	57.85	48.13	35.77
1800	57.87	48.15	35.78
1860	57.87	48.15	35.78
1920	57.99	48.27	35.87
1980	57.99	48.27	35.87
2040	57.93	48.21	35.82

2100	58.26	48.54	36.07
2160	57.74	48.02	35.68
2220	57.52	47.80	35.52
2280	57.60	47.88	35.58
2340	57.74	48.02	35.68
2400	57.90	48.18	35.80
2460	57.80	48.08	35.73
2520	57.85	48.13	35.77
2580	57.38	47.66	35.42
2640	57.94	48.22	35.83
2700	57.98	48.26	35.86
2760	57.00	47.28	35.13
2820	58.19	48.47	36.02
2880	57.94	48.22	35.83
3000	58.15	48.43	35.99
3120	58.22	48.50	36.04
3240	57.90	48.18	35.80
3360	60.62	50.90	37.82
3480	61.10	51.38	38.18
3600	61.69	51.97	38.62
3720	61.68	51.96	38.61
3840	62.10	52.38	38.92
3960	62.11	52.39	38.93
4080	61.82	52.10	38.72
4200	61.90	52.18	38.77
4320	61.20	51.48	38.25

Table 13 pumping test data and its correction for well ID PK4

<b>Well ID:</b> PK5		<b>Depth:</b> 119.3m		
<b>Location:</b> 0568427E, 1351843mN, 1428m				
<b>SWL:</b> 18.20m		<b>Pump position:</b> 89m		
<b>Reference:</b> 1.12m		<b>Date:</b> 08/07/08		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 30.00</b>				
<b>Time (min)</b>	<b>Water level(m)</b>	<b>Draw Down(m)</b>	<b>un confind correction</b>	<b>correct draw down</b>
0	18.2	0.00		0.00

0.5	26.70	8.50	7.90	6.11
1	29.50	11.30	10.24	7.92
1.5	31.70	13.50	11.98	9.28
2	32.60	14.40	12.67	9.81
2.5	32.90	14.70	12.90	9.99
3	33.30	15.10	13.20	10.22
3.5	33.80	15.60	13.57	10.51
4	34.30	16.10	13.94	10.79
4.5	34.55	16.35	14.12	10.93
5	34.90	16.70	14.38	11.13
6	35.55	17.35	14.84	11.49
7	36.05	17.85	15.19	11.76
8	36.50	18.30	15.51	12.01
9	37.20	19.00	15.99	12.38
10	37.70	19.50	16.33	12.64
12	37.90	19.70	16.47	12.75
14	38.75	20.55	17.03	13.19
16	39.20	21.00	17.33	13.41
18	39.60	21.40	17.58	13.61
20	40.05	21.85	17.87	13.84
25	40.85	22.65	18.37	14.23
30	41.40	23.20	18.71	14.49
35	41.75	23.55	18.93	14.65
40	42.03	23.83	19.10	14.79
45	42.31	24.11	19.27	14.92
50	42.58	24.38	19.43	15.04
55	42.85	24.65	19.59	15.16
60	43.03	24.83	19.69	15.25
70	43.37	25.17	19.89	15.40
80	43.71	25.51	20.09	15.55
90	43.93	25.73	20.21	15.65
100	44.12	25.92	20.32	15.73
110	44.28	26.08	20.41	15.80
120	44.42	26.22	20.49	15.86
140	44.62	26.42	20.60	15.95
160	45.00	26.80	20.81	16.11
180	45.07	26.87	20.85	16.14
210	45.60	27.40	21.14	16.37
240	45.90	27.70	21.31	16.50
270	46.15	27.95	21.44	16.60
300	46.30	28.10	21.52	16.66
330	46.39	28.19	21.57	16.70
360	46.55	28.35	21.65	16.76
420	47.15	28.95	21.97	17.01
480	47.28	29.08	22.03	17.06

540	47.55	29.35	22.17	17.17
600	47.78	29.58	22.29	17.26
660	47.87	29.67	22.33	17.29
720	48.05	29.85	22.42	17.36
780	48.17	29.97	22.48	17.41
840	48.28	30.08	22.54	17.45
900	48.38	30.18	22.59	17.49
960	48.71	30.51	22.75	17.62
1020	48.74	30.54	22.77	17.63
1080	48.82	30.62	22.81	17.66
1140	48.99	30.79	22.89	17.72
1200	49.33	31.13	23.05	17.85
1260	49.43	31.23	23.10	17.89
1320	49.5	31.30	23.14	17.91
1380	49.42	31.22	23.10	17.88
1440	49.39	31.19	23.08	17.87
1500	49.50	31.30	23.14	17.91
1560	49.72	31.52	23.24	17.99
1620	49.60	31.40	23.18	17.95
1680	49.66	31.46	23.21	17.97
1740	49.45	31.25	23.11	17.89
1800	49.65	31.45	23.21	17.97
1860	49.75	31.55	23.25	18.00
1920	49.85	31.65	23.30	18.04
1980	49.80	31.60	23.28	18.02
2040	49.80	31.60	23.28	18.02
2100	49.75	31.55	23.25	18.00
2160	49.79	31.59	23.27	18.02
2220	49.90	31.70	23.33	18.06
2280	49.86	31.66	23.31	18.04
2340	49.79	31.59	23.27	18.02
2400	49.99	31.79	23.37	18.09
2460	50.07	31.87	23.41	18.12
2520	50.00	31.80	23.37	18.10
2580	49.93	31.73	23.34	18.07
2640	49.81	31.61	23.28	18.03
2700	49.93	31.73	23.34	18.07
2760	49.98	31.78	23.36	18.09
2820	50.01	31.81	23.38	18.10
2880	49.90	31.70	23.33	18.06
3000	49.85	31.65	23.30	18.04
3120	50.00	31.80	23.37	18.10
3240	49.88	31.68	23.32	18.05
3360	50.00	31.80	23.37	18.10
3480	49.94	31.74	23.34	18.07

3600	49.94	31.74	23.34	18.07
3720	50.10	31.90	23.42	18.13
3840	50.41	32.21	23.56	18.24
3960	50.38	32.18	23.55	18.23
4080	50.43	32.23	23.57	18.25
4200	50.34	32.14	23.53	18.22
4320	50.40	32.20	23.56	18.24

Table 14 pumping test data and its correction for well ID PK5

<b>Well ID:</b> PK-6		<b>Depth:</b> 145.00m		
<b>Location:</b> 0569299E, 1341882mN, 1480m				
<b>SWL:</b> 18.10m		<b>Pump position:</b> 72m		
<b>Reference:</b> 0.58m		<b>Date:</b> 16/05/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 40.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confind sc</b>	<b>Sc</b>
0	18.10	0.00		0.00
0.5	23.82	5.72	5.50	4.94
1	24.90	6.80	6.50	5.82
1.5	25.90	7.80	7.40	6.64
2	26.45	8.35	7.89	7.08
2.5	26.96	8.86	8.34	7.48
3	27.35	9.25	8.69	7.79
3.5	27.72	9.62	9.01	8.08
4	28.04	9.94	9.29	8.33
4.5	28.31	10.21	9.52	8.54
5	28.52	10.42	9.71	8.70
6	28.95	10.85	10.08	9.03
7	29.20	11.10	10.29	9.23
8	29.61	11.51	10.64	9.54
9	29.84	11.74	10.83	9.71
10	29.89	11.79	10.88	9.75
12	30.10	12.00	11.05	9.91
14	30.20	12.10	11.14	9.99

16	30.25	12.15	11.18	10.02
18	30.30	12.20	11.22	10.06
20	30.40	12.30	11.30	10.14
25	30.55	12.45	11.43	10.25
30	30.69	12.59	11.55	10.35
35	30.74	12.64	11.59	10.39
40	30.88	12.78	11.71	10.50
45	30.99	12.89	11.80	10.58
50	31.15	13.05	11.93	10.70
55	31.27	13.17	12.03	10.79
60	31.38	13.28	12.12	10.87
70	31.45	13.35	12.18	10.92
80	31.55	13.45	12.26	10.99
90	31.63	13.53	12.33	11.05
100	31.66	13.56	12.35	11.07
110	31.69	13.59	12.37	11.10
120	31.72	13.62	12.40	11.12
140	31.78	13.68	12.45	11.16
160	31.83	13.73	12.49	11.20
180	31.88	13.78	12.53	11.24
210	31.93	13.83	12.57	11.27
240	31.98	13.88	12.61	11.31
270	32.00	13.90	12.63	11.32
300	32.03	13.93	12.65	11.35
330	32.06	13.96	12.68	11.37
360	32.07	13.97	12.69	11.38
420	32.09	13.99	12.70	11.39
480	32.11	14.01	12.72	11.40
540	32.14	14.04	12.74	11.43
600	32.16	14.06	12.76	11.44
660	32.18	14.08	12.78	11.46
720	32.20	14.10	12.79	11.47
780	32.22	14.12	12.81	11.49
840	32.25	14.15	12.83	11.51
900	32.27	14.17	12.85	11.52
960	32.29	14.19	12.87	11.54
1020	32.31	14.21	12.88	11.55
1080	32.33	14.23	12.90	11.57
1140	32.34	14.24	12.91	11.57
1200	32.36	14.26	12.92	11.59
1260	32.37	14.27	12.93	11.59

1320	32.38	14.28	12.94	11.60
1380	32.39	14.29	12.95	11.61
1440	32.39	14.29	12.95	11.61
1500	32.40	14.30	12.95	11.62
1560	32.39	14.29	12.95	11.61
1620	32.38	14.28	12.94	11.60
1680	32.39	14.29	12.95	11.61
1740	32.38	14.28	12.94	11.60
1800	32.37	14.27	12.93	11.59
1860	32.36	14.26	12.92	11.59
1920	32.36	14.26	12.92	11.59
1980	32.37	14.27	12.93	11.59
2040	32.38	14.28	12.94	11.60
2100	32.39	14.29	12.95	11.61
2160	32.39	14.29	12.95	11.61
2220	32.40	14.30	12.95	11.62
2280	32.41	14.31	12.96	11.62
2340	32.42	14.32	12.97	11.63
2400	32.43	14.33	12.98	11.64
2460	32.44	14.34	12.99	11.65
2520	32.43	14.33	12.98	11.64
2580	32.44	14.34	12.99	11.65
2640	32.45	14.35	13.00	11.65
2700	32.45	14.35	13.00	11.65
2760	32.46	14.36	13.00	11.66
2820	32.48	14.38	13.02	11.67
2880	32.46	14.36	13.00	11.66
3000	32.45	14.35	13.00	11.65
3120	32.46	14.36	13.00	11.66
3240	32.46	14.36	13.00	11.66
3360	32.46	14.36	13.00	11.66
3480	32.46	14.36	13.00	11.66
3600	32.47	14.37	13.01	11.67
3720	32.48	14.38	13.02	11.67
3840	32.48	14.38	13.02	11.67
3960	32.49	14.39	13.03	11.68
4080	32.51	14.41	13.04	11.70
4200	32.54	14.44	13.07	11.72
4320	32.55	14.45	13.08	11.73

Table 15 pumping test data and its correction for well ID PK6

Well ID: PK-7		Depth: 183.00m		
Location: 0569882E, 1341651mN, 1479m				
SWL: 21.42m		Pump position: 78m		
Reference: 0.64m		Date: 26/06/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 40.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confind sc</b>	<b>Sc</b>
0	21.42	0.00		
0.5	37.30	15.88	14.26	8.64
1	37.90	16.48	14.74	8.93
1.5	38.85	17.43	15.48	9.38
2	39.11	17.69	15.68	9.50
2.5	39.36	17.94	15.88	9.62
3	40.03	18.61	16.39	9.93
3.5	40.42	19.00	16.69	10.11
4	41.31	19.89	17.35	10.52
4.5	41.70	20.28	17.64	10.69
5	42.07	20.65	17.92	10.86
6	42.80	21.38	18.45	11.18
7	43.10	21.68	18.67	11.31
8	43.50	22.08	18.95	11.49
9	43.89	22.47	19.23	11.66
10	44.27	22.85	19.50	11.82
12	44.71	23.29	19.81	12.01
14	44.94	23.52	19.97	12.10
16	45.16	23.74	20.13	12.20
18	45.43	24.01	20.31	12.31
20	45.73	24.31	20.52	12.44
25	46.00	24.58	20.71	12.55
30	46.29	24.87	20.91	12.67
35	46.40	24.98	20.98	12.71
40	46.75	25.33	21.22	12.86
45	47.29	25.87	21.58	13.08
50	47.36	25.94	21.63	13.11
55	47.46	26.04	21.69	13.15

60	47.64	26.22	21.81	13.22
70	47.83	26.41	21.94	13.29
80	47.96	26.54	22.02	13.35
90	48.27	26.85	22.23	13.47
100	48.43	27.01	22.33	13.53
110	48.57	27.15	22.42	13.59
120	48.80	27.38	22.57	13.68
140	49.00	27.58	22.70	13.76
160	49.17	27.75	22.81	13.83
180	49.34	27.92	22.92	13.89
210	49.54	28.12	23.05	13.97
240	49.67	28.25	23.13	14.02
270	49.81	28.39	23.22	14.07
300	49.97	28.55	23.32	14.13
330	50.10	28.68	23.41	14.18
360	50.14	28.72	23.43	14.20
420	50.20	28.78	23.47	14.22
480	50.38	28.96	23.58	14.29
540	50.52	29.10	23.67	14.35
600	50.67	29.25	23.77	14.40
660	50.80	29.38	23.85	14.45
720	50.87	29.45	23.89	14.48
780	50.90	29.48	23.91	14.49
840	50.91	29.49	23.92	14.49
900	50.97	29.55	23.95	14.52
960	51.01	29.59	23.98	14.53
1020	51.08	29.66	24.02	14.56
1080	51.13	29.71	24.05	14.58
1140	51.16	29.74	24.07	14.59
1200	51.20	29.78	24.10	14.60
1260	51.27	29.85	24.14	14.63
1320	51.34	29.92	24.18	14.65
1380	51.39	29.97	24.21	14.67
1440	51.43	30.01	24.24	14.69
1500	51.47	30.05	24.26	14.70
1560	51.51	30.09	24.29	14.72
1620	51.55	30.13	24.31	14.73
1680	51.59	30.17	24.34	14.75
1740	51.61	30.19	24.35	14.75
1800	51.63	30.21	24.36	14.76
1860	51.66	30.24	24.38	14.77

1920	51.67	30.25	24.38	14.78
1980	51.70	30.28	24.40	14.79
2040	51.79	30.37	24.46	14.82
2100	51.83	30.41	24.48	14.84
2160	51.88	30.46	24.51	14.85
2220	51.85	30.43	24.49	14.84
2280	51.91	30.49	24.53	14.87
2340	52.02	30.60	24.60	14.91
2400	52.05	30.63	24.62	14.92
2460	52.08	30.66	24.63	14.93
2520	52.10	30.68	24.65	14.94
2580	52.15	30.73	24.68	14.95
2640	52.20	30.78	24.71	14.97
2700	52.26	30.84	24.74	14.99
2760	52.30	30.88	24.77	15.01
2820	52.35	30.93	24.80	15.03
2880	52.33	30.91	24.79	15.02
3000	52.35	30.93	24.80	15.03
3120	52.40	30.98	24.83	15.05
3240	52.44	31.02	24.85	15.06
3360	52.48	31.06	24.88	15.07
3480	52.43	31.01	24.85	15.06
3600	52.40	30.98	24.83	15.05
3720	52.41	30.99	24.83	15.05
3840	52.44	31.02	24.85	15.06
3960	52.45	31.03	24.86	15.06
4080	52.44	31.02	24.85	15.06
4200	52.43	31.01	24.85	15.06
4320	52.43	31.01	24.85	15.06

Table 16 pumping test data and its correction for well ID PK7

<b>Well ID:</b> PK-8		<b>Depth:</b> 180.00m		
<b>Location:</b> 0569817E, 1341059mN, 1465m				
<b>SWL:</b> 18.66m		<b>Pump position:</b> 72m		
<b>Reference:</b> 0.68m		<b>Date:</b> 03/05/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 50.00</b>				

<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confind sc</b>	<b>Sc</b>
0	18.66	0.00		
0.5	24.78	6.12	5.96	4.16
1	24.88	6.22	6.06	4.23
1.5	25.10	6.44	6.26	4.37
2	25.40	6.74	6.55	4.57
2.5	25.62	6.96	6.75	4.72
3	25.72	7.06	6.85	4.78
3.5	25.81	7.15	6.93	4.84
4	25.95	7.29	7.06	4.93
4.5	26.09	7.43	7.20	5.03
5	26.18	7.52	7.28	5.08
6	26.32	7.66	7.41	5.18
7	26.42	7.76	7.50	5.24
8	26.53	7.87	7.61	5.31
9	26.64	7.98	7.71	5.38
10	26.75	8.09	7.81	5.46
12	27.05	8.39	8.09	5.65
14	27.16	8.50	8.19	5.72
16	27.37	8.71	8.39	5.86
18	27.49	8.83	8.50	5.94
20	27.53	8.87	8.54	5.96
25	27.83	9.17	8.81	6.15
30	28.15	9.49	9.11	6.36
35	28.46	9.80	9.39	6.56
40	28.67	10.01	9.59	6.69
45	28.83	10.17	9.73	6.80
50	29.00	10.34	9.89	6.90
55	29.27	10.61	10.13	7.08
60	29.52	10.86	10.36	7.23
70	29.78	11.12	10.60	7.40
80	29.94	11.28	10.74	7.50
90	30.28	11.62	11.05	7.71
100	30.41	11.75	11.16	7.80
110	30.63	11.97	11.36	7.93
120	30.82	12.16	11.53	8.05
140	31.22	12.56	11.89	8.30
160	31.50	12.84	12.14	8.48

180	31.85	13.19	12.45	8.70
210	32.20	13.54	12.76	8.91
240	32.58	13.92	13.10	9.15
270	32.91	14.25	13.39	9.35
300	33.12	14.46	13.57	9.48
330	33.46	14.80	13.87	9.69
360	33.54	14.88	13.94	9.74
420	33.82	15.16	14.19	9.91
480	34.15	15.49	14.47	10.11
540	34.36	15.70	14.66	10.23
600	34.61	15.95	14.87	10.39
660	34.79	16.13	15.03	10.49
720	34.89	16.23	15.11	10.55
780	35.02	16.36	15.23	10.63
840	35.16	16.50	15.35	10.72
900	35.27	16.61	15.44	10.78
960	35.40	16.74	15.55	10.86
1020	35.47	16.81	15.61	10.90
1080	35.54	16.88	15.67	10.94
1140	35.62	16.96	15.74	10.99
1200	35.66	17.00	15.78	11.02
1260	35.73	17.07	15.84	11.06
1320	35.82	17.16	15.91	11.11
1380	35.91	17.25	15.99	11.17
1440	35.97	17.31	16.04	11.20
1500	36.04	17.38	16.10	11.24
1560	36.08	17.42	16.13	11.27
1620	36.12	17.46	16.17	11.29
1680	36.16	17.50	16.20	11.31
1740	36.19	17.53	16.23	11.33
1800	36.22	17.56	16.25	11.35
1860	36.24	17.58	16.27	11.36
1920	36.27	17.61	16.30	11.38
1980	36.31	17.65	16.33	11.40
2040	36.34	17.68	16.36	11.42
2100	36.37	17.71	16.38	11.44
2160	36.40	17.74	16.41	11.46
2220	36.43	17.77	16.43	11.47
2280	36.46	17.80	16.46	11.49
2340	36.49	17.83	16.48	11.51
2400	36.51	17.85	16.50	11.52

2460	36.54	17.88	16.53	11.54
2520	36.56	17.90	16.54	11.55
2580	36.58	17.92	16.56	11.56
2640	36.60	17.94	16.58	11.58
2700	36.62	17.96	16.59	11.59
2760	36.64	17.98	16.61	11.60
2820	36.66	18.00	16.63	11.61
2880	36.67	18.01	16.64	11.62
3000	36.77	18.11	16.72	11.68
3120	36.83	18.17	16.77	11.71
3240	36.88	18.22	16.81	11.74
3360	36.92	18.26	16.85	11.76
3480	36.96	18.30	16.88	11.79
3600	36.99	18.33	16.91	11.81
3720	37.65	18.99	17.46	12.19
3840	37.10	18.44	17.00	11.87
3960	37.13	18.47	17.02	11.89
4080	37.16	18.50	17.05	11.91
4200	37.20	18.54	17.08	11.93
4320	37.16	18.50	17.05	11.91

Table 17 pumping test data and its correction for well ID PK8

<b>Well ID:</b> PK-9		<b>Depth:</b> 145.00m	
<b>Location:</b> 0569483E, 1341614mN, 1460m			
<b>SWL:</b> 24.73m		<b>Pump position:</b> 84m	
<b>Reference:</b> 0.88m		<b>Date:</b> 14/06/09	
<b>CONSTANT DISCHARGE RATE TEST</b>			
<b>Q(l/sec): 50.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>Sc</b>
0	24.73	0.00	
0.5	27.63	2.90	2.67
1	27.70	2.97	2.73
1.5	27.69	2.96	2.72
2	27.68	2.95	2.72
2.5	27.67	2.94	2.71
3	27.52	2.79	2.57
3.5	27.68	2.95	2.72

4	27.68	2.95	2.71
4.5	27.67	2.94	2.71
5	27.68	2.95	2.72
6	27.67	2.94	2.71
7	27.67	2.94	2.71
8	27.68	2.95	2.71
9	27.68	2.95	2.72
10	27.68	2.95	2.72
12	27.68	2.95	2.72
14	27.67	2.94	2.71
16	27.69	2.96	2.72
18	27.70	2.97	2.73
20	27.71	2.98	2.74
25	27.66	2.93	2.70
30	27.67	2.94	2.71
35	27.68	2.95	2.72
40	27.69	2.96	2.72
45	27.70	2.97	2.73
50	27.71	2.98	2.74
55	27.72	2.99	2.75
60	27.73	3.00	2.76
70	27.75	3.02	2.78
80	27.76	3.03	2.79
90	27.77	3.04	2.80
100	27.78	3.05	2.81
110	27.80	3.07	2.83
120	27.66	2.93	2.70
140	27.67	2.94	2.71
160	27.68	2.95	2.72
180	27.69	2.96	2.72
210	27.69	2.96	2.72
240	27.68	2.95	2.72
270	27.66	2.93	2.70
300	27.67	2.94	2.71
330	27.68	2.95	2.72
360	27.69	2.96	2.72
420	27.70	2.97	2.73
480	27.71	2.98	2.74
540	27.72	2.99	2.75
600	27.73	3.00	2.76
660	27.74	3.01	2.77

720	27.67	2.94	2.71
780	27.68	2.95	2.72
840	27.66	2.93	2.70
900	27.68	2.95	2.72
960	27.65	2.92	2.69
1020	27.68	2.95	2.72
1080	29.58	2.95	2.72
1140	29.63	4.90	4.51
1200	29.62	4.89	4.50
1260	29.64	4.91	4.52
1320	28.65	3.92	3.61
1380	27.70	2.97	2.73
1440	27.67	2.94	2.71
1500	29.52	4.79	4.41
1560	29.34	4.61	4.24
1620	29.10	4.37	4.02
1680	28.91	4.18	3.85
1740	28.69	3.96	3.64
1800	28.51	3.78	3.48
1860	28.31	3.58	3.30
1920	27.60	2.87	2.64
1980	27.61	2.88	2.65
2040	27.62	2.89	2.66
2100	27.64	2.91	2.68
2160	27.66	2.93	2.70
2220	29.68	4.95	4.56
2280	29.73	5.00	4.60
2340	29.80	5.07	4.67
2400	29.80	5.07	4.67
2460	29.81	5.08	4.68
2520	29.65	4.92	4.53
2580	29.67	4.94	4.55
2640	29.66	4.93	4.54
2700	29.65	4.92	4.53
2760	29.69	4.96	4.57
2820	29.70	4.97	4.57
2880	29.72	4.99	4.59
3000	29.78	5.05	4.65
3120	29.77	5.04	4.64
3240	29.76	5.03	4.63
3360	29.78	5.05	4.65

3480	29.77	5.04	4.64
3600	29.76	5.03	4.63
3720	29.78	5.05	4.65
3840	29.77	5.04	4.64
3960	29.78	5.05	4.65
4080	29.78	5.05	4.65
4200	29.77	5.04	4.64
4320	29.78	5.05	4.65

Table 18 pumping test data and its correction for well ID PK9

<b>Well ID:</b> PHG1		<b>Depth:</b> 130.00m	
<b>Location:</b> 0567690E, 1338577mN, 1483m			
<b>SWL:</b> 25.08m		<b>Pump position:</b> 72m	
<b>Reference:</b> 0.73m		<b>Date:</b> 09/06/09	
<b>CONSTANT DISCHARGE RATE TEST</b>			
<b>Q(l/sec): 50.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	
0	25.08	0.00	
0.5	26.81	1.73	
1	27.00	1.92	
1.5	27.10	2.02	
2	27.17	2.09	
2.5	27.21	2.13	
3	27.27	2.19	
3.5	27.31	2.23	
4	27.34	2.26	
4.5	27.36	2.28	
5	27.38	2.30	
6	27.43	2.35	
7	27.46	2.38	
8	27.50	2.42	
9	27.54	2.46	
10	27.56	2.48	
12	27.59	2.51	
14	27.61	2.53	
16	27.63	2.55	

18	27.65	2.57	
20	27.68	2.60	
25	27.74	2.66	
30	27.80	2.72	
35	27.86	2.78	
40	27.91	2.83	
45	27.96	2.88	
50	28.00	2.92	
55	28.04	2.96	
60	28.10	3.02	
70	28.14	3.06	
80	28.18	3.10	
90	28.22	3.14	
100	28.26	3.18	
110	28.32	3.24	
120	28.34	3.26	
140	28.36	3.28	
160	28.38	3.30	
180	28.41	3.33	
210	28.45	3.37	
240	28.48	3.40	
270	28.51	3.43	
300	28.54	3.46	
330	28.57	3.49	
360	28.60	3.52	
420	28.70	3.62	
480	28.76	3.68	
540	28.84	3.76	
600	28.94	3.86	
660	28.98	3.90	
720	28.99	3.91	
780	28.90	3.82	
840	29.00	3.92	
900	29.00	3.92	
960	28.90	3.82	
1020	28.86	3.78	
1080	28.86	3.78	
1140	28.89	3.77	
1200	28.84	3.76	
1260	28.84	3.76	
1320	28.83	3.75	

1380	28.82	3.76	
1440	28.85	3.77	
1500	28.86	3.78	
1560	28.88	3.80	
1620	28.90	3.82	
1680	28.93	3.85	
1740	28.96	3.88	
1800	28.98	3.90	
1860	29.00	3.92	
1920	29.02	3.94	
1980	29.04	3.96	
2040	29.06	3.98	
2100	29.08	3.99	
2160	29.07	3.99	
2220	29.04	3.99	
2280	29.06	3.99	
2340	29.09	3.99	
2400	29.07	3.99	
2460	29.06	3.98	
2520	29.04	3.96	
2580	29.01	3.93	
2640	28.99	3.91	
2700	29.00	3.92	
2760	28.99	3.91	
2820	29.00	3.92	
2880	29.02	3.94	
3000	29.06	3.98	
3120	29.10	4.02	
3240	29.14	4.06	
3360	29.18	4.10	
3480	29.24	4.16	
3600	29.27	4.19	
3720	29.24	4.16	
3840	29.06	3.98	
3960	29.24	4.16	
4080	29.26	4.18	
4200	29.25	4.17	
4320	29.24	4.16	

Table 19 pumping test data and its correction for well ID PHG1

<b>Well ID:</b> PHG2		<b>Depth:</b> 108.00m		
<b>Location:</b> 0567802E, 1337972mN, 1482m				
<b>SWL:</b> 18.61m		<b>Pump position:</b> 84m		
<b>Reference:</b> 0.48m		<b>Date:</b> 30/05/09		
<b>CONSTANT DISCHRG RATE TEST</b>				
<b>Q(l/sec): 45.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confined correction</b>	<b>correct drawdown</b>
0	18.61	0.00		0
0.5	26.24	7.63	7.21	5.0376514
1	27.05	8.44	7.93	5.538349
1.5	27.85	9.24	8.63	6.0264407
2	28.20	9.59	8.93	6.2379733
2.5	28.48	9.87	9.17	6.4063194
3	28.68	10.07	9.35	6.5260878
3.5	28.83	10.22	9.47	6.6156523
4	29.04	10.43	9.65	6.7406655
4.5	29.11	10.50	9.71	6.7822388
5	29.16	10.55	9.75	6.811904
6	29.39	10.78	9.95	6.9480431
7	29.55	10.94	10.09	7.0424373
8	29.64	11.03	10.16	7.0954218
9	29.75	11.14	10.25	7.1600709
10	29.85	11.24	10.34	7.2187381
12	29.97	11.36	10.44	7.289007
14	30.10	11.49	10.55	7.3649696
16	30.18	11.57	10.61	7.411632
18	30.26	11.65	10.68	7.4582306
20	30.31	11.70	10.72	7.4873222
25	30.42	11.81	10.81	7.5512361
30	30.53	11.92	10.91	7.6150293
35	30.61	12.00	10.97	7.6613486
40	30.73	12.12	11.07	7.7307077
45	30.83	12.22	11.15	7.7883973
50	30.92	12.31	11.23	7.8402326

55	31.00	12.39	11.29	7.8862406
60	31.05	12.44	11.33	7.9149632
70	31.10	12.49	11.38	7.9436608
80	31.15	12.54	11.42	7.9723335
90	31.21	12.60	11.47	8.0067078
100	31.26	12.65	11.51	8.0353256
110	31.36	12.75	11.59	8.0924865
120	31.48	12.87	11.69	8.1609478
140	31.55	12.94	11.74	8.2008172
160	31.62	13.01	11.80	8.2406378
180	31.72	13.11	11.88	8.2974395
210	31.77	13.16	11.92	8.325803
240	31.81	13.20	11.96	8.3484758
270	31.86	13.25	12.00	8.3767943
300	31.92	13.31	12.04	8.4107437
330	31.97	13.36	12.09	8.4390074
360	32.02	13.41	12.13	8.4672461
420	32.02	13.41	12.13	8.4672461
480	32.07	13.46	12.17	8.4954599
540	32.20	13.59	12.27	8.5686991
600	32.21	13.60	12.28	8.5743259
660	32.23	13.62	12.29	8.5855766
720	32.24	13.63	12.30	8.5912004
780	32.25	13.64	12.31	8.5968232
840	32.25	13.64	12.31	8.5968232
900	32.25	13.64	12.31	8.5968232
960	32.26	13.65	12.32	8.602445
1020	32.28	13.67	12.34	8.6136856
1080	32.28	13.67	12.34	8.6136856
1140	32.29	13.68	12.34	8.6193044
1200	32.30	13.69	12.35	8.6249223
1260	32.30	13.69	12.35	8.6249223
1320	32.31	13.70	12.36	8.6305391
1380	32.29	13.68	12.34	8.6193044
1440	32.28	13.67	12.34	8.6136856
1500	32.27	13.66	12.33	8.6080658
1560	32.28	13.67	12.34	8.6136856
1620	32.29	13.68	12.34	8.6193044
1680	32.30	13.69	12.35	8.6249223
1740	32.30	13.69	12.35	8.6249223
1800	32.31	13.70	12.36	8.6305391
1860	32.32	13.71	12.37	8.6361549
1920	32.33	13.72	12.38	8.6417698
1980	32.33	13.72	12.38	8.6417698
2040	32.34	13.73	12.38	8.6473836

2100	32.34	13.73	12.38	8.6473836
2160	32.35	13.74	12.39	8.6529964
2220	32.35	13.74	12.39	8.6529964
2280	32.37	13.76	12.41	8.6642191
2340	32.39	13.78	12.42	8.6754378
2400	32.40	13.79	12.43	8.6810456
2460	32.42	13.81	12.45	8.6922583
2520	32.33	13.72	12.38	8.6417698
2580	32.28	13.67	12.34	8.6136856
2640	32.29	13.68	12.34	8.6193044
2700	32.30	13.69	12.35	8.6249223
2760	32.28	13.67	12.34	8.6136856
2820	32.26	13.65	12.32	8.602445
2880	32.23	13.62	12.29	8.5855766
3000	32.17	13.56	12.25	8.5518128
3120	32.04	13.43	12.14	8.4785346
3240	32.06	13.45	12.16	8.4898192
3360	34.07	15.46	13.75	9.6035623
3480	32.08	13.47	12.17	8.5010997
3600	32.09	13.48	12.18	8.5067385
3720	32.11	13.50	12.20	8.518013
3840	32.09	13.48	12.18	8.5067385
3960	32.12	13.51	12.21	8.5236488
4080	32.10	13.49	12.19	8.5123763
4200	32.11	13.50	12.20	8.518013
4320	32.09	13.48	12.18	8.5067385

Table 20 pumping test data and its correction for well ID PHG2

<b>Well ID:</b> PHG3		<b>Depth:</b> 156.00m		
<b>Location:</b> 0568348E, 1337980mN, 1470m				
<b>SWL:</b> 17.15m		<b>Pump position:</b> 72m		
<b>Reference:</b> 0.52m		<b>Date:</b> 04/06/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 50.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>cn confind correction</b>	<b>sc</b>
0	17.15	0.00		
0.5	20.39	3.24	3.19	2.42
1	20.75	3.60	3.54	2.69
1.5	20.96	3.81	3.74	2.84
2.5	21.20	4.05	3.97	3.02
3	21.35	4.20	4.12	3.13
3.5	21.46	4.31	4.22	3.21
4	21.52	4.37	4.28	3.25
4.5	21.61	4.46	4.36	3.32
5	21.64	4.49	4.39	3.34
6	21.76	4.61	4.51	3.43
7	21.91	4.76	4.65	3.53
8	21.99	4.84	4.73	3.59
10	22.13	4.98	4.86	3.69
12	22.24	5.09	4.97	3.77
14	22.35	5.20	5.07	3.85
16	22.46	5.31	5.17	3.93
18	22.55	5.40	5.26	4.00
20	22.65	5.50	5.35	4.07
25	22.76	5.61	5.46	4.15
30	22.91	5.76	5.60	4.26
35	23.07	5.92	5.75	4.37
40	23.13	5.98	5.81	4.41
45	23.26	6.11	5.93	4.51
50	23.30	6.15	5.97	4.54
55	23.37	6.22	6.03	4.59
60	23.42	6.27	6.08	4.62
70	23.55	6.40	6.20	4.71

80	23.64	6.49	6.29	4.78
90	23.78	6.63	6.42	4.88
100	23.82	6.67	6.46	4.91
110	23.90	6.75	6.53	4.96
120	23.98	6.83	6.61	5.02
140	24.09	6.94	6.71	5.10
160	24.19	7.04	6.80	5.17
180	24.26	7.11	6.87	5.22
210	24.33	7.18	6.93	5.27
240	24.39	7.24	6.99	5.31
270	24.45	7.30	7.04	5.35
300	24.51	7.36	7.10	5.40
330	24.58	7.43	7.16	5.45
360	24.63	7.48	7.21	5.48
420	24.72	7.57	7.29	5.54
480	24.81	7.66	7.38	5.61
540	24.92	7.77	7.48	5.68
600	25.00	7.85	7.55	5.74
660	25.08	7.93	7.63	5.80
720	25.14	7.99	7.68	5.84
780	25.17	8.02	7.71	5.86
840	25.25	8.10	7.78	5.92
900	25.25	8.10	7.78	5.92
960	25.26	8.11	7.79	5.92
1020	25.30	8.15	7.83	5.95
1080	25.34	8.19	7.87	5.98
1140	25.34	8.19	7.87	5.98
1200	25.36	8.21	7.89	5.99
1260	25.37	8.22	7.90	6.00
1320	25.38	8.23	7.90	6.01
1380	25.40	8.25	7.92	6.02
1440	25.43	8.28	7.95	6.04
1500	25.45	8.30	7.97	6.06
1560	25.46	8.31	7.98	6.06
1620	25.47	8.32	7.99	6.07
1680	25.49	8.34	8.01	6.08
1740	25.50	8.35	8.01	6.09
1800	25.52	8.37	8.03	6.11
1860	25.53	8.38	8.04	6.11
1920	25.55	8.40	8.06	6.13
1980	25.57	8.42	8.08	6.14

2040	25.59	8.44	8.10	6.15
2100	25.61	8.46	8.12	6.17
2160	25.63	8.48	8.13	6.18
2220	25.64	8.49	8.14	6.19
2280	25.67	8.52	8.17	6.21
2340	25.68	8.53	8.18	6.22
2400	25.68	8.53	8.18	6.22
2460	25.69	8.54	8.19	6.22
2520	25.69	8.54	8.19	6.22
2580	25.66	8.51	8.16	6.20
2640	25.67	8.52	8.17	6.21
2700	25.66	8.51	8.16	6.20
2760	25.68	8.53	8.18	6.22
2820	25.69	8.54	8.19	6.22
2880	25.70	8.55	8.20	6.23
3000	25.73	8.58	8.23	6.25
3120	25.74	8.59	8.24	6.26
3240	25.75	8.60	8.24	6.27
3360	25.77	8.62	8.26	6.28
3480	25.79	8.64	8.28	6.29
3600	25.81	8.66	8.30	6.31
3720	25.85	8.70	8.34	6.34
3840	25.87	8.72	8.35	6.35
3960	25.87	8.72	8.35	6.35
4080	25.88	8.73	8.36	6.36
4200	25.89	8.74	8.37	6.36
4320	25.89	8.74	8.37	6.36

Table 21 pumping test data and its correction for well ID PHG3

<b>Well ID:</b> PHG4		<b>Depth:</b> 116.00m		
<b>Location:</b> 0566854E, 1339249mN, 1507m				
<b>SWL:</b> 29.30m		<b>Pump position:</b> 72m		
<b>Reference:</b> 0.63m		<b>Date:</b> 22/05/09		
<b>CONSTANT DISCHARGE RATE TEST</b>				
<b>Q(l/sec): 45.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>un confind correctio n</b>	<b>correct drawdow n</b>
0	29.30	0.00		
0.5	33.88	4.58	4.41	3.28
1	34.36	5.06	4.85	3.61
1.5	34.55	5.25	5.03	3.74
2	34.68	5.38	5.15	3.82
2.5	34.77	5.47	5.23	3.89
3	34.84	5.54	5.29	3.93
3.5	34.92	5.62	5.37	3.99
4	34.98	5.68	5.42	4.03
4.5	35.02	5.72	5.46	4.05
5	35.07	5.77	5.50	4.09
6	35.12	5.82	5.55	4.12
7	35.20	5.90	5.62	4.18
8	35.24	5.94	5.66	4.20
9	35.29	5.99	5.70	4.24
10	35.32	6.02	5.73	4.26
12	35.35	6.05	5.75	4.28
14	35.37	6.07	5.77	4.29
16	35.39	6.09	5.79	4.30
18	35.43	6.13	5.83	4.33
20	35.45	6.15	5.84	4.33
25	35.50	6.20	5.89	4.38
30	35.53	6.23	5.92	4.40
35	35.56	6.26	5.94	4.42
40	35.59	6.29	5.97	4.44
45	35.62	6.32	6.00	4.46
50	35.65	6.35	6.02	4.48
55	35.69	6.39	6.06	4.50

60	35.72	6.42	6.09	4.52
70	35.74	6.44	6.11	4.54
80	35.76	6.46	6.12	4.55
90	35.77	6.47	6.13	4.56
100	35.78	6.48	6.14	4.56
110	35.80	6.50	6.16	4.58
120	35.81	6.51	6.17	4.58
140	35.85	6.55	6.20	4.61
160	35.88	6.58	6.23	4.63
180	35.92	6.62	6.27	4.66
210	35.96	6.66	6.30	4.68
240	35.01	5.71	5.45	4.69
270	36.05	6.75	6.38	4.74
300	36.08	6.78	6.41	4.76
330	36.11	6.81	6.44	4.78
360	36.17	6.87	6.49	4.82
420	36.19	6.89	6.51	4.84
480	36.20	6.90	6.52	4.84
540	36.22	6.92	6.53	4.86
600	36.23	6.93	6.54	4.86
660	36.25	6.95	6.56	4.88
720	36.28	6.98	6.59	4.89
780	36.30	7.00	6.60	4.91
840	36.33	7.03	6.63	4.93
900	36.35	7.05	6.65	4.94
960	36.37	7.07	6.67	4.95
1020	36.38	7.08	6.68	4.96
1080	36.39	7.09	6.68	4.97
1140	36.40	7.10	6.69	4.97
1200	36.40	7.10	6.69	4.97
1260	36.41	7.11	6.70	4.98
1320	36.44	7.14	6.73	5.00
1380	36.45	7.15	6.74	5.01
1440	36.46	7.16	6.75	5.01
1500	36.47	7.17	6.76	5.02
1560	36.48	7.18	6.76	5.03
1620	36.49	7.19	6.77	5.03
1680	36.49	7.19	6.77	5.03
1740	36.50	7.20	6.78	5.04
1800	36.50	7.20	6.78	5.04
1860	36.50	7.20	6.78	5.04

1920	36.51	7.21	6.79	5.05
1980	36.52	7.22	6.80	5.05
2040	36.53	7.23	6.81	5.06
2100	36.51	7.21	6.79	5.05
2160	36.51	7.21	6.79	5.05
2220	36.52	7.22	6.80	5.05
2280	36.53	7.23	6.81	5.06
2340	36.53	7.23	6.81	5.06
2400	36.54	7.24	6.82	5.07
2460	36.54	7.24	6.82	5.07
2520	36.55	7.25	6.83	5.07
2580	36.56	7.26	6.83	5.08
2640	36.57	7.27	6.84	5.09
2700	36.57	7.27	6.84	5.09
2760	36.57	7.27	6.84	5.09
2820	36.58	7.28	6.85	5.09
2880	36.58	7.28	6.85	5.09
3000	36.58	7.28	6.85	5.09
3120	36.58	7.28	6.85	5.09
3240	36.58	7.28	6.85	5.09
3360	36.58	7.28	6.85	5.09
3480	36.59	7.29	6.86	5.10
3600	36.59	7.29	6.86	5.10
3720	36.60	7.30	6.87	5.11
3840	36.61	7.31	6.88	5.11
3960	36.62	7.32	6.89	5.12
4080	36.63	7.33	6.90	5.12
4200	36.64	7.34	6.91	5.13
4320	36.65	7.35	6.91	5.14

Table 22 pumping test data and its correction for well ID PHG4

**Well ID:** TWJ2      **Depth:** 121.00m  
**Location:** 0573465E, 1355068mN, 1398m  
**SWL:** 25.00m      **Pump position:** 105m  
**Reference:** 1.05m      **Date:** 13/05/08

**CONSTANT DISCHARGE RATE TEST**  
**Q(l/sec): 15.00**

Time (min)	Water level (m)	Draw down (m)	correct draw down
0	25.00	0.00	0.00
0.5	37.70	12.70	10.31
1	39.69	14.69	11.93
1.5	40.85	15.85	12.87
2	41.55	16.55	13.44
2.5	42.15	17.15	13.93
3	42.75	17.75	14.41
3.5	43.55	18.55	15.06
4	44.10	19.10	15.51
4.5	44.35	19.35	15.71
5	44.90	19.90	16.16
6	45.65	20.65	16.77
7	46.04	21.04	17.08
8	46.09	21.09	17.13
9	47.60	22.60	18.35
10	48.25	23.25	18.88
12	49.10	24.10	19.57
14	49.83	24.83	20.16
16	50.50	25.50	20.71
18	51.18	26.18	21.26
20	51.80	26.80	21.76
25	52.92	27.92	22.67
30	53.96	28.96	23.52
35	54.78	29.78	24.18
40	55.49	30.49	24.76
45	56.08	31.08	25.24
50	56.64	31.64	25.69
55	57.19	32.19	26.14
60	57.74	32.74	26.58
70	58.62	33.62	27.30
80	59.43	34.43	27.96
90	60.10	35.10	28.50
100	60.70	35.70	28.99
110	61.35	36.35	29.52

120	61.80	36.80	29.88
135	62.55	37.55	30.49
150	63.12	38.12	30.95
165	63.75	38.75	31.47
180	64.30	39.30	31.91
195	64.75	39.75	32.28
210	65.15	40.15	32.60
225	65.75	40.75	33.09
240	66.17	41.17	33.43
270	66.89	41.89	34.01
300	67.47	42.47	34.49
330	68.22	43.22	35.09
360	68.80	43.80	35.57
420	69.71	44.71	36.30
480	70.38	45.38	36.85
540	71.06	46.06	37.40
600	71.54	46.54	37.79
660	71.92	46.92	38.10
720	72.30	47.30	38.41
780	72.64	47.64	38.68
840	72.80	47.80	38.81
900	73.13	48.13	39.08
960	73.35	48.35	39.26
1020	73.50	48.50	39.38
1080	73.65	48.65	39.50
1140	73.86	48.86	39.67
1200	74.00	49.00	39.79
1260	74.14	49.14	39.90
1320	74.24	49.24	39.98
1380	74.38	49.38	40.10
1440	74.55	49.55	40.23
1500	74.65	49.65	40.32
1560	74.71	49.71	40.36
1620	75.00	50.00	40.60
1680	75.16	50.16	40.73
1740	75.12	50.12	40.70
1800	75.20	50.20	40.76
1860	75.24	50.24	40.79
1920	75.30	50.30	40.84
1980	75.44	50.44	40.96
2040	75.71	50.71	41.18
2100	75.88	50.88	41.31
2160	75.94	50.94	41.36
2220	76.06	51.06	41.46
2280	76.14	51.14	41.53

2340	76.20	51.20	41.57
2400	76.35	51.35	41.70
2460	76.44	51.44	41.77
2520	76.50	51.50	41.82
2580	76.61	51.61	41.91
2640	76.75	51.75	42.02
2700	76.79	51.79	42.05
2760	76.92	51.92	42.16
2820	76.95	51.95	42.18
2880	77.09	52.09	42.30
3000	77.14	52.14	42.34
3120	77.15	52.15	42.35
3240	77.30	52.30	42.47
3360	77.31	52.31	42.48
3480	77.42	52.42	42.57
3600	77.47	52.47	42.61
3720	77.57	52.57	42.69
3840	77.57	52.57	42.69
3960	77.62	52.62	42.73
4080	77.65	52.65	42.75
4200	77.73	52.73	42.82
4320	77.74	52.74	42.82
4440	77.75	52.75	42.83
4560	77.76	52.76	42.84
4680	77.81	52.81	42.88

Table 23 pumping test data and its correction for well ID TWJ2

<b>Well ID:</b> TWJ3		<b>Depth:</b> 202.00m	
<b>Location:</b> 0569491E, 1357769mN, 1428m			
<b>SWL:</b> 17.49m		<b>Pump position:</b> 75m	
<b>Reference:</b> 0.90m		<b>Date:</b> 25/06/08	
<b>CONSTANT DISCHARGE RATE TEST</b>			
<b>Q(l/sec): 60.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>Remark</b>
0	17.49	0.00	0
0.5	21.88	4.39	4.3
1	22.20	4.71	4.71
1.5	22.55	5.06	5.06
2	22.79	5.30	5.3
2.5	22.93	5.44	5.44

3	23.08	5.59	5.59
3.5	23.22	5.73	5.73
4	23.32	5.83	5.83
4.5	23.42	5.93	5.93
5	23.52	6.03	6.03
6	23.67	6.18	6.18
7	23.81	6.32	6.32
8	23.90	6.41	6.41
9	23.98	6.49	6.49
10	24.07	6.58	6.58
11	24.17	6.68	6.68
12	24.29	6.80	6.8
14	24.39	6.90	6.9
16	24.50	7.01	7.01
18	24.55	7.06	7.06
20	24.70	7.21	7.21
25	24.86	7.37	7.37
30	24.95	7.46	7.46
35	25.02	7.53	7.53
40	25.10	7.61	7.61
45	25.19	7.70	7.7
50	25.27	7.78	7.78
55	25.33	7.84	7.84
60	25.43	7.94	7.94
70	25.55	8.06	8.06
80	25.65	8.16	8.16
90	25.74	8.25	8.25
100	25.81	8.32	8.32
120	25.90	8.41	8.41
135	26.00	8.51	8.51
150	26.10	8.61	8.61
165	26.18	8.69	8.69
180	26.27	8.78	8.78
195	26.35	8.86	8.86
210	26.41	8.92	8.92
225	26.48	8.99	8.99
240	26.52	9.03	9.03
270	26.64	9.15	9.15
300	26.72	9.23	9.23
330	26.85	9.36	9.36
360	26.95	9.46	9.46
420	27.12	9.63	9.63
480	27.26	9.77	9.77
540	27.40	9.91	9.91
600	27.54	10.05	10.05

660	27.66	10.17	10.17
720	27.76	10.27	10.27
780	27.85	10.36	10.36
840	27.93	10.44	10.44
900	28.02	10.53	10.53
960	28.10	10.61	10.61
1020	28.10	10.61	10.61
1080	28.27	10.78	10.78
1140	28.34	10.85	10.85
1200	28.38	10.89	10.89
1260	28.43	10.94	10.94
1320	28.47	10.98	10.98
1380	28.52	11.03	11.03
1440	28.58	11.09	11.09
1500	28.63	11.14	11.14
1560	28.72	11.23	11.23
1620	28.77	11.28	11.28
1680	28.82	11.33	11.33
1740	28.85	11.36	11.36
1800	28.92	11.43	11.43
1860	28.98	11.49	11.49
1920	29.01	11.52	11.52
1980	29.06	11.57	11.57
2040	29.17	11.68	11.68
2100	29.14	11.65	11.65
2160	29.18	11.69	11.69
2220	29.24	11.75	11.75
2280	29.28	11.79	11.79
2340	29.35	11.86	11.86
2400	29.40	11.91	11.91
2460	29.43	11.94	11.94
2520	29.46	11.97	11.97
2580	29.50	12.01	12.01
2640	29.54	12.05	12.05
2700	29.55	12.06	12.06
2760	29.55	12.06	12.07
2820	29.57	12.08	12.08
2880	29.59	12.10	12.1
2940	29.65	12.16	12.16
3000	29.68	12.19	12.19
3060	29.71	12.22	12.22
3120	29.72	12.23	12.23
3180	29.75	12.26	12.26
3240	29.77	12.28	12.28
3300	29.78	12.29	12.29

3360	29.80	12.31	12.31
3420	29.82	12.33	12.33
3480	29.88	12.39	12.39
3540	29.91	12.42	12.42
3600	29.92	12.43	12.43
3660	29.98	12.49	12.49
3720	30.00	12.51	12.51
3780	30.03	12.54	12.54
3840	30.05	12.56	12.56
3900	30.08	12.59	12.59
3960	30.09	12.60	12.6
4120	30.09	12.60	12.6
4180	30.10	12.61	12.61
4240	30.10	12.61	12.61
4300	30.11	12.62	12.62
4360	30.12	12.63	12.63

Table 24 pumping test data and its correction for well ID TWJ3

<b>Well ID:</b> TWJ4		<b>Depth:</b> 198.50m	
<b>Location:</b> 0568854E, 1352624mN, 1425m			
<b>SWL:</b> 16.38m		<b>Pump position:</b> 72m	
<b>Reference:</b> 0.84m		<b>Date:</b> 06/06/08	
<b>CONSTANT DISCHRG RATE TEST</b>			
<b>Q(l/sec): 60.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>Correct drawdown</b>
0	16.38	0.00	0.00
0.5	21.85	5.47	4.11
1	22.93	6.55	4.93
1.5	23.55	7.17	5.39
2	23.80	7.42	5.58
2.5	24.05	7.67	5.77
3	24.34	7.96	5.99
3.5	24.49	8.11	6.10
4	24.76	8.38	6.30
4.5	24.92	8.54	6.42
5	25.07	8.69	6.53
6	25.34	8.96	6.74
7	25.64	9.26	6.96
8	25.85	9.47	7.12
9	26.09	9.71	7.30
10	26.25	9.87	7.42

12	26.70	10.32	7.76
14	26.99	10.61	7.98
16	27.15	10.77	8.10
18	27.50	11.12	8.36
20	27.73	11.35	8.54
25	28.25	11.87	8.93
30	28.72	12.34	9.28
35	29.15	12.77	9.60
40	29.48	13.10	9.85
45	29.71	13.33	10.02
50	30.18	13.80	10.38
55	30.40	14.02	10.54
60	30.66	14.28	10.74
70	31.02	14.64	11.01
80	31.86	15.48	11.64
90	32.03	15.65	11.77
100	32.30	15.92	11.97
120	32.55	16.17	12.16
135	32.85	16.47	12.39
150	33.10	16.72	12.57
165	33.40	17.02	12.80
180	33.70	17.32	13.02
195	33.86	17.48	13.14
210	34.05	17.67	13.29
225	34.15	17.77	13.36
240	34.30	17.92	13.48
270	34.65	18.27	13.74
300	34.88	18.50	13.91
330	35.15	18.77	14.12
360	35.25	18.87	14.19
420	35.64	19.26	14.48
480	35.95	19.57	14.72
540	36.21	19.83	14.91
600	36.45	20.07	15.09
660	36.68	20.30	15.27
720	36.87	20.49	15.41
780	37.03	20.65	15.53
840	37.19	20.81	15.65
900	37.35	20.97	15.77
960	37.51	21.13	15.89
1020	37.64	21.26	15.99
1080	37.75	21.37	16.07
1140	37.88	21.50	16.17
1200	37.94	21.56	16.21
1260	38.03	21.65	16.28

1320	38.12	21.74	16.35
1380	38.25	21.87	16.45
1440	38.31	21.93	16.49
1500	38.34	21.96	16.51
1560	38.38	22.00	16.54
1620	38.41	22.03	16.57
1680	38.48	22.10	16.62
1740	38.60	22.22	16.71
1800	38.65	22.27	16.75
1860	38.70	22.32	16.78
1920	38.80	22.42	16.86
1980	38.85	22.47	16.90
2040	38.91	22.53	16.94
2100	38.98	22.60	17.00
2160	39.04	22.66	17.04
2220	39.08	22.70	17.07
2280	39.13	22.75	17.11
2340	39.17	22.79	17.14
2400	39.25	22.87	17.20
2460	39.27	22.89	17.21
2520	39.32	22.94	17.25
2580	39.35	22.97	17.27
2640	39.37	22.99	17.29
2700	39.40	23.02	17.31
2760	39.45	23.07	17.35
2820	39.47	23.09	17.36
2880	39.54	23.16	17.42
2940	39.55	23.17	17.42
3000	39.57	23.19	17.44
3060	39.60	23.22	17.46
3120	39.65	23.27	17.50
3180	39.74	23.36	17.57
3240	39.77	23.39	17.59
3300	39.79	23.41	17.60
3360	39.82	23.44	17.63
3420	39.88	23.50	17.67
3480	39.90	23.52	17.69
3540	39.91	23.53	17.69
3600	39.94	23.56	17.72
3660	39.96	23.58	17.73
3720	39.99	23.61	17.75
3780	40.03	23.65	17.78
3840	40.05	23.67	17.80
3900	40.06	23.68	17.81
3960	40.09	23.71	17.83

4020	40.13	23.75	17.86
4080	40.16	23.78	17.88
4140	40.17	23.79	17.89
4200	40.18	23.80	17.90
4260	40.19	23.81	17.91
4320	40.18	23.80	17.90
4380	40.15	23.77	17.88
4440	40.15	23.77	17.88
4500	40.15	23.77	17.88
4560	40.16	23.78	17.88
4620	40.18	23.80	17.90
4680	40.23	23.85	17.94
4740	40.25	23.87	17.95
4800	40.33	23.95	18.01
4860	40.33	23.95	18.01
4920	40.33	23.95	18.01
4980	40.35	23.97	18.03
5040	40.38	24.00	18.05
5100	40.40	24.02	18.06
5160	40.42	24.04	18.08
5220	40.45	24.07	18.10
5280	40.46	24.08	18.11
5340	40.47	24.09	18.12
5400	40.50	24.12	18.14
5460	40.50	24.12	18.14
5520	40.52	24.14	18.15
5580	40.52	24.14	18.15
5640	40.53	24.15	18.16
5700	40.53	24.15	18.16
5760	40.49	24.11	18.13
5820	40.49	24.11	18.13

Table 24 pumping test data and its correction for well ID TWJ2

# APPENDIX – E

## Recovery test data and its correction

<b>Well ID:</b> TK1		<b>Depth:</b> 164.00m			
<b>Location:</b> 0570275E, 1355009mN, 1418m					
<b>SWL:</b> 21.08m		<b>Pump position:</b> 78m			
<b>Reference:</b> 1.45m		<b>Date:</b> 07/06/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 75.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>un confind sc</b>	<b>correcte d s</b>	<b>t"/t</b>
0	61.48	40.40	25.56	22.89	
0.5	34.50	13.42	11.78	10.55	1560.00
1	33.57	12.49	11.07	9.91	780.00
1.5	33.39	12.31	10.93	9.79	520.00
2	32.78	11.70	10.46	9.36	390.00
2.5	32.56	11.48	10.28	9.21	312.00
3	32.36	11.28	10.12	9.07	260.00
3.5	32.23	11.15	10.02	8.97	222.86
4	32.04	10.96	9.87	8.84	195.00
4.5	31.83	10.75	9.70	8.69	173.33
5	31.67	10.59	9.57	8.57	156.00
6	31.23	10.15	9.21	8.25	130.00
7	30.95	9.87	8.98	8.05	111.43
8	30.73	9.65	8.80	7.88	97.50
9	30.40	9.32	8.53	7.64	86.67
10	30.26	9.18	8.41	7.53	78.00
12	29.87	8.79	8.09	7.24	65.00
14	29.63	8.55	7.89	7.06	55.71
16	29.42	8.34	7.71	6.90	48.75
18	29.11	8.03	7.44	6.67	43.33
20	28.90	7.82	7.26	6.50	39.00
25	28.50	7.42	6.92	6.20	31.20
30	28.17	7.09	6.63	5.94	26.00
35	27.87	6.79	6.37	5.71	22.29
40	27.66	6.58	6.19	5.54	19.50
45	27.44	6.36	5.99	5.37	17.33

50	27.27	6.19	5.84	5.23	15.60
55	27.09	6.01	5.68	5.09	14.18
60	26.89	5.81	5.50	4.93	13.00
70	26.68	5.60	5.31	4.76	11.14
80	26.44	5.36	5.10	4.57	9.75
90	26.23	5.15	4.91	4.40	8.67
100	26.04	4.96	4.74	4.24	7.80
110	25.58	4.50	4.32	3.86	7.09
120	25.75	4.67	4.47	4.00	6.50
140	25.49	4.41	4.23	3.79	5.57
160	25.25	4.17	4.01	3.59	4.88
180	25.07	3.99	3.85	3.44	4.33
210	24.80	3.72	3.59	3.22	3.71
240	24.59	3.51	3.40	3.04	3.25
270	24.38	3.30	3.20	2.87	2.89
300	24.24	3.16	3.07	2.75	2.60
330	24.08	3.00	2.92	2.61	2.36
360	24.00	2.92	2.84	2.55	2.17
420	23.40	2.32	2.27	2.03	1.86
480	23.31	2.23	2.18	1.96	1.63
540	23.16	2.08	2.04	1.83	1.44
600	23.16	2.08	2.04	1.83	1.30
660	23.01	1.93	1.90	1.70	1.18
720	22.87	1.79	1.76	1.58	1.08
780	22.76	1.68	1.65	1.48	1.00

Table 25 Recovery test data and its correction for well ID TK1

<b>Well ID: PK1</b>		<b>Depth:</b> 134.00m			
<b>Location:</b> 0568062E, 1340937mN, 1492m					
<b>SWL:</b> 26.44m		<b>Pump position:</b> 78m			
<b>Reference:</b> 0.82m		<b>Date:</b> 28/06/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 55.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>unconfined sc</b>	<b>sc</b>	<b>t'/t</b>
0	62.10	35.66	24.31	17.70	#DIV/0!
0.5	47.60	21.16	17.16	12.50	14400.00
1	42.10	15.66	13.47	9.81	7200.00
1.5	40.45	14.01	12.26	8.93	4800.00

2	39.10	12.66	11.23	8.18	3600.00
2.5	38.30	11.86	10.60	7.72	2880.00
3	37.70	11.26	10.13	7.38	2400.00
3.5	37.16	10.72	9.69	7.06	2057.14
4	36.70	10.26	9.32	6.79	1800.00
4.5	36.30	9.86	8.99	6.55	1600.00
5	36.10	9.66	8.83	6.43	1440.00
6	35.58	9.14	8.39	6.11	1200.00
7	35.22	8.78	8.09	5.89	1028.57
8	34.88	8.44	7.80	5.68	900.00
9	34.63	8.19	7.59	5.53	800.00
10	34.42	7.98	7.41	5.40	720.00
12	33.93	7.49	6.99	5.09	600.00
14	33.70	7.26	6.79	4.95	514.29
16	33.42	6.98	6.54	4.77	450.00
18	33.23	6.79	6.38	4.65	400.00
20	33.03	6.59	6.20	4.52	360.00
25	32.60	6.16	5.82	4.24	288.00
30	32.25	5.81	5.51	4.01	240.00
35	32.04	5.60	5.32	3.88	205.71
40	31.75	5.31	5.06	3.68	180.00
45	31.45	5.01	4.79	3.49	160.00
50	31.40	4.96	4.74	3.45	144.00
55	31.20	4.76	4.56	3.32	130.91
60	31.00	4.56	4.37	3.19	120.00
70	30.75	4.31	4.14	3.02	102.86
80	30.56	4.12	3.97	2.89	90.00
90	30.30	3.86	3.73	2.71	80.00
100	30.10	3.66	3.54	2.58	72.00
110	29.92	3.48	3.37	2.46	65.45
120	29.69	3.25	3.16	2.30	60.00
140	29.40	2.96	2.88	2.10	51.43
160	29.10	2.66	2.60	1.89	45.00
180	28.83	2.39	2.34	1.70	40.00
210	28.62	2.18	2.14	1.56	34.29
240	28.45	2.01	1.97	1.44	30.00
270	28.22	1.78	1.75	1.28	26.67
300	28.04	1.60	1.58	1.15	24.00
330	28.28	1.84	1.81	1.32	21.82
360	27.15	0.71	0.71	0.51	20.00
420	27.04	0.60	0.60	0.43	17.14
480	26.93	0.49	0.49	0.36	15.00
540	26.87	0.43	0.43	0.31	13.33
600	26.77	0.33	0.33	0.24	12.00

Table 26 Recovery test data and its correction for well ID PK1

<b>Well ID: PK2</b>		<b>Depth:</b> 137.00m			
<b>Location: 0568471E, 1341132mN, 1482m</b>					
<b>SWL: 24.31m</b>		<b>Pump position:</b> 84m			
<b>Reference: 0.75m</b>		<b>Date:</b> 06/05/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 80.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>un confined drawdown</b>	<b>sc for partial penetration</b>	<b>t/t'</b>
0	39.13	14.82	13.58611	5.611063476	
0.5	38.76	14.45	13.27695	5.483381278	2880.00
1	38.01	13.70	12.64556	5.222617022	1440.00
1.5	37.51	13.20	12.22112	5.047324045	960.00
2	36.89	12.58	11.69092	4.828349589	720.00
2.5	35.72	11.41	10.67861	4.410264352	576.00
3	34.27	9.96	9.402688	3.883309996	480.00
3.5	33.89	9.58	9.064402	3.743598128	411.43
4	33.14	8.83	8.391972	3.465884631	360.00
4.5	32.53	8.22	7.840402	3.238086128	320.00
5	32.10	7.79	7.449078	3.076469251	288.00
6	31.80	7.49	7.174831	2.963205161	240.00
7	31.69	7.38	7.07402	2.921570353	205.71
8	31.57	7.26	6.96389	2.876086524	180.00
9	31.50	7.19	6.899572	2.849523431	160.00
10	31.42	7.11	6.825999	2.819137768	144.00
12	31.30	6.99	6.715505	2.773503588	120.00
14	31.19	6.88	6.614076	2.731613555	102.86
16	31.05	6.74	6.484789	2.67821776	90.00
18	30.95	6.64	6.392306	2.64002222	80.00
20	30.85	6.54	6.29971	2.601780276	72.00
25	30.50	6.19	5.974741	2.467568038	57.60
30	30.36	6.05	5.844368	2.413723975	48.00
35	30.12	5.81	5.620359	2.321208262	41.14
40	29.96	5.65	5.47066	2.259382626	36.00
45	29.80	5.49	5.320674	2.197438195	32.00
50	29.63	5.32	5.160998	2.131492072	28.80

55	29.47	5.16	5.010418	2.069302625	26.18
60	29.35	5.04	4.897294	2.02258258	24.00
70	29.10	4.79	4.661101	1.925034532	20.57
80	28.90	4.59	4.47164	1.846787274	18.00
90	28.70	4.39	4.28173	1.768354397	16.00
100	28.55	4.24	4.139002	1.709407928	14.40
110	28.53	4.22	4.119953	1.70154051	13.09
120	28.52	4.21	4.110426	1.697606105	12.00
140	28.50	4.19	4.09137	1.689735903	10.29
160	27.72	3.41	3.344674	1.381350195	9.00
180	27.53	3.22	3.161751	1.305802982	8.00
210	27.30	2.99	2.939775	1.214126959	6.86
240	27.10	2.79	2.746269	1.134209139	6.00
270	26.90	2.59	2.552314	1.054105701	5.33
300	26.76	2.45	2.416278	0.997922851	4.80
330	26.63	2.32	2.289762	0.945671622	4.36
360	26.53	2.22	2.192312	0.905425004	4.00
420	26.33	2.02	1.997076	0.824792555	3.43
480	26.21	1.90	1.879719	0.776323989	3.00
540	26.05	1.74	1.722991	0.711595288	2.67
600	25.93	1.62	1.605256	0.662970802	2.40
660	25.82	1.51	1.49719	0.618339656	2.18
720	25.70	1.39	1.379146	0.569587094	2.00
780	25.60	1.29	1.280651	0.528908914	1.85
840	25.52	1.21	1.201775	0.496332959	1.71
900	25.45	1.14	1.132699	0.467804636	1.60
960	25.42	1.11	1.103078	0.455571251	1.50
1020	25.33	1.02	1.014155	0.418846038	1.41
1080	25.28	0.97	0.964714	0.398426901	1.33
1140	25.25	0.94	0.935036	0.386169849	1.26
1200	25.20	0.89	0.88555	0.36573215	1.20
1260	25.16	0.85	0.845941	0.349373638	1.14
1320	25.13	0.82	0.816222	0.337099881	1.09
1380	25.11	0.80	0.796404	0.328915056	1.04
1440	25.05	0.74	0.736924	0.304349445	1.00

Table 27 Recovery test data and its correction for well ID PK2

<b>Well ID:</b> PK3		<b>Depth:</b> 153.00m		
<b>Location:</b> 0568203E, 1350350mN, 1437m				
<b>SWL:</b> 31.11m		<b>Pump position:</b> 81m		
<b>Reference:</b> 0.66m		<b>Date:</b> 24/06/09		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Q(l/sec): 70.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>sc for partial penetration</b>	<b>t/t'</b>
0	37.33	6.22		
0.5	33.20	2.09	1.3167	720.00
1	33.18	2.07	1.3041	360.00
1.5	32.98	1.87	1.1781	240.00
2	32.88	1.77	1.1151	180.00
2.5	32.88	1.77	1.1151	144.00
3	32.80	1.69	1.0647	120.00
3.5	32.79	1.68	1.0584	102.86
4	32.72	1.61	1.0143	90.00
4.5	32.68	1.57	0.9891	80.00
5	32.66	1.55	0.9765	72.00
6	32.61	1.50	0.945	60.00
7	32.56	1.45	0.9135	51.43
8	32.55	1.44	0.9072	45.00
9	32.51	1.40	0.882	40.00
10	32.50	1.39	0.8757	36.00
12	32.46	1.35	0.8505	30.00
14	32.40	1.29	0.8127	25.71
16	32.35	1.24	0.7812	22.50
18	32.33	1.22	0.7686	20.00
20	32.29	1.18	0.7434	18.00
25	32.25	1.14	0.7182	14.40
30	32.24	1.13	0.7119	12.00
35	32.22	1.11	0.6993	10.29
40	32.13	1.02	0.6426	9.00
45	32.07	0.96	0.6048	8.00
50	32.00	0.89	0.5607	7.20
55	31.97	0.86	0.5418	6.55
60	31.93	0.82	0.5166	6.00
70	31.86	0.75	0.4725	5.14
80	31.86	0.75	0.4725	4.50
90	31.86	0.75	0.4725	4.00

100	31.82	0.71	0.4473	3.60
110	31.80	0.69	0.4347	3.27
120	31.78	0.67	0.4221	3.00
140	31.72	0.61	0.3843	2.57
160	31.69	0.58	0.3654	2.25
180	31.66	0.55	0.3465	2.00
210	31.62	0.51	0.3213	1.71
240	31.59	0.48	0.3024	1.50
270	31.59	0.48	0.3024	1.33
300	31.55	0.44	0.2772	1.20
330	31.53	0.42	0.2646	1.09
360	31.53	0.42	0.2646	1.00

Table 28 Recovery test data and its correction for well ID PK3

<b>Well ID: PK4</b>		<b>Depth:</b> 106.00m		
<b>Location:</b> 0567992E, 1352995mN, 1446m				
<b>SWL:</b> 9.72m		<b>Pump position:</b> 77m		
<b>Reference:</b> 0.58m		<b>Date:</b> 15/06/09		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Q(l/sec): 60.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>corrected drawdown</b>	<b>t/t'</b>
0	61.20	51.48	38.25	
0.5	31.80	22.08	16.41	14400.00
1	30.30	20.58	15.29	7200.00
1.5	28.30	18.58	13.81	4800.00
2	27.42	17.70	13.15	3600.00
2.5	26.76	17.04	12.66	2880.00
3	26.30	16.58	12.32	2400.00
3.5	25.76	16.04	11.92	2057.14
4	25.30	15.58	11.58	1800.00
4.5	24.93	15.21	11.30	1600.00
5	24.70	14.98	11.13	1440.00
6	24.20	14.48	10.76	1200.00
7	23.70	13.98	10.39	1028.57
8	23.30	13.58	10.09	900.00
9	22.90	13.18	9.79	800.00
10	22.56	12.84	9.54	720.00
12	22.20	12.48	9.27	600.00

14	21.50	11.78	8.75	514.29
16	21.05	11.33	8.42	450.00
18	20.64	10.92	8.11	400.00
20	20.30	10.58	7.86	360.00
25	19.42	9.70	7.21	288.00
30	18.94	9.22	6.85	240.00
35	18.47	8.75	6.50	205.71
40	18.00	8.28	6.15	180.00
45	17.40	7.68	5.71	160.00
50	17.31	7.59	5.64	144.00
55	16.97	7.25	5.39	130.91
60	16.72	7.00	5.20	120.00
70	16.25	6.53	4.85	102.86
80	15.88	6.16	4.58	90.00
90	15.60	5.88	4.37	80.00
100	15.28	5.56	4.13	72.00
110	15.08	5.36	3.98	65.45
120	14.83	5.11	3.80	60.00
140	14.47	4.75	3.53	51.43
160	14.10	4.38	3.25	45.00
180	13.79	4.07	3.02	40.00
210	13.52	3.80	2.82	34.29
240	13.25	3.53	2.62	30.00
270	12.99	3.27	2.43	26.67
300	12.78	3.06	2.27	24.00
330	12.80	3.08	2.29	21.82
360	12.48	2.76	2.05	20.00
420	12.00	2.28	1.69	17.14
480	11.80	2.08	1.55	15.00

Table 29 Recovery test data and its correction for well ID PK4

<b>Well ID:</b> PK5		<b>Depth:</b> 119.3.00m			
<b>Location:</b> 0568427E, 1351843mN, 1428m					
<b>SWL:</b> 18.20m		<b>Pump position:</b> 89m			
<b>Reference:</b> 1.12m		<b>Date:</b> 11/07/08			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 30.00</b>					

Time (min)	Water level(m )	RESIDUAL Draw Down(m)	un confin d sc	SC	t/t'
0	50.40	32.20	23.56	18.24	#DIV/0!
0.5	49.05	30.85	22.92	17.74	14400.00
1	47.70	29.50	22.25	17.22	7200.00
1.5	43.90	25.70	20.20	15.64	4800.00
2	37.90	19.70	16.47	12.75	3600.00
2.5	36.40	18.20	15.44	11.95	2880.00
3	35.30	17.10	14.66	11.35	2400.00
3.5	34.73	16.53	14.25	11.03	2057.14
4	33.70	15.50	13.50	10.45	1800.00
4.5	33.13	14.93	13.07	10.12	1600.00
5	32.50	14.30	12.60	9.75	1440.00
6	31.80	13.60	12.06	9.34	1200.00
7	31.04	12.84	11.47	8.88	1028.57
8	30.40	12.20	10.96	8.48	900.00
9	29.90	11.70	10.56	8.17	800.00
10	29.42	11.22	10.17	7.87	720.00
12	28.70	10.50	9.58	7.42	600.00
14	28.10	9.90	9.08	7.03	514.29
16	27.60	9.40	8.66	6.71	450.00
18	27.20	9.00	8.33	6.45	400.00
20	26.82	8.62	8.00	6.19	360.00
25	26.13	7.93	7.41	5.73	288.00
30	25.60	7.40	6.94	5.38	240.00
35	25.20	7.00	6.59	5.10	205.71
40	24.85	6.65	6.28	4.86	180.00
45	24.55	6.35	6.01	4.66	160.00
50	24.32	6.12	5.81	4.50	144.00
55	24.10	5.90	5.61	4.34	130.91
60	23.91	5.71	5.44	4.21	120.00
70	23.60	5.40	5.16	3.99	102.86
80	23.33	5.13	4.91	3.80	90.00
90	23.13	4.93	4.73	3.66	80.00

100	22.94	4.74	4.55	3.52	72.00
110	22.84	4.64	4.46	3.45	65.45
120	22.77	4.57	4.40	3.40	60.00
140	22.63	4.43	4.27	3.30	51.43
160	22.28	4.08	3.94	3.05	45.00
180	22.14	3.94	3.81	2.95	40.00
210	21.88	3.68	3.57	2.76	34.29
240	21.70	3.50	3.40	2.63	30.00
270	21.65	3.45	3.35	2.59	26.67
300	21.43	3.23	3.14	2.43	24.00
330	21.30	3.10	3.02	2.34	21.82
360	20.94	2.74	2.68	2.07	20.00
420	20.86	2.66	2.60	2.01	17.14
480	20.30	2.10	2.06	1.60	15.00
540	20.25	2.05	2.01	1.56	13.33
600	20.19	1.99	1.96	1.52	12.00
660	20.16	1.96	1.93	1.49	10.91
720	20.15	1.95	1.92	1.49	10.00
780	20.04	1.84	1.81	1.40	9.23
840	19.97	1.77	1.74	1.35	8.57
900	19.85	1.65	1.63	1.26	8.00
960	19.80	1.60	1.58	1.22	7.50
1020	19.70	1.50	1.48	1.15	7.06

Table 30 Recovery test data and its correction for well ID PK5

<b>Well ID:</b> PK-6		<b>Depth:</b> 145.00m			
<b>Location:</b> 0569299E, 1341882mN, 1480m					
<b>SWL:</b> 18.10m		<b>Pump position:</b> 72m			
<b>Reference:</b> 0.58m		<b>Date:</b> 19/05/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Draw down (m)</b>	<b>unconfined correction</b>	<b>correct drawdown</b>	<b>t/t'</b>
0	32.55	14.45			
0.5	26.55	8.45	7.98	7.12	14400.00
1	25.07	6.97	6.65	5.94	7200.00
1.5	24.14	6.04	5.80	5.18	4800.00

2	23.51	5.41	5.22	4.66	3600.00
2.5	22.99	4.89	4.73	4.22	2880.00
3	22.40	4.30	4.18	3.73	2400.00
3.5	22.26	4.16	4.05	3.61	2057.14
4	21.98	3.88	3.78	3.38	1800.00
4.5	21.22	3.12	3.06	2.73	1600.00
5	21.55	3.45	3.37	3.01	1440.00
6	21.20	3.10	3.04	2.71	1200.00
7	20.87	2.77	2.72	2.43	1028.57
8	20.66	2.56	2.52	2.25	900.00
9	20.46	2.36	2.32	2.07	800.00
10	20.30	2.20	2.17	1.94	720.00
12	20.07	1.97	1.94	1.74	600.00
14	19.90	1.80	1.78	1.59	514.29
16	19.73	1.63	1.61	1.44	450.00
18	19.60	1.50	1.49	1.33	400.00
20	19.53	1.43	1.42	1.26	360.00
25	19.36	1.26	1.25	1.12	288.00
30	19.21	1.11	1.10	0.98	240.00
35	19.14	1.04	1.03	0.92	205.71
40	19.08	0.98	0.97	0.87	180.00
45	19.00	0.90	0.89	0.80	160.00
50	18.92	0.82	0.82	0.73	144.00
55	18.91	0.81	0.81	0.72	130.91
60	18.90	0.80	0.80	0.71	120.00
70	18.85	0.75	0.75	0.67	102.86
80	18.80	0.70	0.70	0.62	90.00
90	18.75	0.65	0.65	0.58	80.00
100	18.71	0.61	0.61	0.54	72.00
110	18.67	0.57	0.57	0.51	65.45
120	18.63	0.53	0.53	0.47	60.00
140	18.60	0.50	0.50	0.44	51.43
160	18.57	0.47	0.47	0.42	45.00
180	18.54	0.44	0.44	0.39	40.00
210	18.50	0.40	0.40	0.36	34.29
240	18.49	0.39	0.39	0.35	30.00
270	18.48	0.38	0.38	0.34	26.67
300	18.46	0.36	0.36	0.32	24.00
330	18.44	0.34	0.34	0.30	21.82
360	18.41	0.31	0.31	0.28	20.00

Table 31 Recovery test data and its correction for well ID PK6

<b>Well ID:</b> PK-7		<b>Depth:</b> 183.00m			
<b>Location:</b> 0569882E, 1341651mN, 1479m					
<b>SWL:</b> 21.42m		<b>Pump position:</b> 78m			
<b>Reference:</b> 0.64m		<b>Date:</b> 29/06/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 40.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>un confind correction</b>	<b>correct drawdown</b>	t/t'
0	52.43	31.01			
0.5	35.40	13.98	12.73	7.72	14400.0 0
1	31.45	10.03	9.39	5.69	7200.00
1.5	29.48	8.06	7.64	4.64	4800.00
2	28.35	6.93	6.62	4.02	3600.00
2.5	27.49	6.07	5.83	3.54	2880.00
3	27.15	5.73	5.52	3.35	2400.00
3.5	26.87	5.45	5.26	3.19	2057.14
4	26.81	5.39	5.20	3.16	1800.00
4.5	26.51	5.09	4.92	2.99	1600.00
5	26.27	4.85	4.70	2.85	1440.00
6	25.96	4.54	4.41	2.67	1200.00
7	25.75	4.33	4.21	2.55	1028.57
8	25.56	4.14	4.03	2.44	900.00
9	25.48	4.06	3.95	2.40	800.00
10	25.35	3.93	3.83	2.32	720.00
12	25.14	3.72	3.63	2.20	600.00
14	24.86	3.44	3.36	2.04	514.29
16	24.77	3.35	3.28	1.99	450.00
18	24.60	3.18	3.12	1.89	400.00
20	24.53	3.11	3.05	1.85	360.00
25	24.36	2.94	2.88	1.75	288.00
30	24.22	2.80	2.75	1.67	240.00
35	24.09	2.67	2.62	1.59	205.71
40	24.00	2.58	2.54	1.54	180.00



Well ID: PK-8		Depth: 180.00m			
Location: 0569817E, 1341059mN, 1465m					
SWL: 18.66m		Pump position: 72m			
Reference: 0.68m		Date: 08/05/09			

<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 50.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>unconfined correction</b>	<b>correct drawdown</b>	<b>t/t'</b>
0	37.16	18.50	17.05	11.91	
0.5	31.50	12.84	12.14	8.48	14400.00
1	30.52	11.86	11.26	7.87	7200.00
1.5	30.14	11.48	10.92	7.63	4800.00
2	30.05	11.39	10.84	7.57	3600.00
2.5	29.25	10.59	10.11	7.06	2880.00
3	29.26	10.60	10.12	7.07	2400.00
3.5	29.54	10.88	10.38	7.25	2057.14
4	29.58	10.92	10.41	7.27	1800.00
4.5	29.55	10.89	10.39	7.25	1600.00
5	29.37	10.71	10.22	7.14	1440.00
6	29.24	10.84	10.34	7.22	1200.00
7	29.62	10.96	10.45	7.30	1028.57
8	28.97	10.31	9.86	6.88	900.00
9	28.88	10.22	9.78	6.83	800.00
10	28.75	10.09	9.66	6.74	720.00
12	28.54	9.88	9.47	6.61	600.00
14	28.38	9.72	9.32	6.51	514.29
16	28.22	9.56	9.17	6.41	450.00
18	28.10	9.44	9.06	6.33	400.00
20	27.97	9.31	8.94	6.24	360.00
25	27.60	8.94	8.60	6.01	288.00
30	27.33	8.67	8.35	5.83	240.00
35	27.09	8.43	8.13	5.68	205.71
40	26.86	8.20	7.92	5.53	180.00
45	26.62	7.96	7.69	5.37	160.00
50	26.40	7.74	7.49	5.23	144.00
55	25.90	7.24	7.02	4.90	130.91

60	25.72	7.06	6.85	4.78	120.00
70	25.46	6.80	6.60	4.61	102.86
80	25.21	6.55	6.37	4.45	90.00
90	24.90	6.24	6.08	4.24	80.00
100	24.75	6.09	5.93	4.14	72.00
110	24.26	5.60	5.47	3.82	65.45
120	23.86	5.20	5.09	3.55	60.00
140	23.73	5.07	4.96	3.46	51.43
160	23.61	4.95	4.85	3.38	45.00
180	23.58	4.92	4.82	3.36	40.00
210	23.27	4.61	4.52	3.16	34.29
240	23.00	4.34	4.26	2.97	30.00
270	27.66	4.04	3.97	2.77	26.67
300	22.40	3.74	3.68	2.57	24.00
330	22.66	4.00	3.93	2.75	21.82
360	21.65	2.99	2.95	2.06	20.00
420	21.35	2.69	2.66	1.86	17.14
480	21.31	2.65	2.62	1.83	15.00
540	21.20	2.54	2.51	1.75	13.33
600	21.10	2.44	2.41	1.69	12.00
660	20.94	2.28	2.26	1.58	10.91
720	20.80	2.14	2.12	1.48	10.00
780	20.70	2.04	2.02	1.41	9.23
840	20.65	1.99	1.97	1.38	8.57
900	20.60	1.94	1.92	1.34	8.00
960	20.55	1.89	1.87	1.31	7.50
1020	20.45	1.79	1.78	1.24	7.06
1080	20.40	1.74	1.73	1.21	6.67
1140	20.35	1.69	1.68	1.17	6.32
1200	20.30	1.64	1.63	1.14	6.00
1260	20.15	1.49	1.48	1.03	5.71
1320	20.10	1.44	1.43	1.00	5.45
1380	20.06	1.40	1.39	0.97	5.22
1440	20.03	1.37	1.36	0.95	5.00
1500	19.98	1.32	1.31	0.92	4.80
1560	19.90	1.24	1.23	0.86	4.62
1620	19.80	1.14	1.13	0.79	4.44
1680	19.70	1.04	1.04	0.72	4.29
1740	19.65	0.99	0.99	0.69	4.14
1800	19.60	0.94	0.94	0.65	4.00

Table 32 Recovery test data and its correction for well ID PK8

<b>Well ID:</b> PK-9		<b>Depth:</b> 145.00m			
<b>Location:</b> 0569483E, 1341614mN, 1460m					
<b>SWL:</b> 24.73m		<b>Pump position:</b> 84m			
<b>Reference:</b> 0.88m		<b>Date:</b> 17/06/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Q(l/sec): 50.00</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>un confind drwdow n</b>	<b>correct drawdow n</b>	<b>t'/t</b>
0	29.78	5.05	4.91	4.52	
0.5	28.87	4.14	4.05	3.72	14400.00
1	28.50	3.77	3.69	3.40	7200.00
1.5	28.34	3.61	3.54	3.26	4800.00
2	28.30	3.57	3.50	3.22	3600.00
2.5	28.16	3.43	3.37	3.10	2880.00
3	28.06	3.33	3.27	3.01	2400.00
3.5	27.99	3.26	3.20	2.95	2057.14
4	27.84	3.11	3.06	2.81	1800.00
4.5	27.79	3.06	3.01	2.77	1600.00
5	27.77	3.04	2.99	2.75	1440.00
6	27.75	3.02	2.97	2.73	1200.00
7	27.70	2.97	2.92	2.69	1028.57
8	27.61	2.88	2.83	2.61	900.00
9	27.54	2.81	2.77	2.55	800.00
10	27.49	2.76	2.72	2.50	720.00
12	27.37	2.64	2.60	2.39	600.00
14	27.26	2.53	2.50	2.30	514.29
16	27.23	2.50	2.47	2.27	450.00
18	27.21	2.48	2.45	2.25	400.00
20	27.18	2.45	2.42	2.22	360.00
25	27.14	2.41	2.38	2.19	288.00
30	27.04	2.31	2.28	2.10	240.00
35	27.05	2.32	2.29	2.11	205.71
40	27.03	2.30	2.27	2.09	180.00

45	27.01	2.28	2.25	2.07	160.00
50	27.00	2.27	2.24	2.06	144.00
55	26.86	2.13	2.11	1.94	130.91
60	26.82	2.09	2.07	1.90	120.00
70	26.78	2.05	2.03	1.87	102.86
80	26.73	2.00	1.98	1.82	90.00
90	26.70	1.97	1.95	1.79	80.00
100	26.67	1.94	1.92	1.77	72.00
110	26.64	1.91	1.89	1.74	65.45
120	26.61	1.88	1.86	1.71	60.00
140	26.59	1.86	1.84	1.69	51.43
160	26.55	1.82	1.80	1.66	45.00
180	26.51	1.78	1.76	1.62	40.00
210	26.47	1.74	1.72	1.59	34.29
240	26.43	1.70	1.68	1.55	30.00
270	26.39	1.66	1.65	1.51	26.67
300	26.35	1.62	1.61	1.48	24.00
330	26.31	1.58	1.57	1.44	21.82
360	26.25	1.52	1.51	1.39	20.00
420	25.80	1.07	1.06	0.98	17.14
480	25.51	0.78	0.78	0.71	15.00
540	25.31	0.58	0.58	0.53	13.33
600	25.11	0.38	0.38	0.35	12.00
660	25.01	0.28	0.28	0.26	10.91
720	24.90	0.17	0.17	0.16	10.00

Table 33 Recovery test data and its correction for well ID PK9

<b>Well ID:</b> PHG1		<b>Depth:</b> 130.00m	
<b>Location:</b> 0567690E, 1338577mN, 1483m			
<b>SWL:</b> 24.35m		<b>Pump position:</b> 72m	
<b>Reference:</b> 0.73m		<b>Date:</b> 12/06/09	
<b>RECOVERY OF CONSTANT RATE TEST</b>			
<b>Q(l/sec): 50.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>t/t'</b>
0	29.06	3.98	
0.5	27.01	1.93	14400.00
1	27.33	2.25	7200.00

1.5	26.94	1.86	4800.00
2	26.89	1.81	3600.00
2.5	26.72	1.64	2880.00
3	26.62	1.54	2400.00
3.5	26.58	1.50	2057.14
4	26.55	1.47	1800.00
4.5	26.52	1.44	1600.00
5	26.50	1.42	1440.00
6	26.46	1.38	1200.00
7	26.42	1.34	1028.57
8	26.40	1.32	900.00
9	26.38	1.30	800.00
10	26.36	1.28	720.00
12	26.34	1.26	600.00
14	26.31	1.23	514.29
16	26.28	1.20	450.00
18	26.25	1.17	400.00
20	26.23	1.15	360.00
25	26.21	1.13	288.00
30	26.18	1.10	240.00
35	26.15	1.07	205.71
40	26.12	1.04	180.00
45	26.10	1.02	160.00
50	26.08	1.00	144.00
55	26.06	0.98	130.91
60	26.05	0.97	120.00
70	26.03	0.95	102.86
80	26.01	0.93	90.00
90	25.97	0.89	80.00
100	25.93	0.85	72.00
110	25.92	0.84	65.45
120	25.91	0.83	60.00
140	25.89	0.81	51.43
160	25.86	0.78	45.00
180	25.82	0.74	40.00
210	25.80	0.72	34.29
240	25.78	0.70	30.00
270	25.76	0.68	26.67
300	25.75	0.67	24.00
330	25.73	0.65	21.82
360	25.72	0.64	20.00

420	25.71	0.63	17.14
480	25.70	0.62	15.00
540	25.69	0.61	13.33
600	25.68	0.60	12.00
660	25.67	0.59	10.91
720	25.66	0.58	10.00
780	25.65	0.57	9.23
840	25.64	0.56	8.57
900	25.63	0.55	8.00
960	25.62	0.54	7.50
1020	25.61	0.53	7.06
1080	25.60	0.52	6.67
1140	25.59	0.51	6.32

Table 34 Recovery test data and its correction for well ID PHG1

<b>Well ID:</b> PHG2		<b>Depth:</b> 108.00m		
<b>Location:</b> 0567802E, 1337972mN, 1482m				
<b>SWL:</b> 18.61m		<b>Pump position:</b> 84m		
<b>Reference:</b> 0.48m		<b>Date:</b> 02/06/09		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Q(l/sec): 45.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>correct drawdown</b>	<b>t/t'</b>
0	32.09	13.48	12.18207	
0.5	24.48	5.87	3.927155	14400.00
1	23.41	4.80	3.23692	7200.00
1.5	23.35	4.74	3.197877	4800.00
2	23.27	4.66	3.145764	3600.00
2.5	23.20	4.59	3.100112	2880.00
3	23.18	4.57	3.08706	2400.00
3.5	23.13	4.52	3.054412	2057.14
4	23.09	4.48	3.028276	1800.00
4.5	23.03	4.42	2.989041	1600.00
5	22.97	4.36	2.949771	1440.00
6	22.92	4.31	2.917018	1200.00
7	22.88	4.27	2.890798	1028.57
8	22.84	4.23	2.864562	900.00

9	22.80	4.19	2.83831	800.00
10	22.76	4.15	2.812042	720.00
12	22.72	4.11	2.785758	600.00
14	22.66	4.05	2.746302	514.29
16	22.60	3.99	2.70681	450.00
18	22.55	3.94	2.673873	400.00
20	22.51	3.90	2.647505	360.00
25	22.47	3.86	2.621121	288.00
30	22.43	3.82	2.594721	240.00
35	22.39	3.78	2.568306	205.71
40	22.34	3.73	2.535263	180.00
45	22.30	3.69	2.508812	160.00
50	22.36	3.75	2.548483	144.00
55	22.20	3.59	2.442613	130.91
60	22.10	3.49	2.376314	120.00
70	22.00	3.39	2.309916	102.86
80	21.91	3.30	2.250072	90.00
90	21.79	3.18	2.170155	80.00
100	21.70	3.09	2.110122	72.00
110	21.59	2.98	2.03664	65.45
120	21.50	2.89	1.976428	60.00
140	21.50	2.89	1.976428	51.43
160	19.60	0.99	0.686428	45.00
180	19.33	0.72	0.50019	40.00
210	19.27	0.66	0.458705	34.29
240	19.20	0.59	0.410261	30.00
270	19.91	1.08	0.748346	26.67
300	19.10	0.49	0.340969	24.00
330	19.03	0.42	0.292406	21.82
360	18.97	0.36	0.250742	20.00
420	18.93	0.32	0.222945	17.14
480	18.86	0.25	0.174263	15.00
540	18.85	0.24	0.167305	13.33
600	18.83	0.22	0.153385	12.00
660	18.81	0.20	0.13946	10.91
720	18.80	0.19	0.132497	10.00
780	18.78	0.17	0.118567	9.23
840	18.77	0.16	0.1116	8.57
900	18.76	0.15	0.104633	8.00
960	18.74	0.13	0.090695	7.50
1020	18.72	0.11	0.076753	7.06

1080	18.71	0.10	0.06978	6.67
1140	18.70	0.09	0.062807	6.32

Table 36 Recovery test data and its correction for well ID PHG3

<b>Well ID:</b> PHG3		<b>Depth:</b> 156.00m		
<b>Location:</b> 0568348E, 1337980mN, 1470m				
<b>SWL:</b> 17.15m		<b>Pump position:</b> 72m		
<b>Reference:</b> 0.52m		<b>Date:</b> 07/06/09		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>correct drawdown</b>	<b>t/t'</b>
0	25.83	8.68	6.60	
0.5	22.47	5.32	4.04	14400.00
1	21.97	4.82	3.66	7200.00
1.5	21.81	4.66	3.54	4800.00
2	21.59	4.44	3.37	3600.00
2.5	21.50	4.35	3.31	2880.00
3	21.45	4.30	3.27	2400.00
3.5	21.40	4.25	3.23	2057.14
4	21.35	4.20	3.19	1800.00
4.5	21.28	4.13	3.14	1600.00
5	21.16	4.01	3.05	1440.00
6	21.07	3.92	2.98	1200.00
7	20.96	3.81	2.90	1028.57
8	20.90	3.75	2.85	900.00
9	20.85	3.70	2.81	800.00
10	20.80	3.65	2.77	720.00
12	20.73	3.58	2.72	600.00
14	20.60	3.45	2.62	514.29
16	20.56	3.41	2.59	450.00
18	20.50	3.35	2.55	400.00
20	20.45	3.30	2.51	360.00
25	20.35	3.20	2.43	288.00
30	20.25	3.10	2.36	240.00
35	20.10	2.95	2.24	205.71
40	19.90	2.75	2.09	180.00
45	19.80	2.65	2.01	160.00



<b>Well ID:</b> PHG4		<b>Depth:</b> 116.00m			
<b>Location:</b> 0566854E, 1339249mN, 1507m					
<b>SWL:</b> 29.30m		<b>Pump position:</b> 72m			
<b>Reference:</b> 0.63m		<b>Date:</b> 25/05/09			
<b>RECOVERY OF CONSTANT RATE TEST</b>					
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>un confind correctio n</b>	<b>correct drawdow n</b>	<b>t/t'</b>
0	33.65	4.35	4.20	3.11	#DIV/0!
0.5	33.05	3.75	3.64	2.69	14400.00
1	31.90	2.60	2.55	1.89	7200.00
1.5	31.27	1.97	1.94	1.44	4800.00
2	31.21	1.91	1.88	1.39	3600.00
2.5	31.11	1.81	1.78	1.32	2880.00
3	31.09	1.79	1.76	1.31	2400.00
3.5	31.02	1.72	1.70	1.26	2057.14
4	30.98	1.68	1.66	1.23	1800.00
4.5	30.91	1.61	1.59	1.18	1600.00
5	30.84	1.54	1.52	1.13	1440.00
6	30.73	1.43	1.41	1.05	1200.00
7	30.68	1.38	1.36	1.01	1028.57
8	30.63	1.33	1.32	0.97	900.00
9	30.00	0.70	0.70	0.52	800.00
10	29.94	0.64	0.64	0.47	720.00
12	29.95	0.65	0.65	0.48	600.00
14	29.92	0.62	0.62	0.46	514.29
16	29.90	0.60	0.60	0.44	450.00
18	29.89	0.59	0.59	0.44	400.00
20	29.87	0.57	0.57	0.42	360.00
25	29.84	0.54	0.54	0.40	288.00
30	29.81	0.51	0.51	0.38	240.00
35	29.79	0.49	0.49	0.36	205.71
40	29.78	0.48	0.48	0.35	180.00
45	29.75	0.45	0.45	0.33	160.00
50	29.74	0.44	0.44	0.32	144.00

55	29.73	0.43	0.43	0.32	130.91
60	29.72	0.42	0.42	0.31	120.00
70	29.70	0.40	0.40	0.30	102.86
80	29.68	0.38	0.38	0.28	90.00
90	29.67	0.37	0.37	0.27	80.00
100	29.66	0.36	0.36	0.27	72.00
110	29.64	0.34	0.34	0.25	65.45
120	29.63	0.33	0.33	0.24	60.00
140	29.62	0.32	0.32	0.24	51.43
160	29.61	0.31	0.31	0.23	45.00
180	29.60	0.30	0.30	0.22	40.00
210	29.59	0.29	0.29	0.21	34.29
240	29.57	0.27	0.27	0.20	30.00
270	29.53	0.23	0.23	0.17	26.67
300	29.52	0.22	0.22	0.16	24.00
330	29.51	0.21	0.21	0.16	21.82
360	29.51	0.21	0.21	0.16	20.00
420	29.50	0.20	0.20	0.15	17.14
480	29.49	0.19	0.19	0.14	15.00
540	29.48	0.18	0.18	0.13	13.33
600	29.46	0.16	0.16	0.12	12.00
660	29.45	0.15	0.15	0.11	10.91
720	29.43	0.13	0.13	0.10	10.00
780	29.40	0.10	0.10	0.07	9.23
840	29.36	0.06	0.06	0.04	8.57
900	29.35	0.05	0.05	0.04	8.00
960	29.34	0.04	0.04	0.03	7.50
1020	29.33	0.03	0.03	0.02	7.06

Table 38 Recovery test data and its correction for well ID PHG4

<b>Well ID:</b> TWJ2		<b>Depth:</b> 121.00m		
<b>Location:</b> 0573465E, 1355068mN, 1398m				
<b>SWL:</b> 25.00m		<b>Pump position:</b> 105m		
<b>Reference:</b> 1.05m		<b>Date:</b> 16/05/08		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Q(l/sec): 15.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>correct drawdown</b>	<b>t/t'</b>
0	79.40	54.40	44.17	#DIV/0!

0.5	70.80	45.80	37.19	2880.00
1	66.70	41.70	33.86	1440.00
1.5	63.15	38.15	30.98	960.00
2	60.64	35.64	28.94	720.00
2.5	58.00	33.00	26.80	576.00
3	56.91	31.91	25.91	480.00
4	55.33	30.33	24.63	360.00
4.5	54.77	29.77	24.17	320.00
5	54.13	29.13	23.65	288.00
6	53.24	28.24	22.93	240.00
7	52.64	27.64	22.44	205.71
8	52.04	27.04	21.96	180.00
9	51.45	26.45	21.48	160.00
10	50.95	25.95	21.07	144.00
12	50.44	25.44	20.66	120.00
14	49.68	24.68	20.04	102.86
16	48.88	23.88	19.39	90.00
18	48.18	23.18	18.82	80.00
20	47.51	22.51	18.28	72.00
25	46.12	21.12	17.15	57.60
30	45.10	20.10	16.32	48.00
35	44.16	19.16	15.56	41.14
40	43.40	18.40	14.94	36.00
45	42.74	17.74	14.40	32.00
50	42.16	17.16	13.93	28.80
55	41.61	16.61	13.49	26.18
60	41.10	16.10	13.07	24.00
70	40.25	15.25	12.38	20.57
80	39.50	14.50	11.77	18.00
90	38.90	13.90	11.29	16.00
100	38.30	13.30	10.80	14.40
110	37.79	12.79	10.39	13.09
120	37.32	12.32	10.00	12.00
135	36.67	11.67	9.48	10.67
150	36.15	11.15	9.05	9.60
165	35.70	10.70	8.69	8.73
180	35.23	10.23	8.31	8.00
195	34.77	9.77	7.93	7.38
210	34.44	9.44	7.67	6.86
225	34.00	9.00	7.31	6.40

240	33.66	8.66	7.03	6.00
270	33.36	8.36	6.79	5.33
300	32.65	7.65	6.21	4.80
330	32.45	7.45	6.05	4.36
360	32.04	7.04	5.72	4.00
420	31.37	6.37	5.17	3.43
480	31.04	6.04	4.90	3.00
540	29.84	4.84	3.93	2.67
600	29.72	4.72	3.83	2.40
660	29.65	4.65	3.78	2.18
720	29.35	4.35	3.53	2.00
780	29.09	4.09	3.32	1.85
840	28.87	3.87	3.14	1.71
900	28.50	3.50	2.84	1.60
960	28.44	3.44	2.79	1.50
1020	28.29	3.29	2.67	1.41
1080	28.20	3.20	2.60	1.33
1140	28.00	3.00	2.44	1.26
1200	27.93	2.93	2.38	1.20
1260	27.88	2.88	2.34	1.14
1320	27.75	2.75	2.23	1.09
1380	27.43	2.43	1.97	1.04
1440	27.40	2.40	1.95	1.00

Table 39 Recovery test data and its correction for well ID TWJ2

<b>Well ID:</b> TWJ3		<b>Depth:</b> 202.00m	
<b>Location:</b> 0569491E, 1357769mN, 1428m			
<b>SWL:</b> 17.49m		<b>Pump position:</b> 75m	
<b>Reference:</b> 0.90m		<b>Date:</b> 28/06/08	
<b>RECOVERY OF CONSTANT RATE TEST</b>			
<b>Q(l/sec): 60.00</b>			
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>t/t'</b>
0	30.12	12.63	
0.5	26.47	8.98	6600.00
1	24.85	7.36	3300.00
1.5	24.63	7.14	2200.00
2	24.61	7.12	1650.00
2.5	24.56	7.07	1320.00

3	24.5	7.01	1100.00
3.5	24.36	6.87	942.86
4	24.28	6.79	825.00
4.5	24.19	6.7	733.33
5	24.11	6.62	660.00
6	23.97	6.48	550.00
7	23.86	6.37	471.43
8	23.76	6.27	412.50
9	23.68	6.19	366.67
10	23.58	6.09	330.00
12	23.42	5.93	275.00
14	23.3	5.81	235.71
16	23.2	5.71	206.25
18	23.11	5.62	183.33
20	23.04	5.55	165.00
25	22.87	5.38	132.00
30	22.75	5.26	110.00
35	22.64	5.15	94.29
40	22.55	5.06	82.50
45	22.48	4.99	73.33
50	22.4	4.91	66.00
55	22.32	4.83	60.00
60	22.26	4.77	55.00
70	22.19	4.7	47.14
80	22.08	4.59	41.25
90	22.01	4.52	36.67
100	21.93	4.44	33.00
110	21.85	4.36	30.00
120	21.77	4.28	27.50
135	21.7	4.21	24.44
150	21.61	4.12	22.00
165	21.53	4.04	20.00
180	21.47	3.98	18.33
195	21.38	3.89	16.92
210	21.31	3.82	15.71
225	21.26	3.77	14.67
240	21.19	3.7	13.75
270	21.08	3.59	12.22
300	21.02	3.53	11.00
330	20.92	3.43	10.00
360	20.82	3.33	9.17

420	20.7	3.21	7.86
480	20.55	3.06	6.88
540	20.44	2.95	6.11
600	20.35	2.86	5.50
660	20.5	3.01	5.00
720	20.2	2.71	4.58
780	20.13	2.64	4.23
840	20.08	2.59	3.93
900	19.98	2.49	3.67
960	19.84	2.35	3.44
1020	19.8	2.31	3.24
1080	19.77	2.28	3.06
1140	19.72	2.23	2.89
1200	19.63	2.14	2.75
1260	19.56	2.07	2.62
1320	19.52	2.03	2.50
1380	19.49	2	2.39
1440	19.4	1.91	2.29
1500	19.4	1.91	2.20
1560	19.34	1.85	2.12
1620	19.31	1.82	2.04
1680	19.27	1.78	1.96
1740	19.24	1.75	1.90
1800	19.22	1.73	1.83
1860	19.2	1.71	1.77
1920	19.17	1.68	1.72
1980	19.16	1.67	1.67
2040	19.14	1.65	1.62
2100	19.12	1.63	1.57
2160	19.1	1.61	1.53
2220	19.07	1.58	1.49
2280	19.05	1.56	1.45
2340	19	1.51	1.41
2400	18.98	1.49	1.38
2460	18.95	1.46	1.34
2520	18.9	1.41	1.31
2580	18.88	1.39	1.28
2640	18.85	1.36	1.25
2700	18.85	1.36	1.22
2760	18.8	1.31	1.20
2820	18.79	1.3	1.17

2880	18.77	1.28	1.15
2940	18.73	1.24	1.12
3000	18.71	1.22	1.10
3060	18.68	1.19	1.08
3120	18.66	1.17	1.06
3180	18.65	1.16	1.04
3240	18.64	1.15	1.02
3300	18.62	1.13	1.00

Table 39 Recovery test data and its correction for well ID TWJ3

<b>Well ID: TWJ4</b>		<b>Depth: 198.50m</b>		
<b>Location: 0568854E, 1352624mN, 1425m</b>				
<b>SWL: 16.38m</b>		<b>Pump position: 72m</b>		
<b>Reference: 0.84m</b>		<b>Date: 10/06/08</b>		
<b>RECOVERY OF CONSTANT RATE TEST</b>				
<b>Q(l/sec): 60.00</b>				
<b>Time (min)</b>	<b>Water level (m)</b>	<b>Residual Draw down (m)</b>	<b>sc</b>	<b>t/t'</b>
0	40.49	24.11	18.13	#DIV/0!
0.5	34.20	17.82	13.40	5760.00
1	33.30	16.92	12.72	2880.00
1.5	32.92	16.54	12.44	1920.00
2	32.70	16.32	12.27	1440.00
2.5	32.50	16.12	12.12	1152.00
3	32.48	16.10	12.11	960.00
3.5	32.25	15.87	11.93	822.86
4	32.08	15.70	11.81	720.00
4.5	31.82	15.44	11.61	640.00
5	31.73	15.35	11.54	576.00
6	31.50	15.12	11.37	480.00
7	31.22	14.84	11.16	411.43
8	30.98	14.60	10.98	360.00
9	30.77	14.39	10.82	320.00
10	30.58	14.20	10.68	288.00
12	30.23	13.85	10.42	240.00
14	29.91	13.53	10.17	205.71

16	29.62	13.24	9.96	180.00
18	29.30	12.92	9.72	160.00
20	29.15	12.77	9.60	144.00
25	28.58	12.20	9.17	115.20
30	28.22	11.84	8.90	96.00
35	27.68	11.30	8.50	82.29
40	27.41	11.03	8.29	72.00
45	27.14	10.76	8.09	64.00
50	26.79	10.41	7.83	57.60
55	26.55	10.17	7.65	52.36
60	26.31	9.93	7.47	48.00
70	26.86	10.48	7.88	41.14
80	25.47	9.09	6.84	36.00
90	25.25	8.87	6.67	32.00
100	25.84	9.46	7.11	28.80
120	24.81	8.43	6.34	24.00
135	23.91	7.53	5.66	21.33
150	23.64	7.26	5.46	19.20
165	23.41	7.03	5.29	17.45
180	23.30	6.92	5.20	16.00
195	22.94	6.56	4.93	14.77
210	22.74	6.36	4.78	13.71
225	22.62	6.24	4.69	12.80
240	22.54	6.16	4.63	12.00
270	22.26	5.88	4.42	10.67
300	22.00	5.62	4.23	9.60
330	21.24	4.86	3.65	8.73
360	21.54	5.16	3.88	8.00
420	21.20	4.82	3.62	6.86
480	20.86	4.48	3.37	6.00
540	20.52	4.14	3.11	5.33
600	20.46	4.08	3.07	4.80
660	20.34	3.96	2.98	4.36
720	20.24	3.86	2.90	4.00
780	20.17	3.79	2.85	3.69
840	20.05	3.67	2.76	3.43
900	19.88	3.50	2.63	3.20
960	19.65	3.27	2.46	3.00
1020	19.32	2.94	2.21	2.82
1080	19.13	2.75	2.07	2.67
1140	18.93	2.55	1.92	2.53
1200	18.81	2.43	1.83	2.40
1260	18.73	2.35	1.77	2.29
1320	18.59	2.21	1.66	2.18
1380	18.53	2.15	1.62	2.09

1440	18.45	2.07	1.56	2.00
1500	18.36	1.98	1.49	1.92
1560	18.25	1.87	1.41	1.85
1620	18.22	1.84	1.38	1.78
1680	18.08	1.70	1.28	1.71
1740	18.02	1.64	1.23	1.66
1800	17.96	1.58	1.19	1.60
1860	17.92	1.54	1.16	1.55
1920	17.85	1.47	1.11	1.50
1980	17.75	1.37	1.03	1.45
2040	17.68	1.30	0.98	1.41
2100	17.63	1.25	0.94	1.37
2160	17.58	1.20	0.90	1.33
2220	17.49	1.11	0.83	1.30
2280	17.44	1.06	0.80	1.26
2340	17.40	1.02	0.77	1.23
2400	17.36	0.98	0.74	1.20
2460	17.33	0.95	0.71	1.17
2520	17.27	0.89	0.67	1.14
2580	17.21	0.83	0.62	1.12
2640	17.21	0.83	0.62	1.09
2700	17.20	0.82	0.62	1.07
2760	17.16	0.78	0.59	1.04
2820	17.11	0.73	0.55	1.02
2880	17.05	0.67	0.50	1.00

Table 40 Recovery test data and its correction for well ID TWJ4

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Template: C:\Users\Aby\AppData\Roaming\Microsoft\Templates\Normal.dotm  
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