ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDRAULIC ENGINEERING

ANALISIS AND EVALUATION OF HYDERAULIC PARAMETERS IN AKAKE WELL FIELD OF ADDIS ABABA

BY

DEREJE ENDALKACHEW

MAY ,2016

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ANALYSIS & EVALUATION OF HYDRAULIC PARAMETERS IN AKAKE WELL FIELDS OF ADDIS ABABA

BY DEREJE ENDALKACHEW

Thesis Submitted to Addis Ababa Institute of Technology, School of Graduate Studies in partial fulfillment of the requirements for the Degree of Masters of Science in Civil Engineering under Hydraulic Engineering.

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Date defended--------------------

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Declaration

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

Declining water levels caused by withdrawals of water from well in Akaki , the southern part of Addis Ababa have raised concerns with respect to the ability of the aquifer system to sustain production . As the aquifer of akaki in particular is heavily used in this area , understanding the hydraulic parameters of the area is essential for efficient sustainable management of the groundwater resource . A single well test was conducted to estimate the hydraulic parameters of the aquifer. An overview of the hydraulic parameters estimated for the 12 wells in the study clearly show strong evidence of inappropriate estimation. Thus this study was conducted to identify the possible miss-interpretation of the observed time-drawdown , step-drawdown , time-residual drawdown based parameter estimation . After data quality checking , appropriate data correction for partial penetration and unconfinedness (if exists) were conducted. Then the standard methods like Theis curve fitting, Cooper-Jacob methods for time-drawdown data & Theis recovery method for time-residual drawdown data were used for parameter estimation. Beside Aquifer test v3.5 software was also used to verify the results of the original study. Evaluation and analysis result showed that out of the 12 well analyzed , 11 transmissivity values used in the well yield estimate were overestimated (on an average of twenty times) and one underestimated (fivefold) , such highly over estimated transmissivity value misleads the designers & operators in fixing the well yield . Therefore, in this evaluation it is recommended to conduct multiple well test to determine the actual hydraulic parameters of the aquifer in order to obtain the safe yield of the wells which is intended to prolong the productivity of the aquifer and to delay excessive loss of saturated thickness .

Key wards:-**ADDIS ABABA WATER SUPPLY, AKAKI WELL FIELD , SINGLE WELL TEST , TRANSMISSIVITY.**

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List of Acronyms and Abbreviations

AAWSA	Addis Ababa Water & Sewerage Authority
L/S	Liter per second
M^3/S	Cubic meter per second
M^2/s	mater square per second
Masl	above mean sea level
PW	Pumping Well
PP	Partial Penetration
SWAWF	South western Akaki well field
SWL	Static water level
WWDSE	Water works design & supervision enterprise
WF	Well field

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The study area of this research is Akaki well field, situated south of Addis Ababa. It covers a total area of 103 sq. kilometers. Akaki well field is not an independent and isolated aquifer it is part of Ada’a-Becho groundwater system. It is within a wide groundwater basin that covers parts of the southern Abay and Upper Awash surface water basins (WWDSE, 2008). Therefore the groundwater recharge and movement into and out of the aquifers of Akaki well field is seen in the context of the wider groundwater basin.

The Akaki river basin is a primary source of water for much of the population of the southern part of Addis Ababa. Municipal- well pumping from Akaki well field has contributed to the water level decline and, in some areas, declining well yields. Concern related to the rate of water level decline and the longevity of the usefulness of the aquifer have prompted investigation with the goal of prolonging productivity of the aquifer for beneficial use. A recent report on ground water availability shows decline of water levels in wells in these areas as the rate of withdrawal of water from wells in the area has increased.

Most of the previous studies have been concerned more with resource development to meet users’ need and alleviate the current water supply problem with low attention to the understanding of hydraulic characteristics of the area which is essential for efficient Sustainable management of the groundwater resources. However, safe groundwater abstraction and proper study of the aquifer is crucial for sustainability of the resource.

1.2 STATEMENT OF THE PROBLEM

Decline of water level caused by heavily withdrawal of water from Akaki well field and ongoing projects of constructing additional new wells have caused the need to do this research with the aim of evaluating the exaggerated pumping test results to understand the hydraulic characteristics of the aquifer which is intended to prolong the productivity of the aquifer and to delay excessive loss of saturated thickness.

Reviewing the pumping test results of the area indicates highly exaggerated & varied transmitivity of the aquifer for wells which are even close to each other.

To ascertain this water table & potentiometric-surface map of the area was prepared using surfer 12 software (figure 2.1) after which the transmissivity values estimated in the original document were attached to this map to clearly notify the spacing of contours & this attached values .

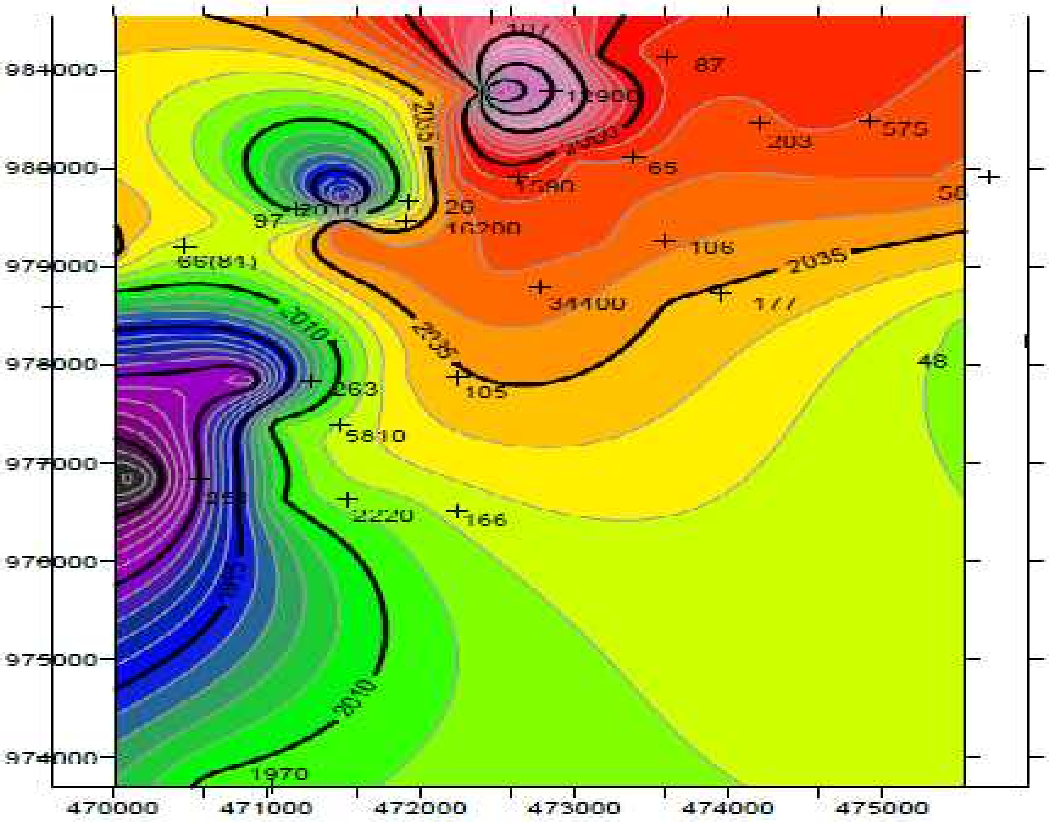

FIGURE 1 : Water table & potentiometric surface map of the Akaki well field 01 with attached transmissivity values.

1.3 OBJECTIVE OF THE RESEARCH

1.3.1GENERAL OBJECTIVE

The primary objective of this study is analysis and evaluation of pumping test data to determine the aquifer hydraulic property of the akaki well field & finally confirm the safe yield of the wells which is intended to prolong the productivity of the aquifer and to delay excessive loss of saturated thickness.

1.3.2 SPECIFIC OBJECTIVE

- To organize the available information and previous work.
- To provide the actual transmitvity, and storativity of the aquifer by using different methods in analyzing & evaluating the pump test data .
- Evaluation of the methodology adopted during study and design of the well

2. LITERATURE REVIEW

2.1 GROUND WATER

"Water is vital for mankind and regions with easy availability of water have always been the most prosperous. Water was one of the most prized national resources in the olden times and occupied a prominent position amongst the pagan gods.

Tremendous quantities of water are stored in the earth's crust. According to Nace (1960) the total volume stored under land areas may be around 80 million km^3, half of which may be at depths less than 800 m. This is about 35 times the quantity of fresh water available on the surface of the earth and is about one third of the volume stored as ice in Polar Regions and the mountain ranges.

Surface water is generally easy and economical to harness, but its availability varies with the seasons, and its use for irrigation frequently brings in its wake problems like water logging. Groundwater, on the other hand, is obtainable all the year round, and its use in conjunction with surface water holds the subsoil water level within reasonable limits. Groundwater reservoir can be used to store water in times of surplus availability. It yields clear water at almost constant temperature that is preferred as compared to surface water for municipal water supply, air conditioning and many industries." (Garg ,1998).

2.2 AQUIFERS

An aquifer is defined by Davis and Dewiest (1966) as "… natural zone (geological formation) below the surface that yields water in sufficiently large amounts to be important economically." The most productive aquifers are generally deposits of glacial outwash, karstic carbonates, permeable sandstones, and highly fractured rocks of all kinds.

2.2.1 CONFINED AQUIFER

An aquifer that is sandwiched between two impermeable layers or formations that are impermeable is called a confined aquifer if it is totally saturated from top to bottom (Figure 2) .

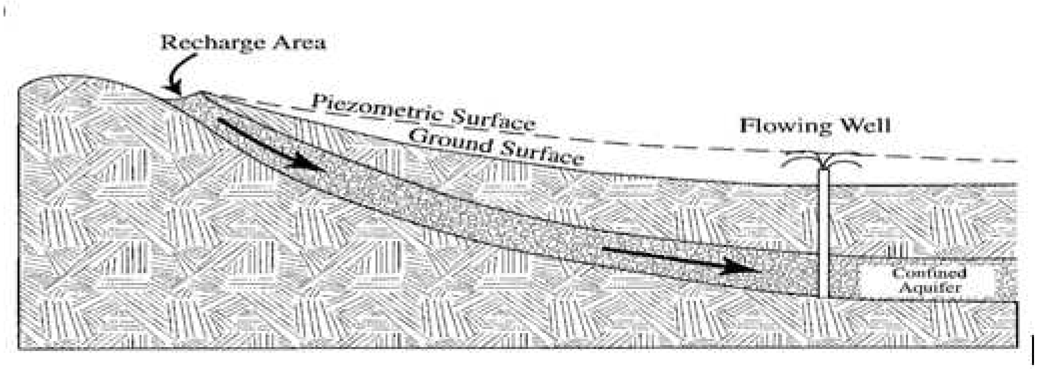

FIGURE 2: Confined Aquifer (source: Jacques W.Delleur,(Editor),2007:Hand book of groundwater engineering .CRC Press, London, 89 pp).

If the recharge area for the aquifer is located at a higher elevation than the top of the aquifer, and a well is drilled into the aquifer, the water level will rise above the top as shown. Such an aquifer is known as an artesian aquifer ; it is named after Artois, France, where such wells are common. It should be noted, however, that the well does not have to be flowing to be termed "artesian," although that is the popular conception. A flowing well is known as a "flowing artesian well."

The water level above the top is known as the piezometric surface (pressure surface), which is the locus of the piezometric head, and it is not to be confused with the water table discussed below. The piezometric surface occurs above the ground surface because the higher elevation of the recharge area causes the pressure head to rise to such an elevation. The water within the aquifer will be partly under elastic storage. Pumping a well or allowing it to flow will release the water from storage.

Artesian or confined aquifers are common in glaciated regions of the world where a body of outwash sand and gravel may have been covered by clay-rich till or lacustrine sediments from a subsequent glaciation. Along the way, it is sandwiched between impermeable or slightly permeable shales which maintain its confined and artesian condition. Wells drilled into this aquifer, even hundreds of miles from its recharge area, often flow from the pressure within the aquifer.(Jacques W.Delleur. et al.(2007))

2.2.2 AN UNCONFINED AQUIFER

An unconfined aquifer possesses no overlying confining layer, but may sit upon an impermeable or slightly permeable bed. Therefore, the top of the unsaturated zone of an unconfined aquifer is most often the ground surface, and the top of the saturated zone is usually under negative pressure or tension. This latter property gives rise to the definition of the water table which is simply the surface where the relative pressure is zero, i.e., the absolute pressure is atmospheric. .(Jacques W.Delleur. et al.(2007))

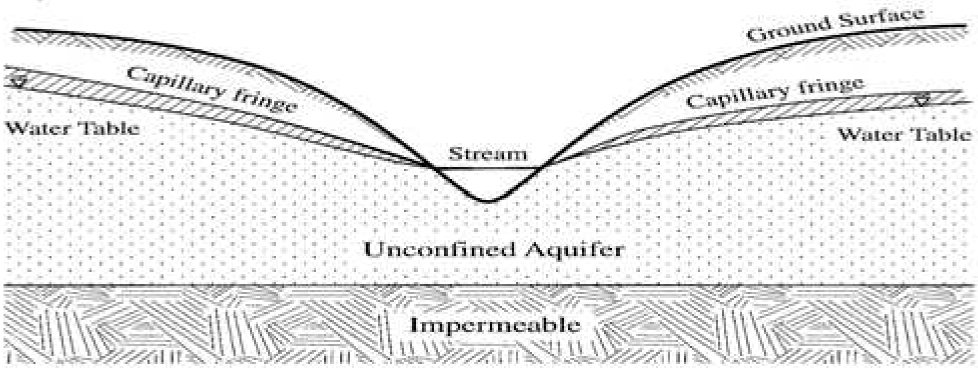

FIGURE 3: Unconfined aquifer. (source: Jacques W.Delleur,(Editor),2007:Hand book of groundwater engineering .CRC Press, London, 89 pp)

2.2.3 SEMI-CONFINED OR LEAKY AQUIFER

There is yet another kind of unit between the permeable and the impermeable, known as an aquitard, which is semi permeable. A totally impermeable bed is termed an aquiclude. An aquifer sandwiched in between an aquitard and an aquiclude, or between two aquitards, is called a semi-confined or leaky aquifer. It usually possesses properties common to a confined aquifer, such as a high piezometric surface, but some water will flow into or out of the aquifer through the aquitard(s) (Figure 4). .(Jacques W.Delleur. et al.(2007))

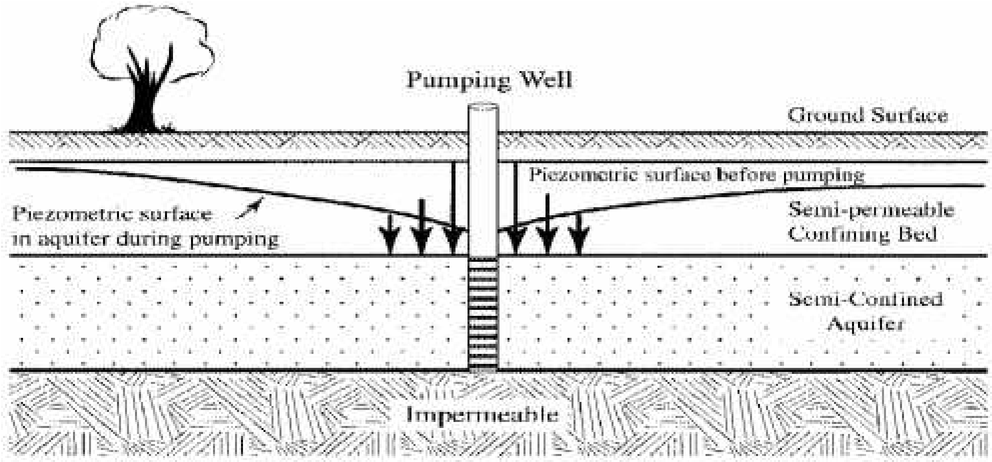

FIGURE 4: A semi confined or leaky aquifer Vertical arrows indicate relative rates of leakage into aquifer as a function of the distance from the well . (source: Jacques W.Delleur,(Editor),2007:Hand book of groundwater engineering .CRC Press, London, 89 pp)

2.3 PROPERTIES OF AQUIFERS

2.3.1 POROSITY

At the time they are formed some rocks contain void spaces while others are solid. Those rocks occurring near the surface of the earth are not totally solid. The physical and chemical weathering processes there continually decompose and disaggregate rock, thus creating voids. Slight movements of rock masses near the surface can cause rocks to crack or fracture. This also results in openings between rocks.

Sediments are assemblages of individual grains that were deposited by water, wind, ice, or gravity. There are opening called pore spaces between the sediment grains, so that sediments are not solid. The cracks, voids, and pore spaces in earth materials are of great importance to the study of hydrogeology. Ground water and soil moisture occur in the voids in otherwise solid earth materials.(Fetter,2001)

The porosity of earth materials is the percentage of the rock or soil that is void of material. It is defined mathematically by the equation

$$n = \frac{100V_V}{V} \quad \text{..............................} \ (2.1)$$

Where :

n= is the porosity (percentage)

V_v= is the volume of void space in a unit volume of earth material .

V=is the unit volume of earth material, including both voids and solids .

2.3.2 SPECIFIC YIELD

Specific yield (S_y) is the ratio of volume of water that drains from a saturated rock owing to the attraction of gravity to the total volume of the rock (Meinzer 1923b)

Water molecules cling to surfaces because of surface tension of the water if gravity exerts a stress on a film of water surrounding a mineral grain, some of the film will pull away and drip downward. The remaining film will be thinner, with a greater surface tension so that, eventually, the stress of gravity will be exactly balanced by the surface tension. **Pendular water** is the moisture clinging to the soil particles because of surface tension. At the moisture content of the specific yield, gravity drainage will cease.

If two samples are equivalent with regard to porosity, but the average grain size of one is much smaller than the other, then the surface area of the finer sample will be larger. In addition, water will be primarily retained in the smaller pores. As a result, more water can be held as pendular by the finer grains.

The **specific retention(S_r)** of a rock or soil is the ratio of the volume of water a rock can retain against gravity drainage to the total volume of the rock (Meinzer 1923b). Since the specific yield represents the volume of water that a rock will yield by gravity drainage, with specific retention the remainder, the sum of the two is equal to porosity.(Fetter,2001) :

$$n = Sy + Sr \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

Where :

n = Porosity

Sy = Specific yield

Sr = Specific retention

The specific retention increases with decreasing grain size. So that a clay may have a porosity of 50% with a specific retention of 48%.

2.3.3 HYDRAULIC CONDUCTIVITY

We have seen that earth materials near the surface generally contain some void space and thus exhibit porosity .Moreover, in most cases these void are interconnected to some degree. Water contained in the voids is capable of moving from one void to another, thus circulating through the soil, sediment, and rock. It is the ability of a rock to transmit water that, together with its ability to hold water, constitute the most significant hydrologic properties . There are some rocks that exhibit porosity but lack interconnected void (e.g. vesicular basalt). These rocks cannot convey water from one void to another. Some sediments and rocks have porosity, but the pores are so small that water flows through the rock with difficulty. Clay and shale are examples. .(Fetter,2001)

Darcy’s Experiment

Darcy found experimentally that discharge, Q, is proportional to the difference in the height of the water, h (hydraulic head), between the ends and inversely proportional to the flow length, L.

$$Q\sim h_{\wedge} - h_B \, andQ\sim -1/L$$

The flow is also obviously proportional to the cross-sectional area of the pipe, A. when combined with proportionality constant, K, the result is the expression known as Darcy’s law:

$$Q = -KA(\frac{h_A - h_B}{L})$$

$$Q = -KA(\frac{dh}{dl})$$

Where dh/dI is known as the hydraulic gradient. The quantity dh represents the change in head between two points that are very close together, and dl is the small distance between these points. The negative sign indicates that flow is in the direction of decreasing hydraulic head. The use of the negative sign necessitates careful determination of the sign of the gradient. If the value of h_2 at point X_2 is greater than h_1 at point X_1 then flow is from point X_2 to X_1. If $h_1 > h_2$, then flow is from X_1 to X_2.

We can rewrite the above Equation as

$$q = -K \frac{dh}{dI}$$

Where q =Q/A. the factor q is called the specific discharge and has the dimensions of length/time (L/T). It is also sometimes called the Darcian velocity. it is not a true velocity as the cross-sectional area, A, is partially blocked with soil material.

We can also rearrange the above Equation to demonstrate that the coefficient K has the dimensions of L/T. this coefficient has been termed the hydraulic conductivity. In other works, it may be referred to as the coefficient of permeability.(Fetter,2001) :

$$K = \frac{-Q}{A(dh/dL)} \quad \text{........................}(2.3)$$

Where :

K = Hydraulic Conductivity

A = Cross section area

$\frac{dh}{dL} =$ Hydraulic Gradient

2.3.4 TRANSMISSIVITY

We have thus far considered the intrinsic permeability of earth materials and their hydraulic conductivity when transmitting water. A useful concept in many studies is aquifer transmissivity, which is a measure of the amount of water that can be transmitted horizontally through a unit width by the full saturated thickness of the aquifer under a hydraulic gradient of 1.

The transmissivity is the product of the hydraulic conductivity and the saturated thickness of the aquifer.

$$T = bK \quad \textbf{..........................} \; (2.4)$$

Where

T is transmissivity (L^2/T)

b is saturated thickness of the aquifer(L)

k is hydraulic conductivity (L/T)

Aquifer transmissivity is a concept that assumes flow through the aquifer to be horizontal. In some cases, this assumption is valid; in others, it is not. .(Fetter,2001)

2.3.5 STORATIVITY

When the head in a saturated aquifer or confining unit changes, water will be either stored or expelled. The **storage coefficient**, or **storativity (S)**, is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head. It is dimensionless quantity.

In the saturated zone, the head creates pressure, affecting the arrangement of mineral grains and the density of the water in the voids. if the pressure increases, the mineral skeleton will expand; if it drops, the mineral skeleton will contract. This is known as elasticity. Likewise, water will contract with an increase in pressure and expand if the pressure drops. When the head in an confining bed declines, the aquifer skeleton compresses, which reduces the effective porosity and expels water. Additional water is released as the pore water expands to due to lower pressure.

The storativity of a saturated aquifer is a function of its thickness. Storativity is a dimensionless quantity, as it involves a volume of water per volume of aquifer. Its values in confined aquifers range from 0.00005 to 0.005.

The **specific storage (Ss)** is the amount of water per unit volume of a saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in head. This is also called the elastic storage coefficient. The concept can be applied to both aquifers and confining unit. The specific storage is given by the following expression (Jacob 1940, 1950; Cooper 1966).

$$S_s = \rho_w \mathbf{g}(\alpha + \mathbf{n}\beta) \text{ .... } (2.5)$$

Where

ρ is the density of water

g is the acceleration of gravity

α the compressibility of the aquifer skeleton

n is the porosity

β the compressibility of the water.

Specific storage has dimensions of1/L. The value of specific storage is very small, generally 3.048E-5 m $^{-1}$ or less.

In a confined aquifer, the head may decline—yet the potentiometric surface remains above the unit . Although water is released from storage, the aquifer remains saturated. The storativity (S) of a confined aquifer is the product of the specific storage (Ss) and the aquifer thickness (b)

$$S = b\,S_s \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.6)$$

Since specific storage has dimensions of 1/L and the aquifer thickness has dimensions of L, storativity is dimensionless. All the water released is accounted for by the compressibility of the mineral skeleton and the pore water. The water comes from the entire thickness of the aquifer. The value of the storativity of confined aquifer is on the order of 0.005 or less.

In an unconfined unit the level of saturation rises from the pore spaces. This storage or release is due to the **specific yield (Sy)** of unit. Water is also stored or expelled depending on the specific storage of the unit for an unconfined, the storativity is found by the formula.

$$S = S_y + b\,S_s \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.7)$$

Where b is the saturated thickness of the aquifer.

The value of Sy is several orders of magnitude greater then b Ss for an unconfined aquifer, and the storativity is usually taken to be equal to the specific yield. For a fine-grained unit, the specific yield may be very small, approaching the same order of magnitude as b Ss. Storativity of unconfined aquifers ranges from 0.02 to 0.3. (Fetter,2001)

2.3.6 WATER TABLE & POTENTIOMETRIC SURFACE MAPS.

Maps of the water table for an unconfined aquifer and of the potentiometric surface of confined aquifer are basic tools of hydro geologic interpretation. These maps are two dimensional representations of three-dimensional surfaces. Such maps can be shown a contour map with lines of equal elevation. They can also be shown as perspective drawings representing a three-dimensional view of the surface.

The data used to construct water –table and potentiometric –surface maps are water level elevations as measured in wells. However, not every well is useful for this purpose.

Some water –supply wells are open borings in rock that include both aquifers and confining beds. Other water –supply wells may have more than one well screen each opposite a different aquifer. Since the water level in such wells is a reflection of the heads in several different units and not one specific unit, they are not useful in making water level maps.

To make a ground-water level map one needs water –level readings made in a number of wells each of which is open only in the aquifer of interest. Since ground water levels can change with time all readings should be made within a short period of time. Some measuring point on each well needs to be surveyed to a common datum so that the water levels can be referenced to a height above the datum; mean sea level is a common datum for this purpose.

If water levels are to be measured in a well that is normally used for water supply one must ensure that the pump has been shut off long enough for the water level to recover to what is termed the static , or non pumping level . Depth to water measurements can be made every few minutes until the water level stops rising.

When making water –table map, it is ideal if all the wells have an open borehole or a well screen at the depth of the water table. However, wells that are cased or screened below the water table can be used if they do not extend too far below the water table. For wells used to make a potentiometric –surface map, all aquifers above the aquifer of interest should be cased off.

Surface-water features such as springs, ponds, lakes ,streams ,and rivers can interact with the water table. In addition the water table is often a subdued reflection of the surface topography. All this must be taken into account when preparing a water –table map.

A base map showing the surface topography and the locations of surface-water features should be prepared. The elevations of lakes and ponds can be helpful information. The locations of the wells are then plotted on the base map, and the water –level elevations are noted. The datum for the water level in wells should be the same as the datum for the surface topography. Contours of equal ground –water elevations are then drawn. Interpolation of contours between data points is strongly influenced by the surface topography and surface –water features, for example ground water contours cannot be higher than the surface topography. The depth to ground water will typically be greater beneath hills than beneath valleys. If a lake is present , the lake surface is flat as is the water table beneath it. Hence, ground water contours must go around it. The only exception to this rule is when the lake is perched on low permeability sediments and has a surface elevation above the main water table. Ground – water contours form a V, pointing upstream when they cross a gaining stream . Ground water contours bend downstream when they cross a losing stream. In general the potentiometric surface of a confined aquifer is not influenced by the surface topography and surface water features. Because there is no direct hydraulic connection between a river and a confined aquifer beneath it , potentiometric –surface contours are not influenced by the presence of the river. Potentiometric –surface contours can even be above the land surface. This indicates that if a well were to be drilled at that location, it would flow.

In areas where the water table or potentiometric surface has a shallow gradient , the ground –water contours will be space well apart. If the gradient is steep the ground water contours will be closer together. Ground water will flow in the general direction that the water table or potentiometric surface is sloping(Fetter,2001).With only three ground water elevations known from wells estimates of local ground water contours and flow directions can be determined . From field measurements of static water levels in wells within a basin a water level contour map can be constructed . flow lines sketched perpendicular to contours show directions of movement.(Figure 5).

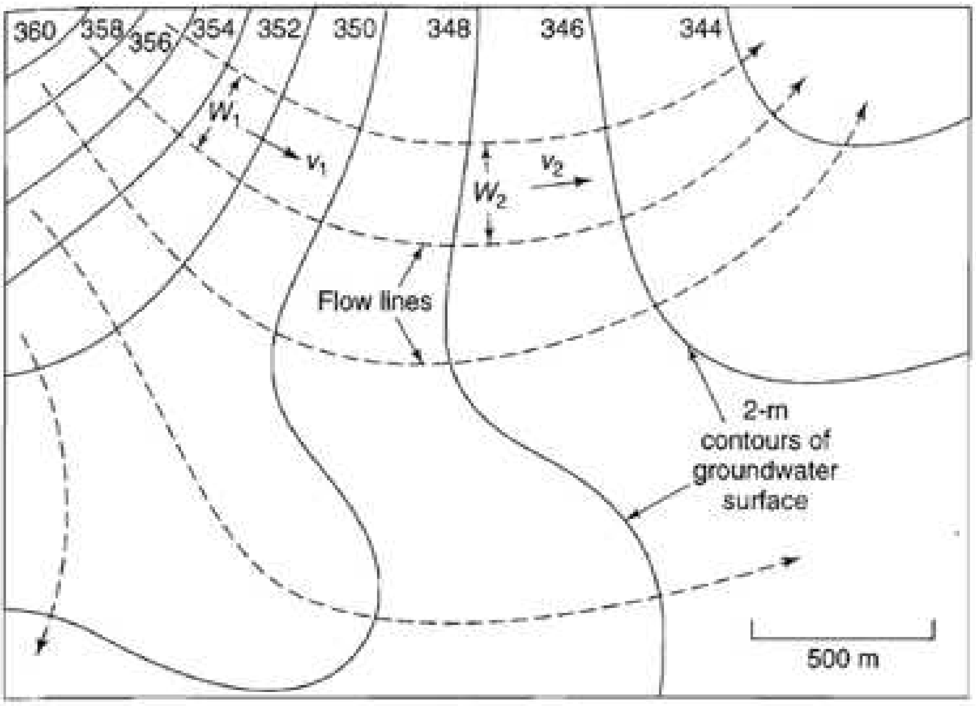

FIGURE 5: contour map of a groundwater surface showing flow lines. (Source :Ground water hydrology by David Keith Todd 2nd edition ,88 PP)

Contour maps of ground water levels together with flow lines are useful data for locating areas of favorable hydraulic conductivity. Convex contours indicate regions of ground water recharge while concave contours are associated with ground water discharge. Furthermore, areas of favorable hydraulic conductivity can be ascertained from the spacing of contours. The procedure can be illustrated by treating two adjacent flow lines as impermeable boundaries because there can be no flow across a flow line. if the aquifer is uniformly thick the flow at sections 1 and 2 (Figure 5) equals:

$$q = w_1 v_1 = w_2 v_2$$

Where v is velocity and W is the width of the flow section perpendicular to the flow. From Darcy's law

$$w_1 k_1 i_1 = w_2 k_2 i_2$$

Which can be rewritten

$$\frac{k_1}{k_2} = \frac{w_2 i_2}{w_1 i_1}$$

Where K is hydraulic conductivity and i is hydraulic gradient. The rations W_2/ W_1 and i_2/i_1 can be estimated from the water level contour map (Figure 5) for the special case of nearly parallel flow lines, the above equation reduces to

$$\frac{k_1}{k_2} = \frac{i_2}{i_1} \text{………………}(2.8)$$

Which may be interpreted as indicating that in an area of uniform groundwater flow areas with wide contour spacing's (flat gradients) possess higher hydraulic conductivities than those with narrow spacing's (steep gradients). Therefore, in the figure above prospects for a productive well are better near section 2 than 1.(Todd,2007)

2.4 PUMPING TESTS

2.4.1 THE PRINCIPLE

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 . Kruseman et.al. (2000)

2.4.2 DURATION OF THE PUMPING TEST

The question of how many hours to pump the well in a pumping test is difficult to answer because the period of pumping depends on the type of aquifer and the degree of accuracy desired in establishing its hydraulic characteristics. Economizing on the period of pumping is not recommended because the cost of running the pump a few extra hours is low compared with the total costs of the test. Besides, better and more reliable data are obtained if pumping continues until steady or pseudo-steady flow has been attained. At the beginning of the test, the cone of depression develops rapidly because the pumped water is initially derived from the aquifer storage immediately around the well. But as pumping continues, the cone expands and deepens more slowly because, with each additional meter of horizontal expansion, a larger volume of stored water becomes available. This apparent stabilization of the cone often leads inexperienced observers to conclude that steady state has been reached. Inaccurate measurements of the drawdown in the piezometers - drawdown that are becoming smaller and smaller as pumping continues - can lead to the same wrong conclusion. In reality, the cone of depression will continue to expand until the recharge of the aquifer equals the pumping rate.

In some tests, steady-state or equilibrium conditions occur a few hours after the start of pumping; in others, they occur within a few days or weeks; in yet others, they never occur, even though pumping continues for years. It is our experience that, under average conditions, a steady state is reached in leaky aquifers after 15 to 20 hours of pumping; in a confined aquifer, it is good practice to pump for 24 hours; in an unconfined aquifer, because the cone of depression expands slowly, a longer period is required, say **3** days. Kruseman et.al. (2000)

2.4.3 PROCESSING THE DATA

CONVERSION OF THE DATA

The water-level data collected before, during, and after the test should first be expressed in appropriate units. The measurement units of the International System are recommended , but there is no fixed rule for the units in which the field data and hydraulic characteristics should be expressed. Transmissivity, for instance, can be expressed in m2/s or m2/d. Field data are often expressed in units other than those in which the final results are presented. Time data, for instance, might be expressed in seconds during the first minutes of the test, minutes during the following hours, and actual time later on, while water-level data might be expressed in different units of length appropriate to the timing of the observations.

It will be clear that before the field data can be analyzed, they should first be converted: the time data into a single set of time units (e.g. minutes) and the drawdown data into a single set of length units (e.g. meters), or any other unit of length that is suitable . Kruseman et.al. (2000)

CORRECTION OF THE DATA

Before being used in the analysis, the observed water levels may have to be corrected for external influences (i.e. those not related to the pumping). To find out whether this is necessary, one has to analyze the local trend in the hydraulic head or water table. The most suitable data for this purpose are the water-level measurements taken in a ‘distant’ piezometer during the test, but measurements taken at the test site for some days before and after the test can also be used.

If, after the recovery period, the same constant water level is observed as during the pre-testing period, it can safely be assumed that no external events influenced the hydraulic head during the test. If, however, the water level is subject to unidirectional or rhythmic changes, it will have to be corrected. Kruseman et.al. (2000)

INTERPRETATION OF THE DATA

Calculating hydraulic characteristics would be relatively easy if the aquifer system (i.e. aquifer plus well) were precisely known. This is generally not the case, so interpreting a pumping test is primarily a matter of identifying an unknown system. System identification relies on models, the characteristics of which are assumed to represent the characteristics of the real aquifer system.

Theoretical models comprise the type of aquifer , and initial and boundary conditions. Typical outer boundary conditions & Inner boundary conditions are associated with the pumped well (e.g. fully or partially penetrating, small or large diameter, well losses). In a pumping test, the type of aquifer and the inner and outer boundary conditions dominate at different times during the test. They affect the drawdown behavior of the system in their own individual ways. *So,* to identify an aquifer system, one must compare its drawdown behavior with that of the various theoretical models. The model that compares best with the real system is then selected for the calculation of the hydraulic characteristics.

System identification includes the construction of diagnostic plots and specialized plots. Diagnostic plots are log-log plots of the drawdown versus the time since pumping started. Specialized plots are semi-log plots of drawdown versus time, or drawdown versus distance to the well; they are specific to a given flow regime. A diagnostic plot allows the dominating flow regimes to be identified; these yield straight lines on specialized plots. The characteristic shapes of the curves can help in selecting the appropriate model. In a number of cases, a semi-log plot of drawdown versus time has more diagnostic value than a log-log plot. In this evaluation it is therefore recommend that both types of graphs to be constructed.

The choice of 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. A troublesome fact is that theoretical solutions to well-flow problems are usually not unique. Some models, developed for different aquifer systems, yield similar responses to a given stress exerted on them. This makes system identification and model selection a difficult affair. One can reduce the number of alternatives by conducting more field work, but that could make the total costs of the test prohibitive. In many cases, uncertainty as to which model to select will remain. We shall discuss this problem briefly below. Kruseman et.al. (2000)

AQUIFER CATEGORIES

Aquifers fall into two broad categories: unconsolidated aquifers and consolidated fractured aquifers. Within both categories, the aquifers may be confined, unconfined, or leaky. Figure below shows log-log and semi-log plots of the theoretical time-drawdown relationships for confined, unconfined, and leaky unconsolidated aquifers. These graphs are presented in pairs because, although log-log plots are diagnostic, as the oil industry states, It is believed that semi-log plots can sometimes be even more diagnostic. This becomes clear if we look at Parts A and A' of the figure. These refer to an ideal, confined, unconsolidated aquifer, homogeneous and isotropic, and pumped at a constant rate by a fully penetrating well of very small diameter. From the semi-log plot (Part A'), we can see that the time-drawdown relationship at early pumping times is not linear, but at later times it is. If a linear relationship like this is found, it should be used to calculate the hydraulic characteristics because the results will be much more accurate than those obtained by matching field data plots with the curve of Part A.

Parts B and B' of the figure below show the curves for an unconfined, homogeneous, isotropic aquifer of infinite lateral extent and with a delayed yield. These two curves are characteristic. At early pumping times, the curve of the log-log plot (Part B) follows the curve for the confined aquifer shown in Part A. Then, at medium pumping times, it shows a flat segment. This reflects the recharge from the overlying, less permeable aquifer, which stabilizes the drawdown. At late times, the curve again follows a portion of the curve of Part A. The semi-log plot is even more characteristic: it shows two parallel straight-line segments at early and late pumping times.

Parts C and C’ of the figure below refer to a leaky aquifer. At early pumping times, the curves follow those of Parts A and A’. At medium pumping times, more and more water from the aquitard (or aquitards) is reaching the aquifer. Eventually, at late pumping times, all the water pumped is from leakage through the aquitard(s), and the flow towards the well has reached a steady state. This means that the drawdown in the aquifer stabilizes, as is clearly reflected in both graphs. Kruseman et.al. (2000)

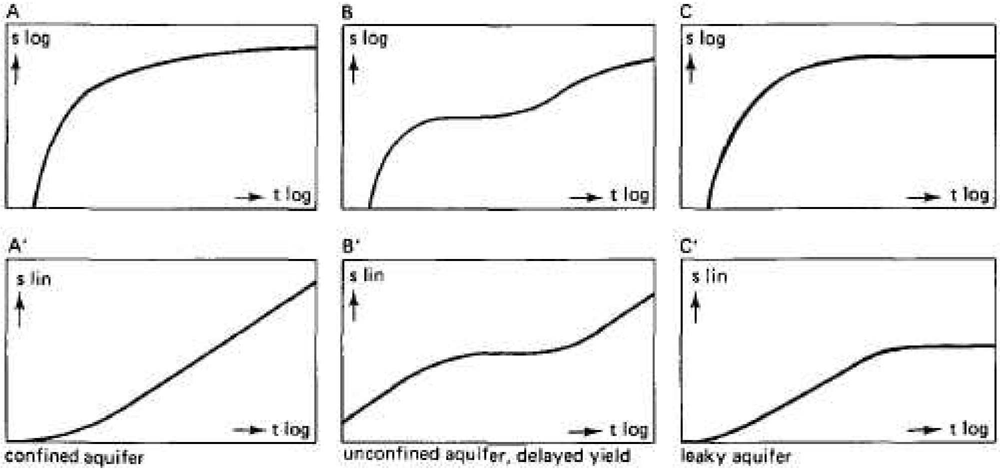

FIGURE 6: Log-log and semi-log plots of the theoretical time- drawdown relationships of unconsolidated aquifers: (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 49 PP)

SPECIFIC BOUNDARY CONDITIONS

When field data curves of drawdown versus time deviate from the theoretical curves of the main types of aquifer, the deviation is usually due to specific boundary conditions (e.g. partial penetration of the well, well-bore storage, recharge boundaries, or impermeable boundaries). Specific boundary conditions can occur individually (e.g. a partially penetrating well in an otherwise homogeneous, isotropic aquifer of infinite extent), but they often occur in combination (e.g. a partially penetrating well near a deeply incised river or canal). Obviously, specific boundary conditions can occur in all types of aquifers. Kruseman et.al. (2000)

Partial penetration of the well

Theoretical models usually assume that the pumped well fully penetrates the aquifer, so that the flow towards the well is horizontal. With a partially penetrating well, the condition of horizontal flow is not satisfied, at least not in the vicinity of the well. Vertical flow components are thus induced in the aquifer, and these are accompanied by extra head losses in and near the well. Figure below shows the effect of partial penetration. The extra head losses it induces are clearly reflected. Kruseman et.al. (2000)

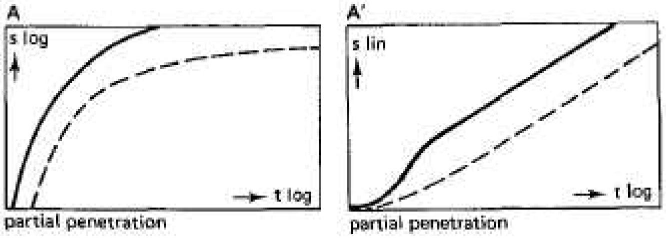

FIGURE 7: the effect of the well's partial penetration on the time –drawdown relationship in an unconsolidated, confined aquifer. The bashed curves are those of parts A and A of figure 6 (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 52 PP)

Well-bore storage

All theoretical models assume a line source or sink, which means that well-bore storage effects can be neglected. But all wells have a certain dimension and thus store some water, which must first be removed when pumping begins. The larger the diameter of the well, the more water it will store, and the less the condition of line source or sink will be satisfied. 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. In a log-log plot of drawdown versus time, the effect of well-bore storage is reflected by a straight-line segment with a slope of unity.

If a pumping test is conducted in a large-diameter well and drawdown data from observation wells or piezometers are used in the analysis, it should not be forgotten that those data will also be affected by the well-bore storage in the pumped well. At early pumping time, the data will deviate from the theoretical curve, although, in a log-log plot, no early-time straight-line segment of slope unity will appear. Figure 8 shows the effect of well-bore storage on time-drawdown plots of observation wells or piezometers. Kruseman et.al. (2000)

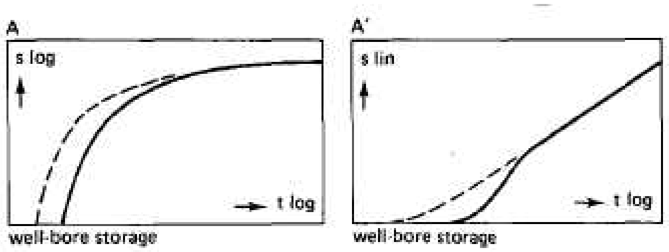

FIGURE 8: The effect of well-bore storage in the pumped well on the theoretical time-drawdown plots of observation wells or piezometers. The dashed curves are those of parts A and A of Figure 6 (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 52 PP)

Recharge or impermeable boundaries

The theoretical curves of all the main aquifer types can also be affected by recharge or impermeable boundaries. This effect is shown in figure below. Parts A and A' of the figure show a situation where the cone of depression reaches a recharge boundary. When this happens, the drawdown in the well stabilizes. The field data curve then begins to deviate more and more from the theoretical curve, which is shown in the dashed segment of the curve. Impermeable (no-flow) boundaries have the opposite effect on the drawdown. If the cone of depression reaches such a boundary, the drawdown will double. The field data curve will then steepen, deviating upward from the theoretical curve. This is shown in Parts B and B' of figure below. Kruseman et.al. (2000)

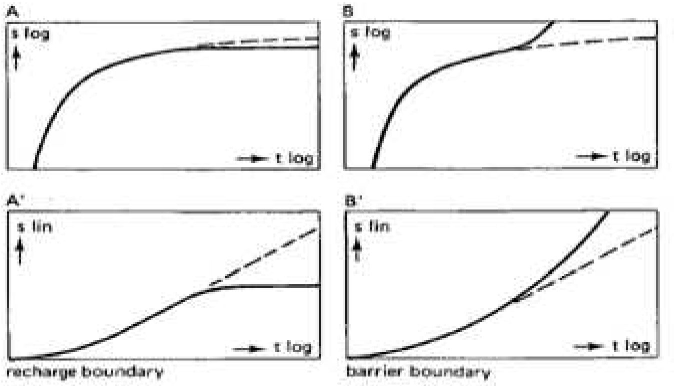

FIGURE 9: the effect of a recharge boundary (Parts A and A') and an impenetrable boundary parts B and B') on the theoretical time- drawdown relationship in a confined unconsolidated aquifer. The dashed curves are those of parts A and A' of Figure 6 (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 53 PP)

2.4.4 Methods for evaluating pumping tests in confined aquifers

When a fully penetrating well pumps a confined aquifer (Figure 10), the influence of the pumping extends radially outwards from the well with time, and the pumped water is withdrawn entirely from the storage within the aquifer. In theory, because the pumped water must come from a reduction of storage within the aquifer, only unsteady-state flow can exist. In practice, however, the flow to the well is considered to be in a steady state if the change in drawdown has become negligibly small with time. Methods for evaluating pumping tests in confined aquifers are available for both steady-state flow and unsteady-state flow **.**

The assumptions and conditions underlying the methods are:

1) The aquifer is confined;

2) The aquifer has a seemingly infinite areal extent;

3) The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;

4) Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test;

5) The aquifer is pumped at a constant discharge rate;

6) Well penetrates the entire thickness of the aquifer & thus receives water by horizontal flow. And, in addition, for unsteady-state methods:

7) The water removed from storage is discharged instantaneously with decline of head;

8) The diameter of the well is small, i.e. the storage in the well can be neglected. Kruseman et.al. (2000)

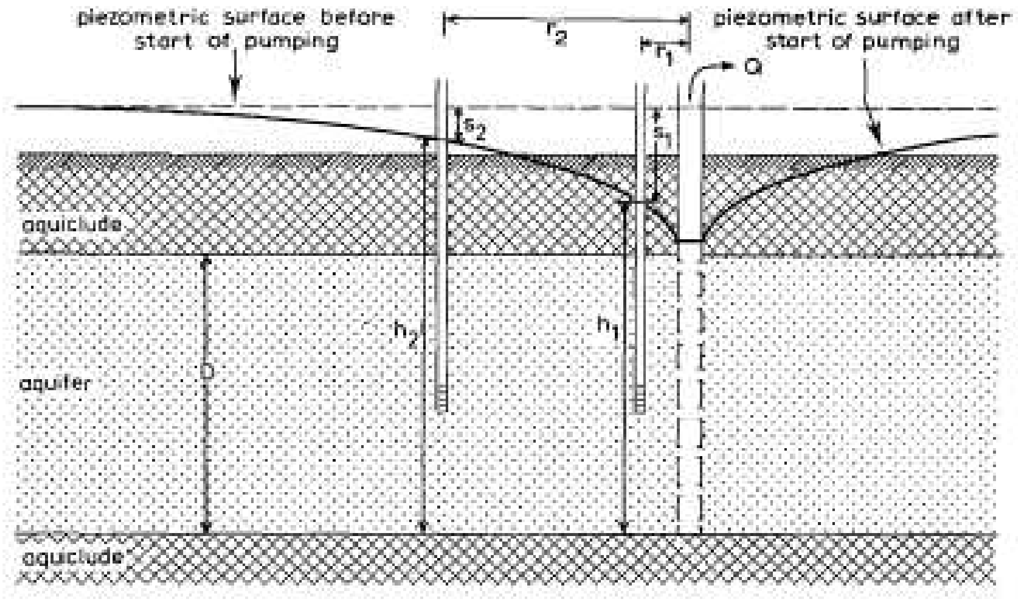

FIGURE 10: Cross-section of **a** pumped confined aquifer (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 53 PP)

A. Theis method(Unsteady-state flow)

Theis (1935) was the first to develop a formula for unsteady-state flow that introduces the time factor and the storativity. He noted that when a well penetrating an extensive confined aquifer is pumped at a constant rate, the influence of the discharge extends outward with time. The rate of decline of head, multiplied by the storativity and summed over the area of influence, equals the discharge.

The unsteady-state (or Theis) equation, which was derived from the analogy between the flow of groundwater and the conduction of heat, is written as

$$s = \frac{Q}{4\text{®}KD}\int_{u}^{u)} \frac{e^{-y}\,dy}{y} = \frac{Q}{4\text{®}KD}\,\mathrm{W(u)} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...2.9$$

Where

s = the drawdown in m measured at a distance r in m from the well

Q= the constant well discharge in m^3/d

KD= the transmissivity of the aquifer in m^2/d

u = r^2S / 4KDt and consequently **S=** 4KDtu / r^2

S = the dimensionless storativity of the aquifer

t = the time in days since pumping started

r = the distance between the well & observation well in m

From the above Equation, it will be seen that, if s can be measured for one or more values of r and for several values of t , and if the well discharge Q is known, S and KD can be determined. The presence of the two unknowns and the nature of the exponential integral make it impossible to effect an explicit solution.

Using Equations 2.9 , Theis devised the ‘curve-fitting method’ (Jacob 1940) to determine S and KD. Theis’s curve-fitting method is based on the assumptions above and on the following limiting condition:

The flow to the well is in unsteady state, i.e. the drawdown differences with time are not negligible, nor is the hydraulic gradient constant with time.

Remarks

- When the hydraulic characteristics have to be calculated separately for each piezometer, a plot of s versus t or s versus 1/t for each piezometer is used with a type curve W(u) versus 1 /u or W(u) versus u, respectively;
- In applying the Theis curve-fitting method, and consequently all curve-fitting methods, one should, in general, give less weight to the **early data** because they

may not closely represent the theoretical drawdown equation on which the type curve is based. Among other things, the theoretical equations are based on the assumptions that the well discharge remains constant and that the release of the water stored in the aquifer is immediate and directly proportional to the rate of decline of the pressure head. In fact, there may be a time lag between the pressure decline and the release of stored water, and initially also the well discharge may vary as the pump is adjusting itself to the changing head. This probably causes initial disagreement between theory and actual flow. As the time of pumping extends, these effects are minimized and closer agreement may be attained;

- If the observed data on the logarithmic plot exhibit a flat curvature, several apparently good matching positions, depending on personal judgment, may be obtained. In such cases, the graphical solution becomes practically indeterminate and one must resort to other methods. Kruseman et.al. (2000)

B. Cooper & Jacob method (Unsteady-state flow)

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

$$S = \frac{Q}{4\text{®}KD} W(u) = \frac{Q}{4\text{®}KD}(-0.5772 - In u + u - \frac{u^2}{2.2:} + \frac{u^3}{3.3:} - ...) \text{ ………..(2.10)}$$

From $u = r^2 S/4KDt$, 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 In 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

$$S = \frac{Q}{4\text{®}KD}(-0.5772 - In \frac{r^2 S}{4KDt}) \quad \text{…………… (2.11)}$$

With

an error less than	1%	2%	5%	10%
For u smaller than	0.03	0.05	O. 1	0.15

Because Q, KD, and S are constant, if we use drawdown observations at a short distance r from the well, a plot of drawdown S versus the logarithm of t forms a straight line (Figure 11). If this line is extended until it intercepts the time-axis where s = 0, the intercept point has the coordinates s = 0 and t = t_o. Substituting these values into the Equation 2.11 gives:

$$S = \frac{2.25KDt_0}{r^2} \text{ …………………….. (2.12)}$$

$$KD = \frac{2.30Q}{4®\Delta S} \text{ ………………………… (2.13)}$$

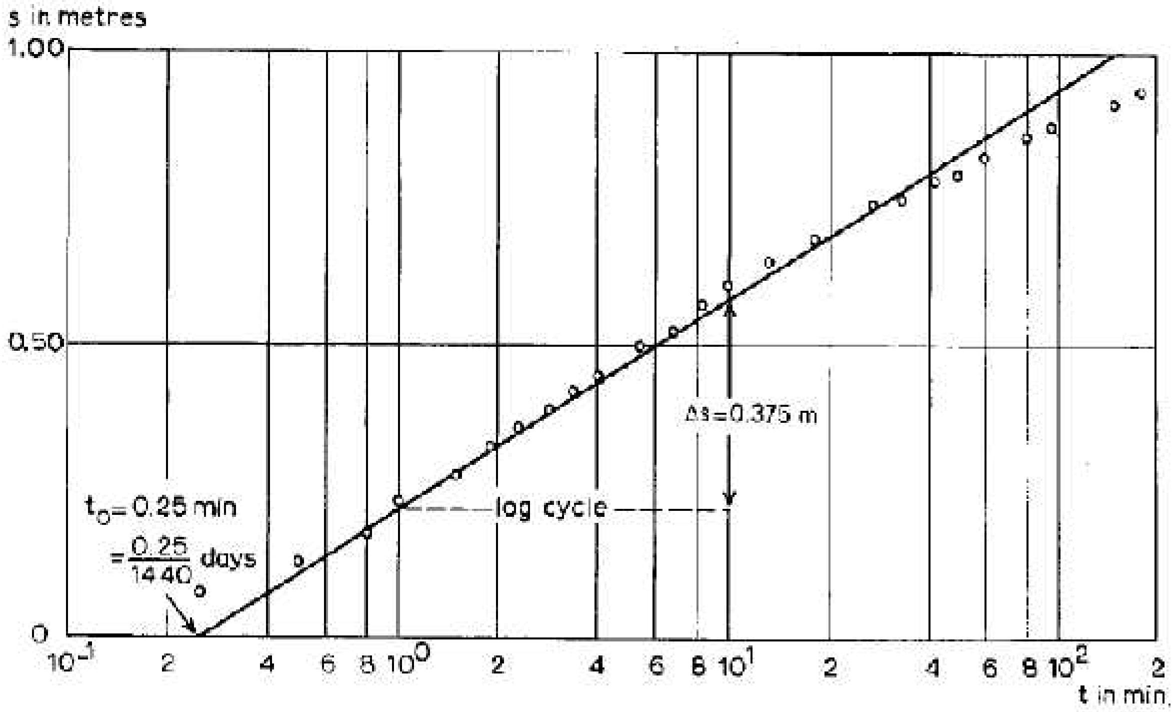

FIGURE 11: Analysis of pumping test data with the Jacob method . (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 66 PP)

The following assumptions and conditions should also be satisfied in order to apply Jacob

- The assumptions listed at the beginning of this topic;
- 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 $u <$ O. l), 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. For all practical purposes, therefore, we suggest using $u < 0.1$ as a condition for Jacob's method.
When the values of KD and S are determined, they are introduced into the equation $u = r^2S/4KDt$ to check whether $u < 0.1$, which is a practical condition for the applicability of the Jacob method. Kruseman et.al. (2000)

In comparing the cooper- Jacob solution with the Theis solution, as these are graphical methods of solution, there will often be a slight variation in the solutions, depending upon the accuracy of the graph construction and subjective judgments in matching field data to type curves. An aquifer test may be made even if no observation wells exists. In this case , drawdown must be measured in the pumping well. Energy losses occur as the water rushes into the well , so that the head in the aquifer is higher than the water level in the pumping well .**For this reason ,aquifer storativity cannot be determined** ; however , a plot of drawdown versus time for the pumping well can be used to determine aquifer transmissivity . **The cooper- Jacob method is preferred for this analysis as it will remove the influence of factors that deviate from the ideal** , such as turbulent flow , well skins , and partial penetration (Butler 1990) . It important that the well be pumped at a constant rate ,as any slight fluctuations will immediately affect the water level in the well. Likewise ,drawdown data for the start of pumping are affected by the volume of water stored in the well casing. At the start of pumping , the water comes from storage within the well casing rather than from the aquifer , especially if the well diameter is large with respect to the rate of pumping . The measured drawdown data should be adjusted to compensate for this factor (Schafer 1978).

If because of turbulent well losses as the water enters the well , the drawdown inside well is significantly greater than the drawdown in the formation just outside the well, use of time-drawdown data from a single well pump test will understate the formation transmissivity. This can be overcome by measuring the recovery of the water level in the well after the pump has been shutdown. Time-recovery data can be plotted and the aquifer transmissivity determined. Fetter(2001)

2.4.5 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 12 below shows the change in water level with time during and after a pumping test. 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 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 . Kruseman et.al. (2000)

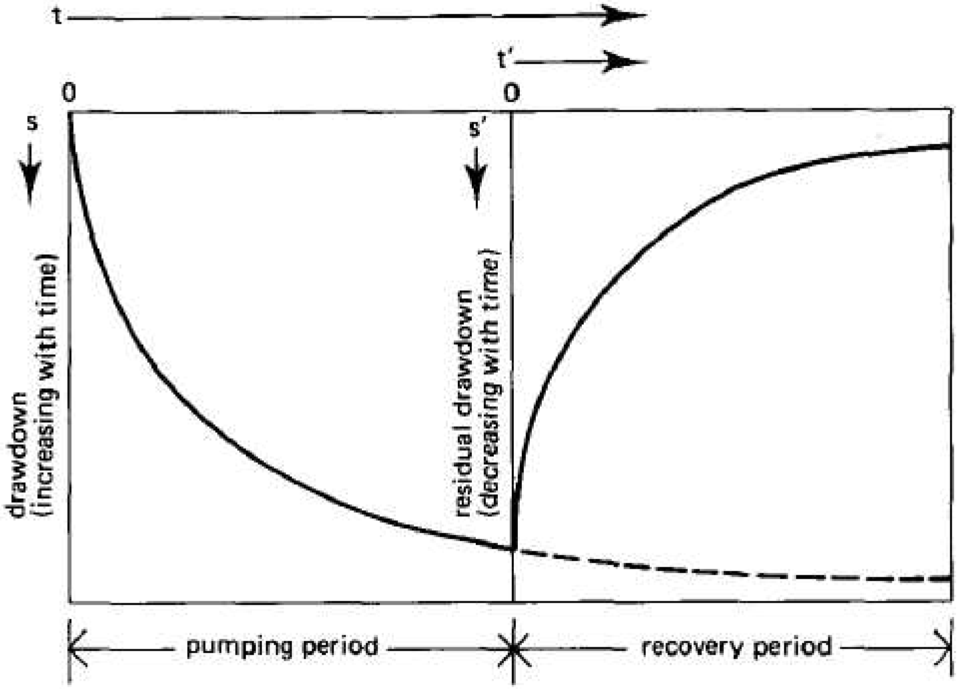

FIGURE 12: Time drawdown and residual drawdown (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 193 PP)

2.4.6 PARTIALLY PENETRATING WELLS

Some aquifers are so thick that it is not justified to install a fully penetrating well. Instead, the aquifer has to be pumped by a partially penetrating well. Because partial penetration induces vertical flow components in the vicinity of the well, the general assumption that the well receives water from horizontal flow is not valid. 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. It is negligible if measured at a distance that is 1.5 to 2 times greater than the saturated thickness of the aquifer, depending on the amount of penetration. If the aquifer has obvious anisotropy on the vertical plane, the effect is negligible at distances $r > 2D(K_h / K_V) \wedge 1/2.$ Hence, the standard methods of analysis cannot be used for $r < 2D(K_h / K_v) \wedge 1/2$ unless allowance is made for partial penetration. For long pumping times (t > DS/2K), the effects of partial penetration reach their maximum value for a particular well/piezometer configuration and then remain constant. Where r = distance of the piezometer from the well , D = Saturated thickness ,K_h = hydraulic conductivity for horizontal flow, in m/d, K_v = hydraulic conductivity for vertical flow, in m/d, t = the time in days since pumping started , S = the dimensionless storativity of the aquifer & K = hydraulic conductivity of the aquifer , in m/d.

The Theis recovery method can be used if the well is only partially penetrating. For long pumping times in such a well, i.e. t, > **$(D^2S)/2KD$,** the semi-log plot of **s** versus t yields a straight line with a slope identical to that of a completely penetrating well (Hantush 1961b). Thus, if the straight line portion of the recovery curve is long enough, i.e. if both t, and t' are greater than **(10 D2S)/KD,** the Theis recovery method can be applied (Uffink 1982).

Muskat (1932, 1937)determined the potential distribution for steady flow to the partially penetrating well shown in figure below part c (or part a with b2 =0) he integrates point sinks along the well's screen and employs the method of images to introduce the effect of the impervious bottom and ceiling of a confined aquifer. The assumption of uniform distribution of inflow along the screen leads to a result in which the well's screen is not an equipotential surface.

Actually in addition to the ordinary flux contribution of a radial character entering each unit length along the well the lower parts receive most of the flux coming from that part of the aquifer which is not penetrated by the well. This additional flux is not uniformly distributed along the well; it is more concentrated near its extremities. To reduce the error introduced by this non uniform distribution. Muskat introduce correction factors. Under certain conditions, he obtains:

$$H - \phi_w = \frac{Q_w}{4\pi}\frac{b}{b_s}\left[2\ln\left(\frac{4B}{r_w}\right) - G\left(\frac{b_s}{B}\right) - 2\left(\frac{b_s}{B}\right)\ln\left(\frac{4B}{R}\right)\right]$$

$$G\left(\frac{b_s}{B}\right) = \frac{\Gamma\left(0.875\frac{b_s}{B}\right)\Gamma\left(0.125\frac{b_s}{B}\right)}{\Gamma\left(1-0.875\frac{b_s}{B}\right)\Gamma\left(1-0.125\frac{b_s}{B}\right)}$$

Where H=static water level , ϕ_w= head at the well, Q $_w$ = well discharge , b $_s$ = screen length, r_w = radius of the well , G= tensoral field, Γ = segment of the total boundary. Kozeny. (1933) summarized Muskat analysis by a somewhat simpler empirical expression which is sufficiently accurate for most practical cases.

$$S_w = \frac{1}{C} * \frac{Q_w}{2\pi} \ln \frac{R}{r_w}$$

$$C = \left(\frac{b_s}{B}\right)\left[1 + 7\left(\frac{r_w}{2b_s}\right)^{\frac{1}{2}} \cos\left(\frac{\pi \ _s}{2B}\right)\right] \text{..................} \ (2.14)$$

Where S_w is the drawdown in the pumped well. From the equation of partially penetrating well & from equation of a fully penetrating well it follows that for the same drawdown S_w, C is the ratio between Q $_w$ of a partially penetrating well and that a fully penetrating one. The correction C was also given by Wenzel (1942).

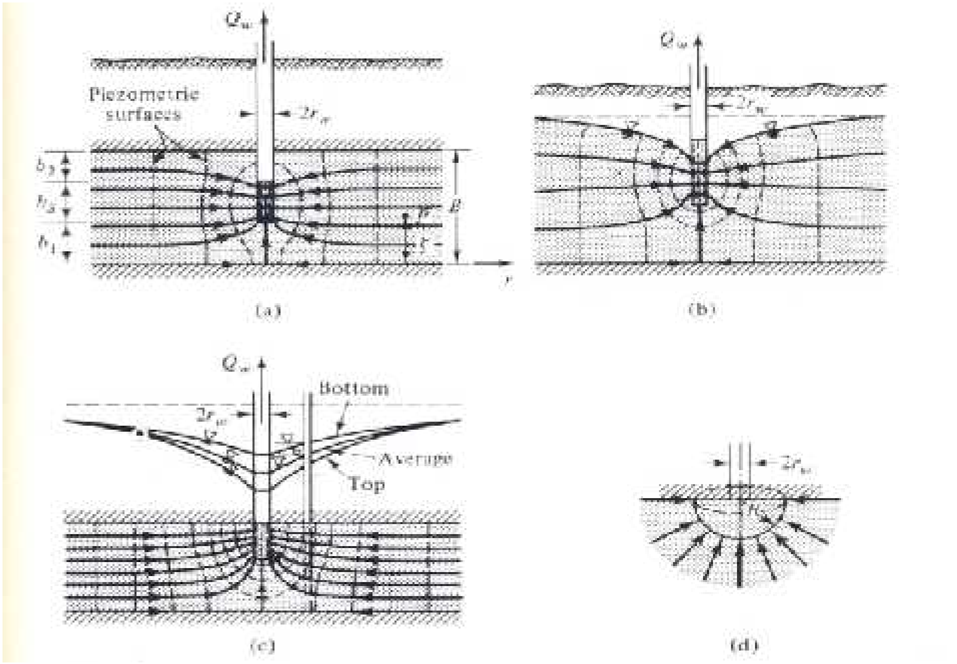

FIGURE 13: partially penetrating wells (a) in a confined aquifer (b) in a phreatic aquifer (c) draw -dawn curves along a streamlines (d) zero penetration in a thick aquifer. (Source: hydraulics of groundwater by Jacob Bear, 345 PP)

2.4.7 SINGLE-WELL TESTS

A single-well test is a test in which no piezometers are used. Water-level changes during pumping or recovery are measured only in the well itself. The drawdown in a pumped well, however, is influenced by well losses and well-bore storage. In the hydraulics of well flow, the well is generally regarded as a line source or line sink, i.e. the well is assumed to have an infinitesimal radius so that the well-bore storage can be neglected. In reality, any well has a finite radius and thus a certain storage capacity. Well-bore storage is large when compared with the storage in an equal volume of aquifer material. In a single-well test, well-bore storage must be considered when analyzing the drawdown data.

Papadopoulos and Cooper (1967) observed that the influence of well-bore storage on the drawdown in a well decreases with time and becomes negligible at $t > 25 r_c^2 / KD,$ where r_c is the radius of the unscreened part of the well, where the water level is changing.

To determine 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 made. If the early-time drawdown plot as a unit-slope straight line, we can conclude that wellbore storage effects exist.

The Papadopoulos-Cooper curve-fitting method and Rushton-Singh's modified version of it are applicable for confined aquifers. Jacob's straight-line method , does not require any corrections for nonlinear well losses and can be used for confined or leaky aquifers, and so also can Hurr-Worthington's approximation method . All four methods are applicable if the early-time data are affected by well-bore storage, provided that sufficient late-time data $(t > 25 r_c^2 / KD,)$ are also available.

A recovery test is invaluable if the pumping test is performed without the use of piezometers. The methods for analyzing residual drawdown data are straight-line methods. The transmissivity of the aquifer is calculated from the slope of a semi-log straight-line, i.e. from differences in residual drawdown. Those influences on the residual drawdown that are or become constant with time, i.e. well losses, partial penetration, do not affect the calculation of the transmissivity. The methods presented in recovery test are also applicable to single-well recovery test data. In applying these methods, one must make allowance for those influences on the residual drawdown that do not become constant with time, e.g. well-bore storage. Kruseman et.al. (2000)

Confined and leaky aquifers, Jacob's straight-line method

Jacob's straight-line method can also be applied to single-well constant discharge tests to estimate the aquifer transmissivity. However, not all the assumptions underlying the Jacob method are met if data from single-well tests are used. Therefore, the following additional conditions should also be satisfied:

- For single-well tests in confined aquifers

$$t > 25 r_c^2 / KD \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.15}$$

If this time condition is met, the effect of well-bore storage can be neglected;

- For single-well tests in leaky aquifers

$$\frac{25 r_c^2}{KD} < t < \frac{cS}{20} \left(= \frac{L^2 S}{20KD}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.16}$$

As long as t < CS/20, the influence of leakage is negligible. Where C=hydraulic resistance of the aquitard .

Remarks

- The drawdown in the well reacts strongly to even minor variations in the discharge rate. Therefore, a constant discharge is an essential condition for the use of the Jacob method;
- There is no need to correct the observed drawdown for well losses before applying the Jacob method; the aquifer transmissivity is determined from drawdown differences ΔS_w which are not influenced by well losses as long as the discharge is constant;

- In theory, Jacob's method can also be applied if the well is partially penetrating, provided that late-time ($t > D^2S/2KD$) data are used. According to Hantush (1964), the additional drawdown due to partial penetration will be constant for t > D2S/2KD and hence will not influence the value of Δs, as used in Jacob’s method;
- Instead of using the time condition $t > 25r^2_c / KD$ to determine when the effect of well-bore storage can be neglected, we can use the ‘one and one-half log cycle rule of thumb’ (Ramey 1976). On a diagnostic log-log plot, the early-time data may plot as a unit-slope straight line ($\Delta S_w/\Delta t = l$), indicating that the drawdown data are dominated by well-bore storage. According to Ramey, the end of this unit-slope straight line is about 1.5 log cycles prior to the start of the semi-log straight line as used in the Jacob method.

Theis’s recovery method

The Theis recovery method is also applicable to data from single-well recovery tests conducted in confined, leaky or unconfined aquifers. The method can be used if the following assumptions and conditions are met:

- The assumptions & condition underlying the methods for evaluating pumping tests, adjusted for recovery tests, with the exception of the assumption that require the diameter of the well to be small, i.e. the storage in the well can be neglected is replaced by:

$$t_p > 25\, r_c^2 / KD;$$

$$t^{'} > 25\, r_c^2 / KD,$$

For unconfined aquifers only late-time recovery data can be used ;

- The flow to the well is in an unsteady state;
- $u < 0.01$, i.e. $t_p > 25\, r^2_w S/KD$;
- $u' < 0.01$, i.e. $t' > 25\, r^2_w S/KD$

Remarks

- Storage in the well may influence S'_w at the beginning of a recovery test. If the conditions $t_p > 25\, r^2_C/KD$ and $t' > 25\, r^2_C/KD$ are met, a semi-log plot of S'_w versus t/t’ yields a straight-line and Theis’s recovery method is applicable. Because the observed recovery data should plot as a straight-line for at least one log cycle of t/t', Uffink (1982) recommends that both t, and t' should be at least 500 r^2_c / KD;

- If the pumped well is partially penetrating, the Theis recovery method can be used, provided that both t, and t' are greater than $D^2S/2KD$.

2.4.8 WELL PERFORMANCE TESTS

Aquifer and Well Losses

The drawdown in a pumped well consists of two components: the aquifer losses and the well 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. The drawdown S_1 corresponding to this linear aquifer loss can be expressed as

$$s_1 = B_{1(r_w 1)} Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.17)}$$

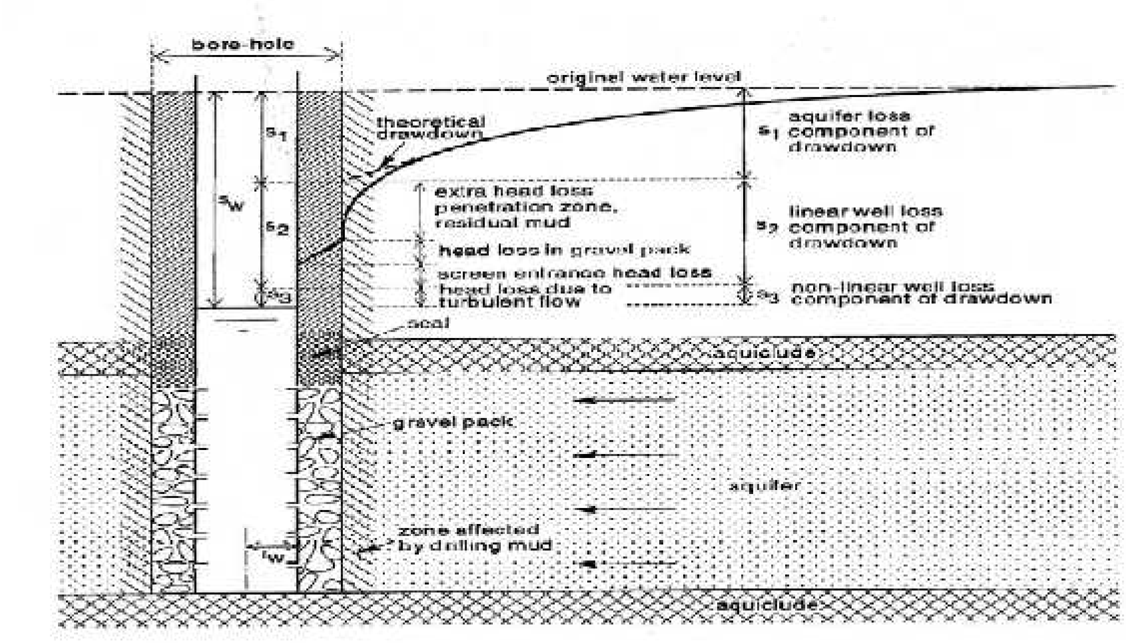

FIGURE 14: Various components of head losses in a pumped well. (Source: analysis and evaluation of pumping test data by G.P. Kruseman and N.A. de Ridder 2nd edition 199 PP)

Where B_1 is the linear aquifer loss coefficient in day/m2. This coefficient can be calculated from the well flow equations. For confined aquifers for example, it can be expressed using Equations

$$B_{1(rwt)} = \frac{W(u)}{4\circledR T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{2.18}$$

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

$$S_2 = B_2 Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \tag{2.19}$$

Where B_2 is the linear well loss coefficient in day/m2.

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

$$S_3 = CQ^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \tag{2.20}$$

Where C is the nonlinear well loss coefficient in day $^P/m^{3P-1}$, 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

$$S_w = (B_1 + B_2)Q + CQ^p = BQ + CQ^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{2.21}$$

Where $S_w = S_1 + S_2 + S_3$ Jacob (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; from personal experience, its value may be even higher in fractured rock aquifers. 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 above can be found from the analysis of so-called step-drawdown tests.

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, Ew, is defined as the ratio of the aquifer head loss to the total head losses; it reads when expressed as a percentage

$$E_w = \left\{ \frac{B_1 Q}{BQ + CQ^P} \right\} X 100\% \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2.22)$$

The well efficiency according to the above Equation 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 the above Equation 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:

$$L_P = \left\{ \frac{BQ}{BQ + CQ^P} \right\} X 100\% \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.23)$$

It should be noted, that Equation above is sometimes erroneously used to calculate the well efficiency.

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.

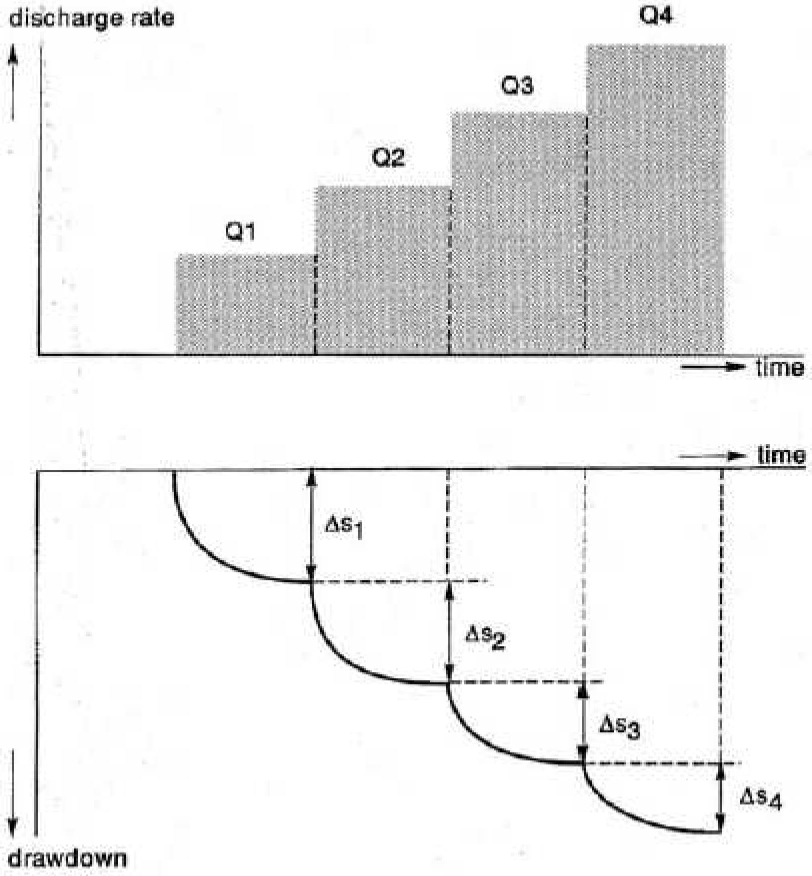

FIGURE 15: Principles of a step-drawdown test. (Source: Hand book of groundwater Engineering Delleur et al.(1999) ,335 PP)

In step-drawdown analyses, use is made of so-called diagnostic plots. Values of 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 $S_w/Q = B$. Equation (2.23) reduces to

$$S_w = BQ \quad \text{………………………………….(2.24)}$$

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 Sw /Q = B + C Q. Equation (2.23) then reduces to

$$S_w = BQ + CQ^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.25)$$

The above equation 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 values of B and C can be found directly from the diagnostic plot of 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.

- The points fall on a curved line, i.e., P ≠ 2 in Equation (2.23). 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.

3. RESEARCH METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

The study area of this research is Akaki well field, situated south of Addis Ababa. It covers a total area of 103 sq kilometer. akaki well field is not an independent & Isolated aquifer it is within a wide ground water basin (WWDSE,2008). Therefore the ground water recharge & Movement into & out of the aquifer of a kaki well field is seen in the context of the wider ground water basin.

The study area has an elevation of 2110-2050 m.a.s.l. It has a geographical zone of 8^0 47' 25''-8^0 53'6'' N and 38^0 44' 00''-38^0 49' 18'' E with geomorphology of flat plain garben with scoria & Vascular Basalt Hills bounded by mountains in NW and SE direction.

The well field according to their time of development is grouped to four well fields & presented in the following table:

TABLE 1:. Name and Number of wells in Akaki well field

S/N	Well Field Name	No of Wells	Remark
1	Old Shallow Well Field	24	Old & Shallow
2	Well Field 01(Phase 2)	24	Connected to the system before 5 years
3	Well Field 03(Phase 3B)	24	Recently connected to the system
4	Well field 02(Phase 3A)	20	On Progress

due to the availability of full & Completed data & also problem found in it well field 01(Phase 2 project) is selected to do this research .

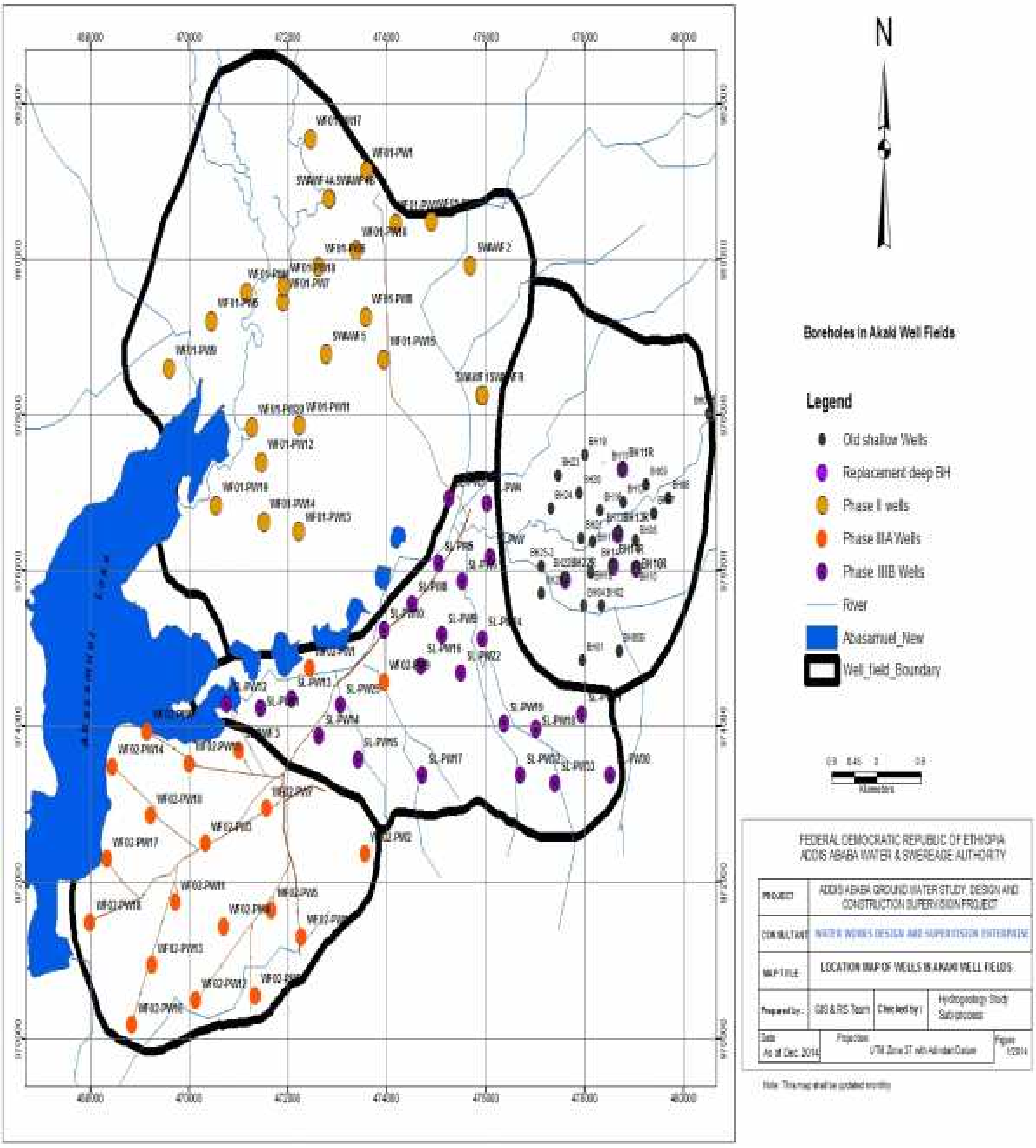

Figure 16 - Location map of the study area (source : A.A.W.S.A. , 2014. Volume IV Well Completion Report of Test Well At Groundwater Prospective Sites).

3.2 DATA COLLECTION

The research utilized both primary and secondary data in evaluating the research problem. The primary data collection includes measuring elevation & Locations of each wells using GPS in order to verify (Cheek) what was measured by the contractors. And also a field visit was done in order to evaluate(to have a general over view of the area) the topography of the area, surface and ground water interaction and the secondary data collection includes collection of well accomplishment report which includes single well pump test results, geological logging, casing arrangement etc from the consultants (WWDSE) . After the data collection they are adjusted, compiled for the evaluation process

3.3 DATA ANALYSIS METHOD.

after the necessary primary & secondary data are collected the analysis was started by checking the data quality .As far as the data quality Concerned some of the pump test data contains non uniform (Up & Down) Draw downs (pw-3,pw-13) and some well show a constant single draw dawn value thrown out the whole time of the pumping test (Constant pump test number 2 of SWAWF-4B) were completely taken out from the evaluation process as they don’t follow or show any theoretical model of any aquifer type.

After the data quality checking the next step was the selection of methods for evaluating the pump test data in order to calculate the required aquifer characteristics of the area. In doing so the following were three methods were selected for analyzing the data

1. **Theis method**
2. **Cooper & Jacob method**
3. **Theis Recovery method**

1. Theis method

Calculating hydraulic characteristics would be relatively easy if the aquifer system (i.e. aquifer plus well) were precisely known. This is not generally not the case, so interpreting a pumping test is primarily a matter of identifying an unknown system. System identification relies on models, the characteristics of which are assumed to represent the characteristics of the real aquifer system, so, to identify an aquifer system, one must compare its draw down behavior with that of the various theoretical models.

The model that compares best with the real system is selected for the calculation of the hydrochloric characteristics.

First in order to categorize the type our aquifer after preparing a log- log & semi-log graph of the pumping test comparison was made with plots of the theoretical time draw down curves from which conclusion was made (except at one well location) that the aquifer of the area is unconfined aquifer . Looking the geological log of each well also confirm this conclusion . In addition from BCECOM 2002 report calculated storage coefficient at the akaki well field ranges b/n 0.02 to 0.006 with mean value of about 0.01. . For the prospective site an average storage Coefficient of 0.02 is considered Since low value of BCEOM do not represent the deep aquifer (WWDSE,2011.Groundwater resources development on prospective sites volume 1 executive summary, ADDIS ABABA ETHIOPIA .PP19).

From all the above reasons conclusion was made the aquifer of the study is to be unconfined aquifer. Even if Theis method was derived for confined aquifer even with a delayed yield effect (an unconfined aquifer) as the time draw dawn curve will eventually exhibit a straight line segment under a slope for late- time condition. So if the pumping time is sufficiently long, the physical properties of an unconfined aquifer can thus also be found by using Theis & also Jacob method provided that the draw down in an unconfined aquifer are large compared to the aquifer saturated thickness need to be corrected .Jacques W.Delleur. et al.(2007).So in the analysis correction for an unconfined was made in order to use Theis confined aquifer formula .

2. Copper Jacob Method

In single well test as there is no observation wells exists , draw down must be measured in the pumping well. Energy losses occurs as the water rushes in to the well, so that the head in the aquifer is higher than the water level in the pumping well. The copper Jacob method is preferred for this analysis as it will remove the influence of factor that deviate from the ideal, such as turbulent flow, well skins, and partial penetration(Butler 1990) . As in our case as all the pump test made were all single well test copper Jacob was used for the above reasons (Fetter ,2001).

Jacob method can also be applied if the well is partially penetrating provided that late time data are used. According to Hantush (1964) the additional drawdown due to a partial penetration will be constant for $t>D^2S/2KD$ and hence will not influence the value of ΔS_w as used in Jacob's method (Kruseman,2000) . Due the above reason and also on order to consider the effect of well bore storage during the evaluation more focus was given to late time data

3 Theis Recover Method

Residual Draw down data are more reliable than pumping test data because recovery occurs at a Constant rate, where as a constant discharge during pumping is often difficult to achieve in the field. 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 aquifer & unconfined aquifer , & aquifer that are only partially penetrated by a well (Kruseman,2000).

The Theis recovery method can also be used if the well is partially penetrating. For long pumping times in such a well i.e. $t>D^2S/2KD$,the semi-log graph of S versus t yields a straight line with a slope identical to that of a completely penetrating well (Hantush 1961b).Thus, if the straight line portion of the recovery is long enough ,i.e. if both t & t' are greater than $10D^2S/KD$ the Theis recover method can also applied. (Kruseman,2000).

Recovery test is invaluable if the pumping test is performed without the use of piezometer. The method for analyzing residual draw down data are straight line method. The transmissivity of the aquifer is calculated from the slope of a semi- log straight line, i.e. from difference in residual draw dawn. Those influences on the residual draw down that are or become constant with time, i.e well losses, and partial penetrations, do not affect the calculation of the transmissivity.

The methods presented in recovery test are also applicable to single – well recovery test data . In applying these methods ,one must make allowance for those influence on the residual draw down that do not become constant with time , e.g. Well bore storage (Kruseman,2000)

In summery more focus was given to the wells that were considered to be with a transmitivity exaggerated as was explained in the statement of the problem but all the wells were evaluated for the sake of checking . During evaluation more focus also was given for late time data & recovery data for all the reasons explained above . While looking the pump test made by the contractors only for three wells that have step drawdown test without problems were found ,for them correction for well loss (design , construction & partial penetration effects) was made from the efficiency calculated from the step draw down test while for the rest of the well i.e. wells without having step draw down test correction is only done using kozeny correction factor for partial penetration . finally correction for unconfined aquifer was done for all the pumps . For pump test results which have different slope during the early & late time pumping , they were considered separately to get a reasonable result of the aquifer characteristics . At last in evaluating the data after the decision was made which method of evaluation to be used the data are analyzed using basic Excel spread sheet & Aquifer Test 3.5 was also used for uncorrected data to confirm that the original analysis to be evaluated was made with this data's(APPENDEX C). Finally the flow chart of the research methodology is presented in the following figure.

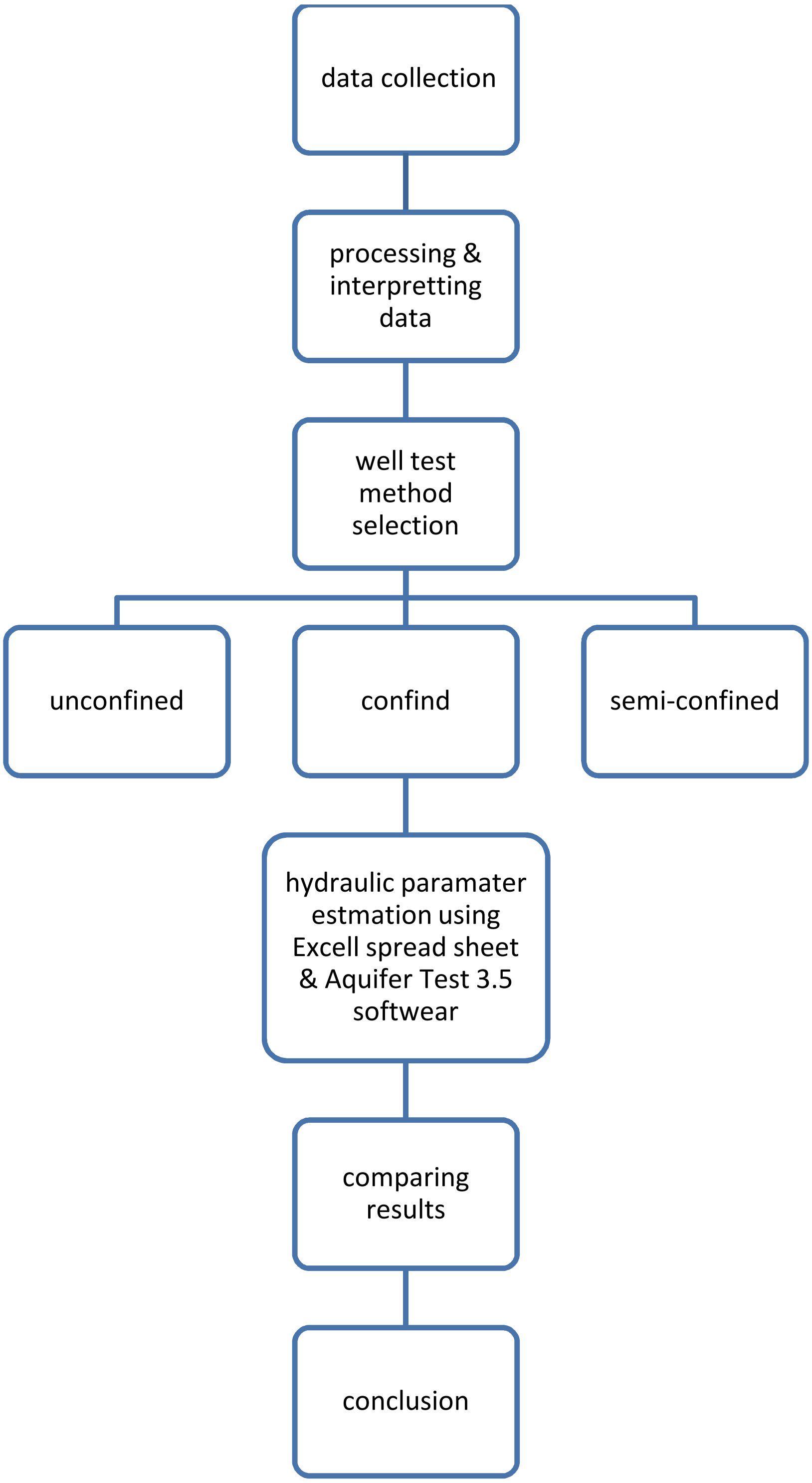

FIGURE 17 : Flow chart of the research methodology

4. RESULT AND DISCUSSION

4.1 WELL INFORMATION

The study area of this research is Akaki well field, situated south of Addis Ababa. It covers a total area of 103 sq kilometer and has an elevation of 2100 - 2050 m.a.s.l. It has a geographical zone of 8^0 47' 25"-8^0 53'6" N and 38^0 44' 00"-38^0 49' 18" E with geomorphology of flat plain garben with scoria & Vascular Basalt Hills bounded by mountains in NW and SE direction. The study area has four well fields with a total of 92 wells . The brief description of the selected well field of this research paper i.e. well field 01(Phase 2 project) is presented as follows .

TABLE 2 : SUMMERY OF WELL INFORMATION

No	Well Index	Well type	Coordinate UTM Zone 37 Adindan		Elev, m	Contractor	Depth, m	Static water level, m	Dynamic water level, m	Draw down, m	Q, test, (l/S)	Transmis. (m2/day)
			UTM east	UTM north								
1	SWAWF1R	OBS well	475945	978251	2060	ANBG	416	45.2	156.4	111.2	12.1	47.6
2	SWAWF2	Production well	475697	979915	2055	CGCOC	448	9.5	98.8	89.4	54.5	58.3
3	SWAWF3	Production well	471027	973709	2056	CGCEB	379	44	58.2	14.2	90	1970
4	SWAWF4A	OBS well	472846	980785	2180	CGCOC	120	8.2	60.5	52.3	30	606
5	SWAWF4B	Production well	472836	980785	2058	CGCOC	481	8	16.9	9	90	12900
6	SWAWF5	Production well	472779	978788	2054	ANBG	486	9.7	14.2	4.5	90	34400
7	WF01-PW1	OBS well	473597	981135	2079	ANBG	500	21.7	98.3	76.7	10.5	86.7
8	WF01-PW2	Production well	474204	980459	2069	ANBG	250	21.2	106.1	84.8	62.2	203
9	WF01-PW3	Production well	474918	980486	2073	CGCEB	480	21.8	90.5	68.7	28	575
10	WF01-PW4	Production well	471185	979580	2061	Layne	500	37.38	132.8	95.42	122	96.7
11	WF01-PW5	Production well	470469	979211	2050	Layne	506	14.53	125.01	110.48	140	66.2
12	WF01-PW6	Production well	472630	979912	2058	CGCOC	533	8.4	92.9	84.6	72.9	1590
13	WF01-PW7	Production well	471909	979461	2055	SGEC	500.8	8.8	106.9	98.1	7.25	26.5
14	WF01-PW8	Production well	473583	979260	2063	CGCOC	483.7	17.5	99.9	82.4	50	106
15	WF01-PW9	Production well	469612	978592	2054	Layne	514	23	149.7	126.74	70	81.5
16	WF01-PW11	Production well	472245	977865	2056	ANBG	500	27.5	81.5	54	62.2	105
17	WF01-PW12	Production well	471476	977396	2049	ANBG	480	34.1	39.7	5.6	101	5810
18	WF01-PW13	Production well	472233	976508	2057	CGCEB	400	40.4	105.9	65.5	22	166
19	WF01-PW14	Production well	471521	976630	2050	CGCOC	552	39.7	42	2.3	76.3	2220
20	WF01-PW15	Production well	473944	978722	2066	SGEC	492	30.3	117.9	87.7	40	177
21	WF01-PW16	Production well	473386	980122	2062	CGCOC	549	11.4	143	131	31	65.4
22	WF01-PW17	Production well	472460	981553	2064	SGEC	500	Artesian	85.7	85.7	48.75	107
23	WF01-PW18	Production well	471918	979657	1969	Tana	272	9.32	13.01	3.68	140	16200
24	WF01-PW19	Production well	470557	976837	1972	Tana	269	54.43	109.18	54.75	67	251
25	WF01-PW20	Production well	471289	977837	1978	Tana	500	26.7	127.02	100.32	40	263

4.2 DATA CORRECTION

4.2.1 DATA QUALITY

Data Quality Checking has been done both by preparing semi-log & log-log plots of drawdown versus time, after which comparison was made with theoretical curves. In addition detail inspection of the raw data was also made to see the trends of the drawdown for the presence of any unique values.

All the problems found & decisions made during this evaluation are summarize as follows.

The data collected from constant discharge test of well ID SWAWF- 5 (only pump test number 2), SWAWF- 4B (both single well test of pump test no. 1 & 2) show almost a constant value of draw down in undulating fashion since the start of the test, which even they doesn’t explain that both the aquifers are gaining water from another source, so a decision was made to ignore those data

As explained in the original report to be evaluated due to the malfunction of the deep meter the data from well ID PW-2 were ignored & only the recovery data are evaluated.

In addition data from the constant discharge pump test of well PW-3, PW- 8 & PW- 13 shows significant up & down values of drawdown that limits the ability to match theoretical curves to these data sets, so the most reliable data set used in evaluation was the recovery data.

Finally other than the main problem of not conducting step drawdown in most of the well excavated significant data quality problem of step drawdown test were found an in well PW-4 and PW-3 and decision was made to ignore this data’s.

4.2.2 PARTIAL PENETRATION

Some aquifers are so thick that it is not justified to install a fully penetrating well. Instead, the aquifer has to be pumped by a partially penetrating well. Because partial penetration induces vertical flow components in the vicinity of the well, the general assumption that the well receives water from horizontal flow is not valid. 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.

Kozeny. (1933) proposed a correction factor to consider the effect of the extra head loss that caused by wells that penetrate partially as follows.

$$S_w = \frac{1}{C} * \frac{Q_w}{2\pi} \ln \frac{R}{r_w}$$

$$C = \left(\frac{b_s}{B}\right)\left[1 + 7\left(\frac{r_w}{2b_s}\right)^{\frac{1}{2}} \cos\left(\frac{\pi \; {}_s}{2B}\right)\right]$$

Where S_w is the drawdown in the pumped well. From the above equation of partially penetrating well & from equation of a fully penetrating well it follows that for the same drawdown S_w, C is the ratio between Q_w of a partially penetrating well and that a fully penetrating one.

In this evaluation thesis for well **(PW-7,SWAWF-2 & SWAWF- 4B)** in which step drawdown are conducted first their efficiencies are calculated and then used as a correction factor to correct the measured draw down for well loss. The graphs and calculation of efficiencies of this two wells are presented in the figures and tables below.

For the other wells **(PW-1,PW-6,SWAWF-5,PW-2,PW-4,PW-18,PW-3,PW-8 & PW-13)** in which step drawdown were not conducted first kozeny correction factors (attached in appendix A) are calculated and then used as a correction factor to correct the measured draw down for the extra head loss caused by partial penetration .

4.2.3 UNCONFINED AQUIFER

Jacob (1950) showed that if the drawdown in an unconfined aquifer are small compared to the initial saturated thickness of the aquifer, the condition of horizontal flow toward the well is approximately satisfied, so that Equations for confined aquifers can also be applied to determine the physical properties. The only changes required are that the storativity S be replaced by the specific yield *Sy* of the unconfined aquifer, and that the transmissivity T be defined as the transmissivity of the initial saturated thickness of the aquifer.

When the drawdown in an unconfined aquifer are large compared with the aquifer's original saturated thickness, the observed drawdown need to be corrected before this equations can be used. Jacob (1944) proposed the following correction.

$$S_C = s - \frac{S^2}{2D}$$

where S_C is the corrected drawdown in m, S is the observed drawdown in m, and D is the saturated aquifer thickness in m prior to pumping. This correction is only needed when the maximum drawdown at the end of the test is larger than 5% of the original saturated aquifer thickness.

In this evaluation for all wells **(PW-1,PW-6,SWAWF-5,PW-2,PW-4,PW-18,PW-7,PW-3,PW-8 & PW-13)** by looking their plot of draw down verses time & by studying their well log formation, correction for unconfined was made (attached in appendix B) in order to use confined aquifer formulas for aquifer which are considered to be unconfined

4.3 STEP DRAWDOWN TEST

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.

In step drawdown analysis, use is made of so called diagnostic plots. Values of S_W/Q versus Q are therefore plotted on arithmetic paper, where S_W represents the drawdown at the end of each step. Various configuration of diagnostic plots are than possible. From this possibilities the practical one is when the points fall on a straight line under a slope. This means Sw/Q = B+CQ which reduces to equation:

$$Sw=BQ+CQ^2$$

The above eqn. in known as the Jacob equation. based on this equation., Jacob (1947) develop an analysis method to calculate the value of B & C .

Well efficiency (EW) is defined as the ratio of aquifer head loss (theoretical loss) to the total head loss (Aquifer loss + well loss) . The well efficiency can only be assessed when the results of a step-drawdown are available .

$$\text{¦} = \frac{BQ}{BQ+CQ^2} X100$$

$$\text{¦} = \frac{S_{Aq}}{S_{Total}}$$

$$\text{¦} = \frac{S_{Aq}}{S_{Aq}+S_w}$$

From which $S_w = S_{Aq}(\frac{1}{n}+1)$ ....(1)

As we know $S_{Total} = S_w + S_{Aq}$ ....(2)

Substituting eqn. (1) above in (2) we can conclude that :

$$S_{Aq} = \text{¦}\, S_{Total}$$

In this evaluation thesis for well **(PW-7,SWAWF-2 & SWAWF- 4B)** in which step drawdown are conducted first their efficiencies are calculated and then used as a correction factor to correct the measured draw down for well loss. The graphs and calculation of efficiencies of this three wells are presented in the figures(18A-18F) and tables 3 below.

WELL INDEX PW-7

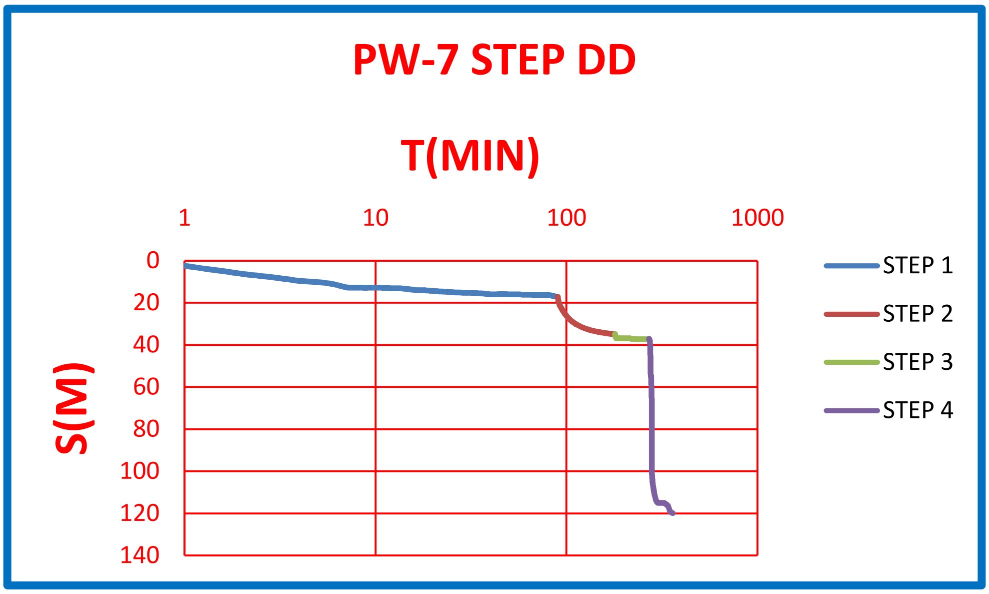

FIGURE 18A:Time-drawdown plot of field data of a step drawdown test well PW-7

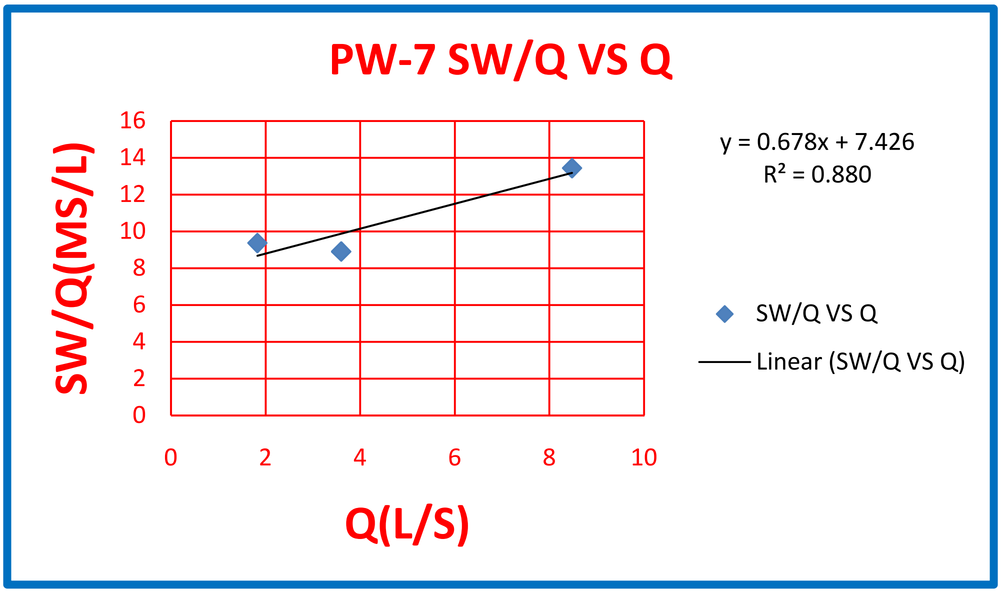

FIGURE 18B: Diagnostic plot Sw/Q versus Q of PW-7 field data of a step-drawdown test with the Jacob's analysis method.

WELL INDEX SWAWF-2

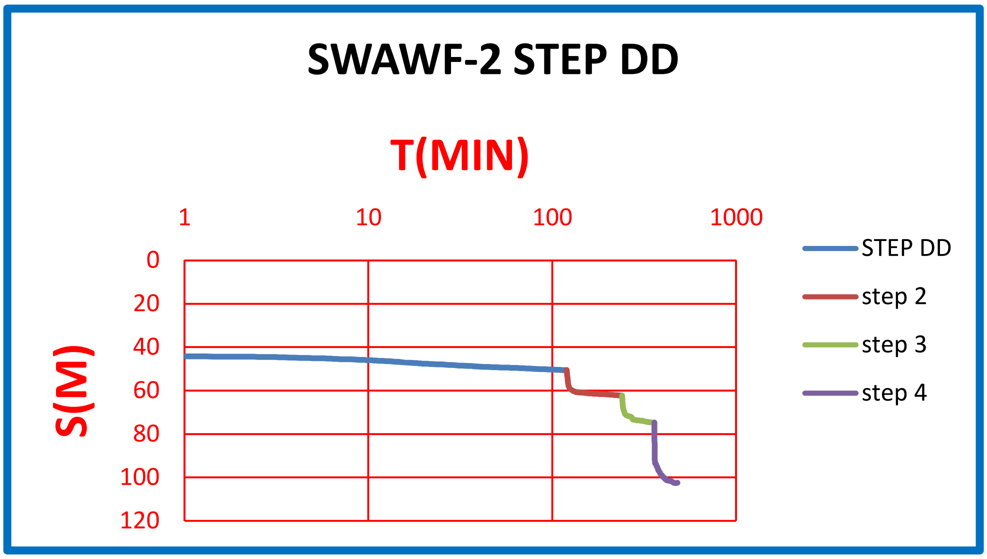

FIGURE 18C: Time-drawdown plot of field data of a step-drawdown test well SWAWF-2

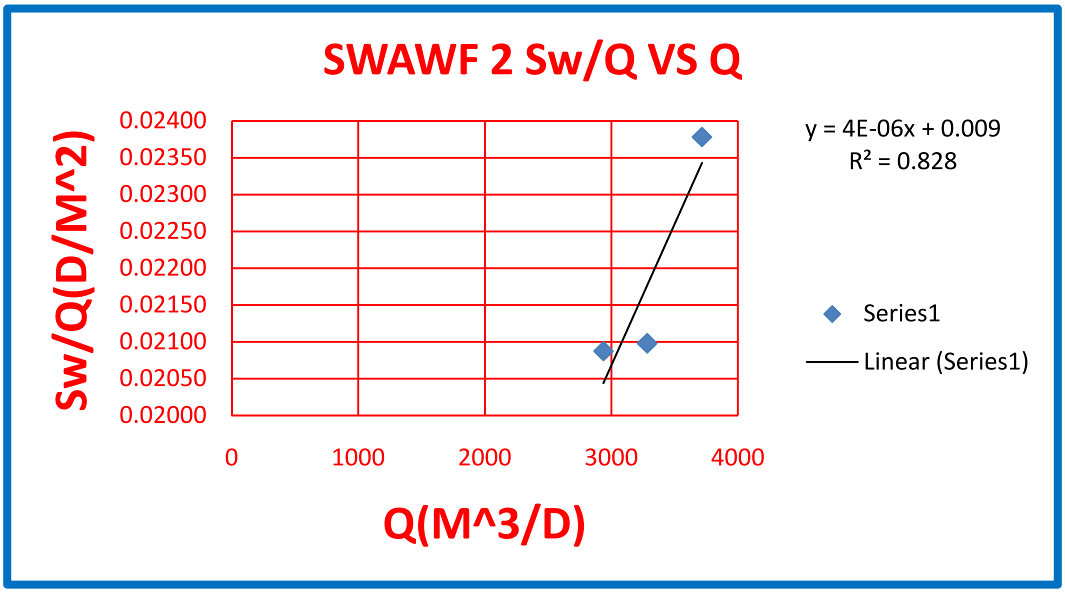

FIGURE 18D: Diagnostic plot Sw/Q versus Q of SWAWF-4B field data of a step-drawdown test with the Jacob's analysis method.

WELL INDEX SWAWF 4B

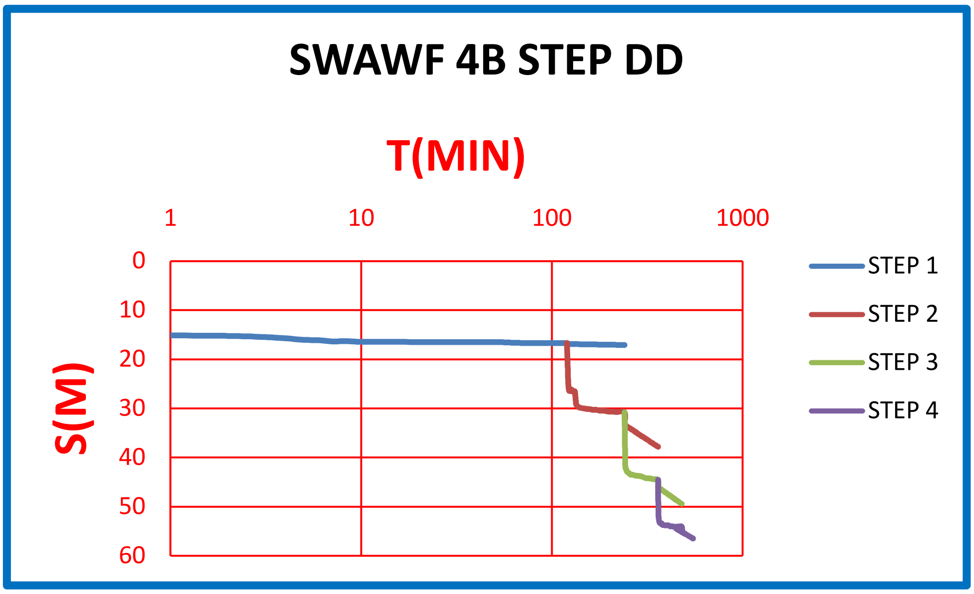

FIGURE 18E: Time-drawdown plot of field data of a step-drawdown test well SWAWF-4B

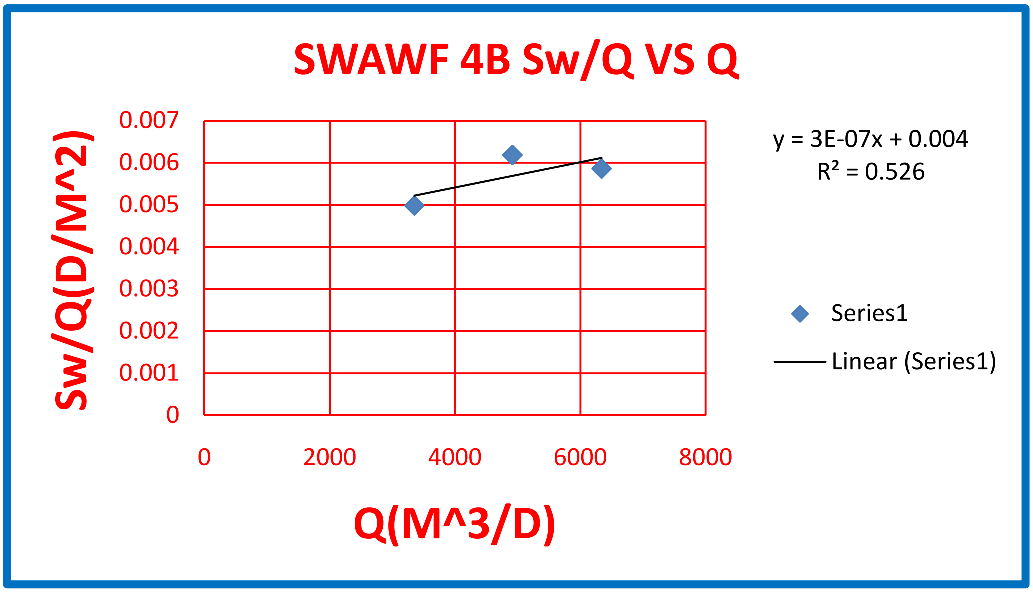

FIGURE 18F: Diagnostic plot Sw/Q versus Q of SWAWF-4B field data of a step-drawdown test with the Jacob's analysis method.

TABLE 3 :SUMMERY OF STEP DRAWDOWN RESULTS

NUMBER	WELL ID	B	C	R^2	EFFICENCY(%)
1	PW-7	7.426	0.678	0.88	60.17
2	SWAWF 2	0.009	4.00E-06	0.828	32.35
3	SWAWF 4B	0.004	3.00E-07	0.53	63.16

4.4 TIME DRAWDAWN DATA ANALYSIS

4.4.1 THEIS METHOD OF ANALYSIS

Theis (1935) was the first to develop a formula for unsteady-state flow that introduces the time factor and the storativity. He noted that when a well penetrating an extensive confined aquifer is pumped at a constant rate, the influence of the discharge extends outward with time. The rate of decline of head, multiplied by the storativity and summed over the area of influence, equals the discharge. The unsteady-state (or Theis) equation, which was derived from the analogy between the flow of groundwater and the conduction of heat, is written as

$$s = \frac{Q}{4\circledR KD}\int_{u}^{u)} \frac{e^{-y}\,dy}{y} = \frac{Q}{4\circledR KD}\,\mathrm{W(u)}$$

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 m3/d
KD= the transmissivity of the aquifer in m2/d
u = r ^{2}S / 4KDt and consequently **S=** 4KDtu / r^2
S = the dimensionless storativity of the aquifer
t = the time in days since pumping started

From the above Equation, it will be seen that, if s can be measured for one or more values of r and for several values of t , and if the well discharge Q is known, S and KD can be determined. The presence of the two unknowns and the nature of the exponential integral make it impossible to effect an explicit solution. Using Equations written above , Theis devised the ‘curve-fitting method’ (Jacob 1940) to determine S and KD.

Based on this method of evaluation all the twelve pumping well were analyzed and the results of the curve fitting are presented below (figure 19A-19I)

WELL INDEX PW-1

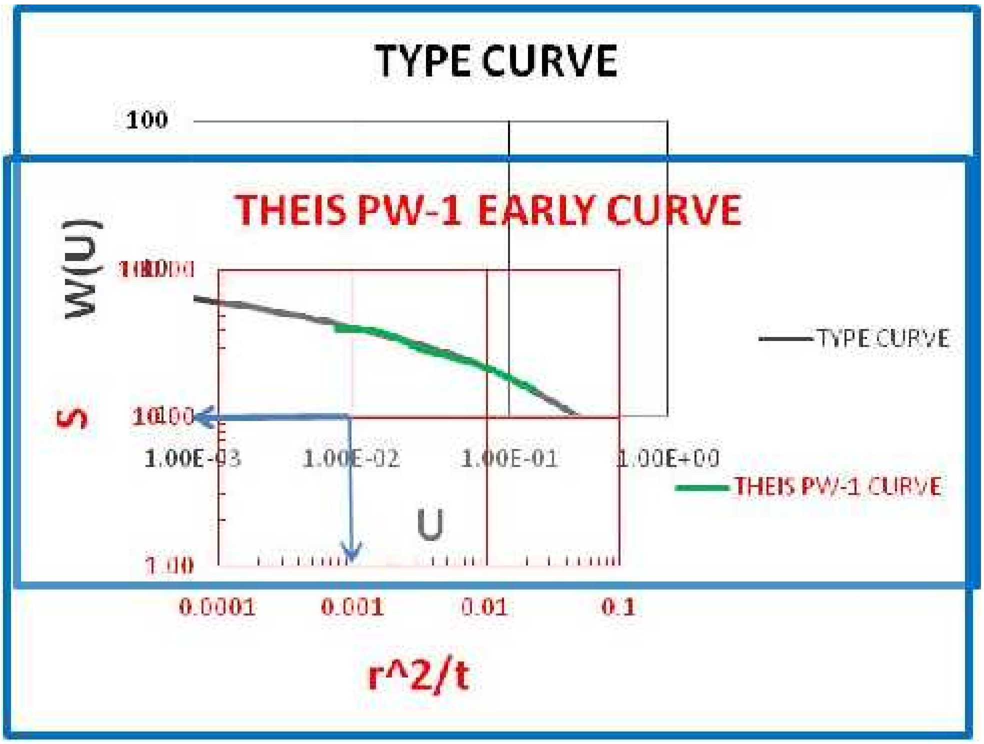

FIGURE 19A : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING WELL PW-01

WELL INDEX PW-6

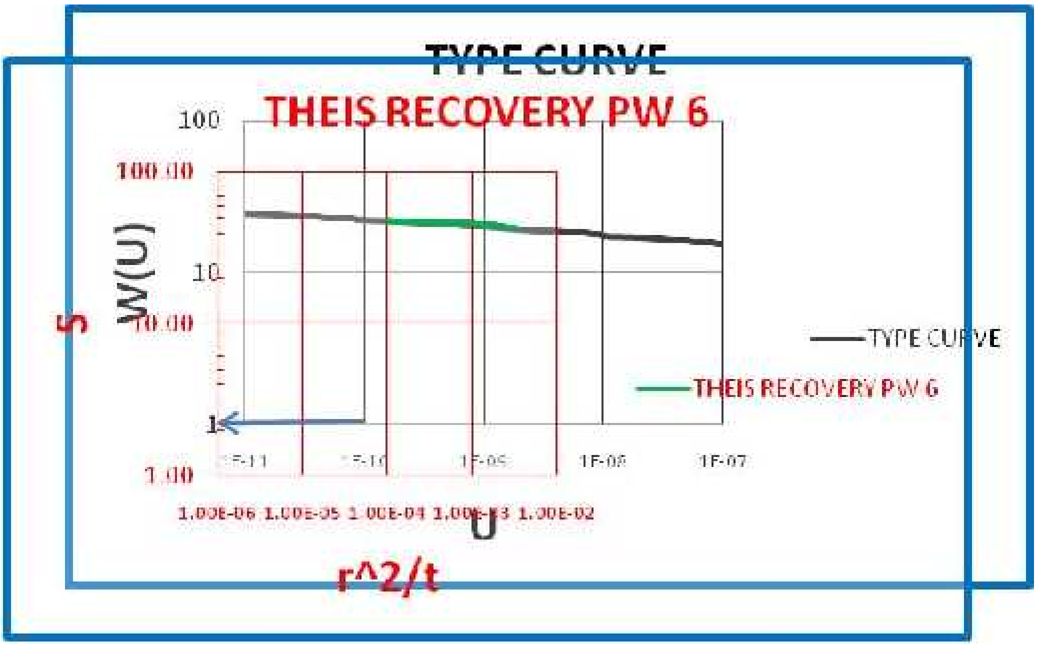

FIGURE 19B : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING WELL PW-6

WELL INDEX PW-2

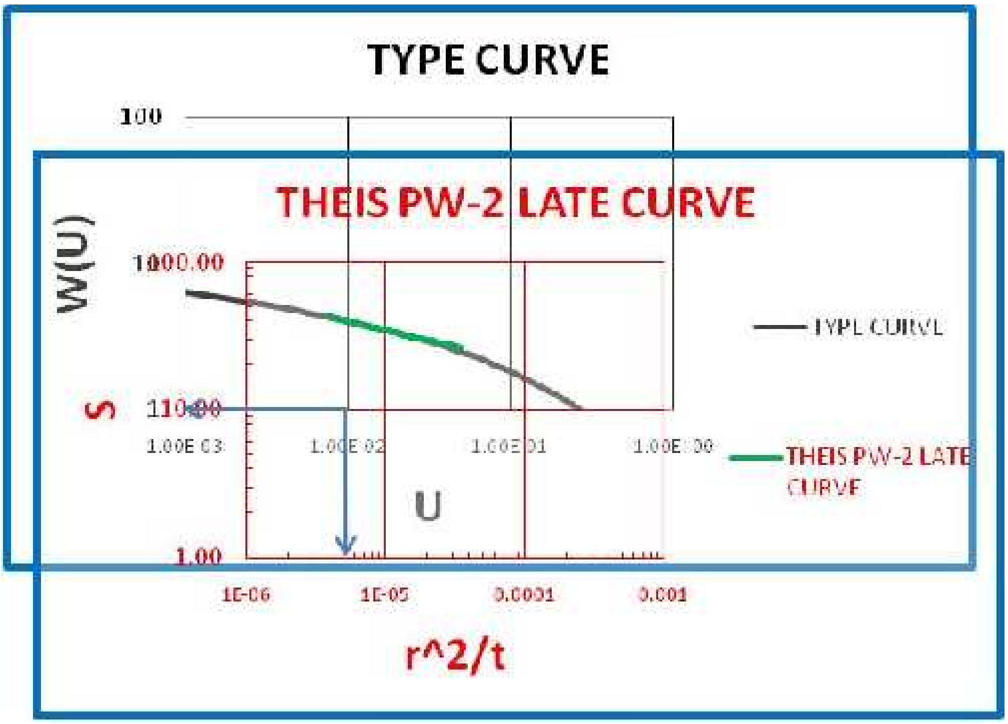

FIGURE 19C : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING TEST 2 WELL PW 2

WELL INDEX PW-4

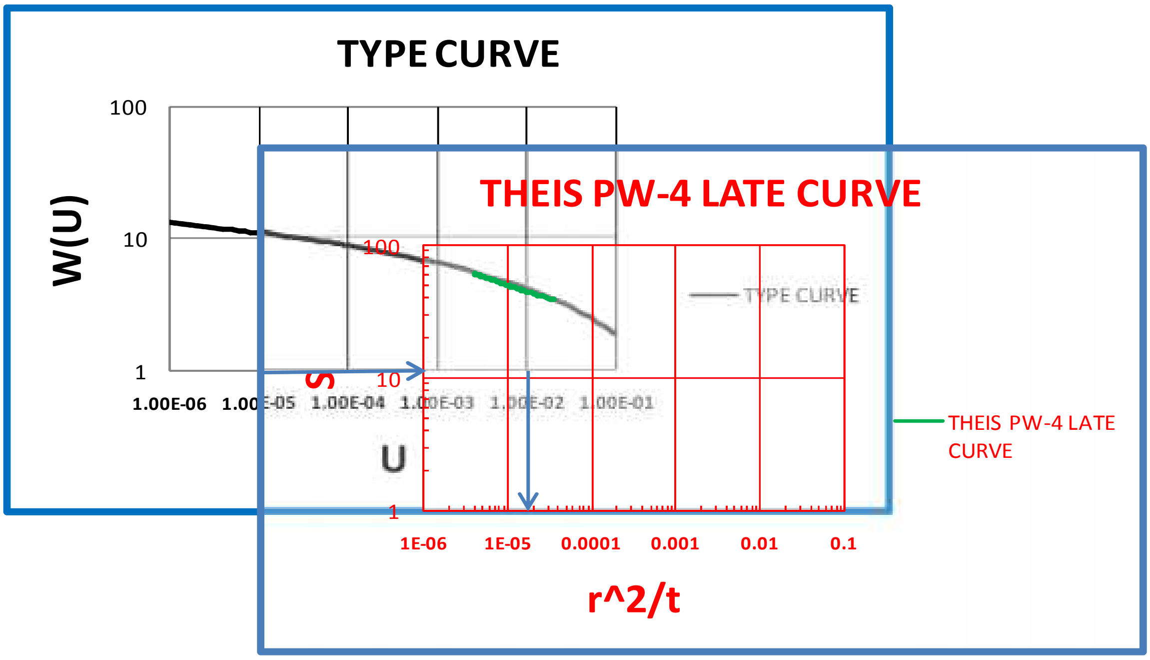

FIGURE 19D : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING TEST WELL PW 4

WELL INDEX PW-18

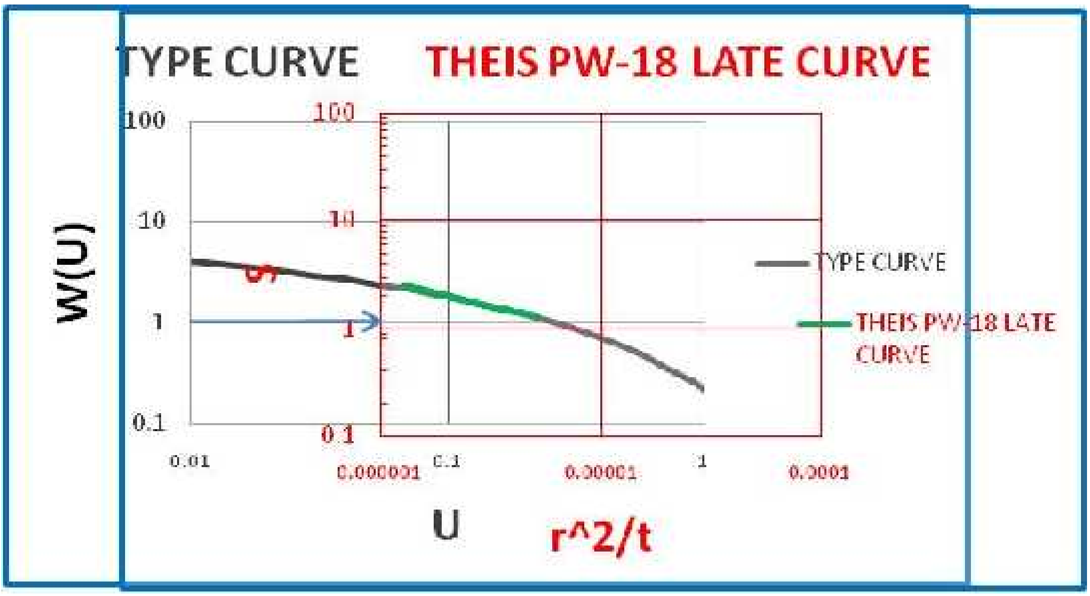

FIGURE 19E : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING TEST WELL PW 18

WELL INDEX PW-7

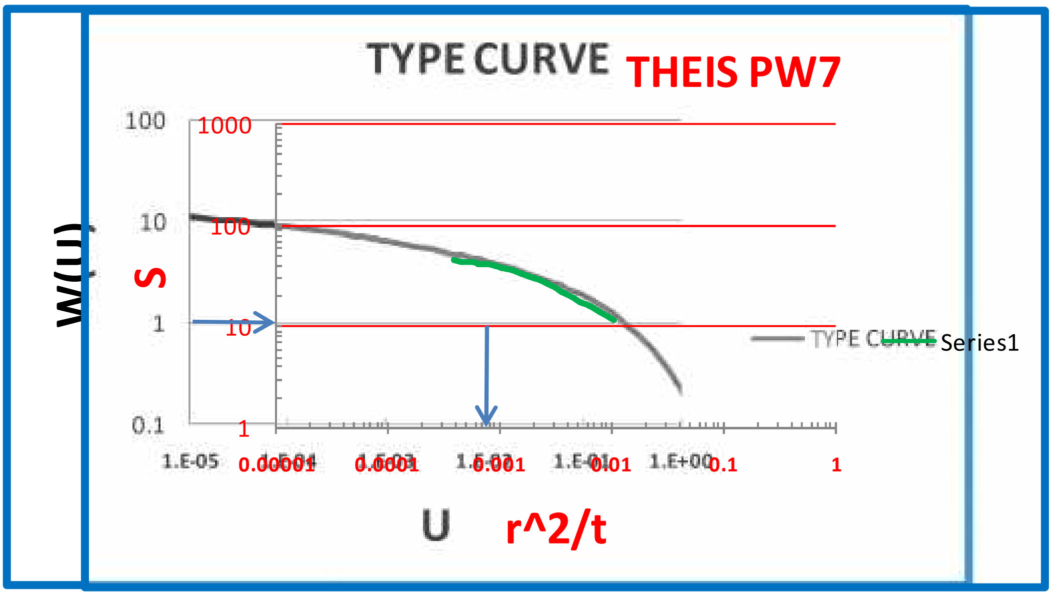

FIGURE 19F : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING WELL PW 7

WELL INDEX SWAWF - 2

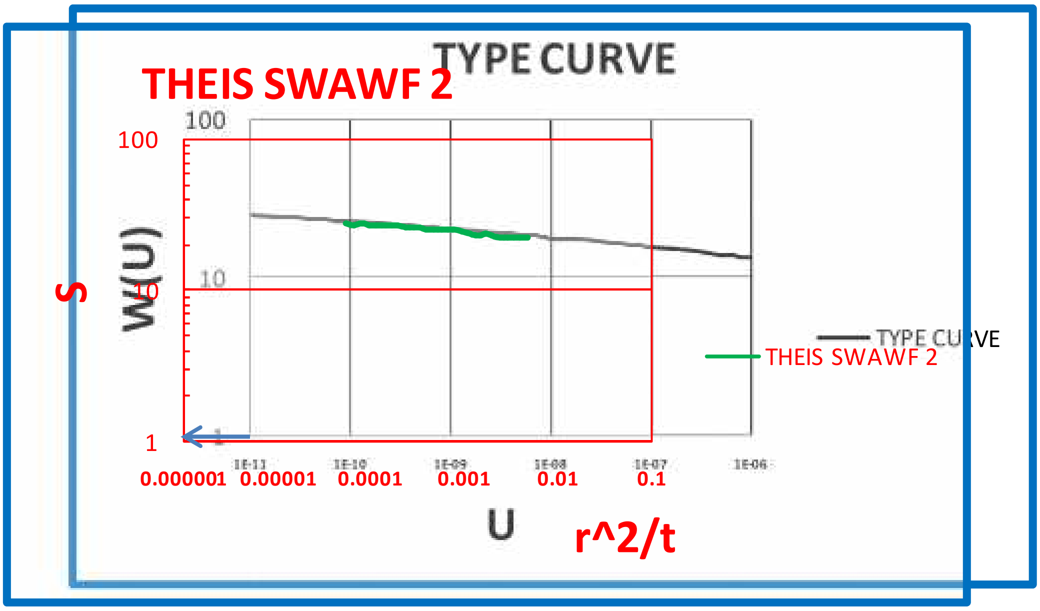

FIGURE 19G : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING WELL SWAWF 2

WELL INDEX SWAWF-4B

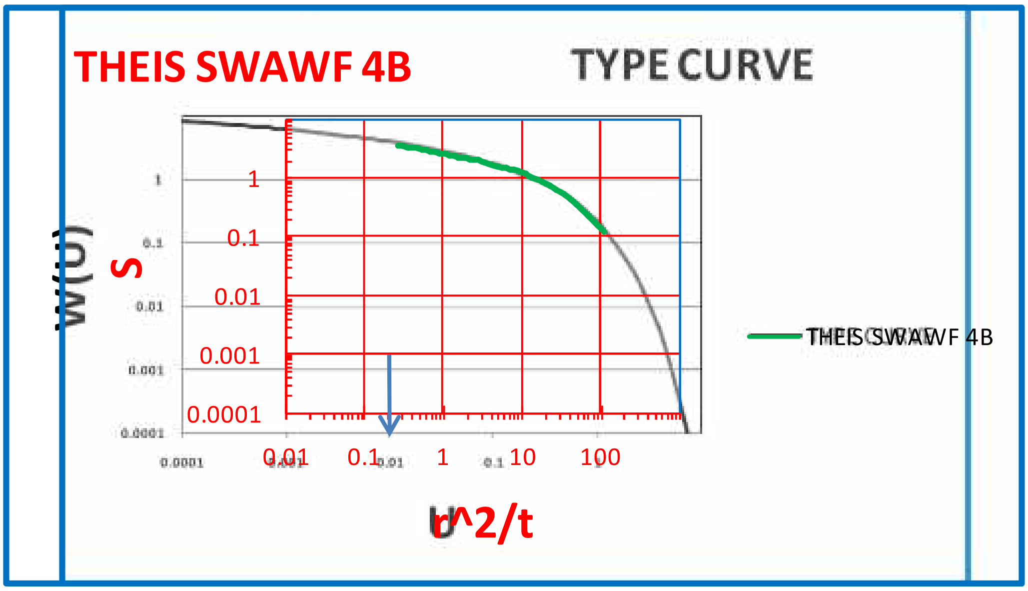

FIGURE 19H : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING WELL SWAWF 4B

WEEL INDEX SWAWF-5

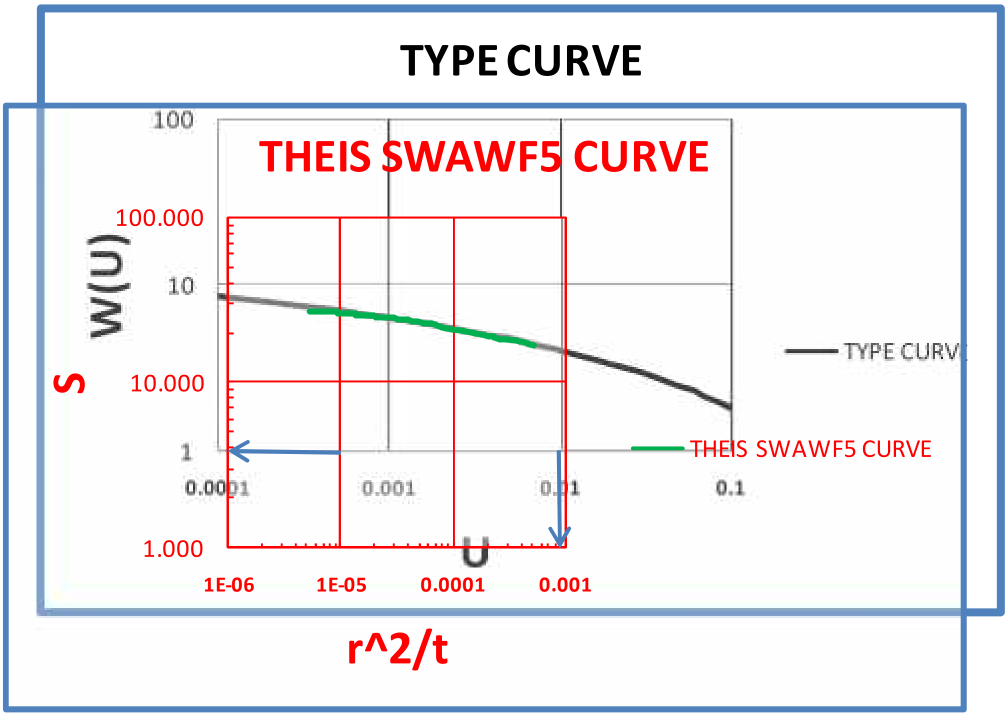

FIGURE 19I : THEIS METHOD OF SUPERPOSITION FOR CONSTANT PUMPING 1 WELL SWAWF 5

TABLE 4: SUMMERY OF THEIS METHOD OF ANALYSIS

No	Well Index	Q (m3/day)	for w(u) = 1 S =	for u = 0.01 r2/t =	Trammisivity Estimated(m^2/d)	Storativity Estimated	Remark
1	PW-1	907	10	1.44	7	0.2	
2	PW-6	6807	2.2	-	246	-	
3	PW-2	5400	10	-	43	-	
4	PW-4	10541	12.5	-	67	-	
5	PW-18	12096	1.6	-	802	-	
6	PW-7	626	11	0.0006	5	0.2097	
7	SWAWF-2	4705	1.25	-	300	-	
8	SWAWF-4B	7776	0.85	0.6	728	0.0337	
9	SWAWF-5	7776	3.9	-	159	-	
10	PW-3	-	-	-	-	-	**Only recovery data is used**
11	PW-8	-	-	-	-	-	**Only recovery data is used**
12	PW-13	-	-	-	-	-	**Only recovery data is used**

4.4.2 COOPER AND JACOB METHOD OF ANALYSIS

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

$$S = \frac{Q}{4\circledR KD} W(u) = \frac{Q}{4\circledR KD}(-0.5772 - Inu + u - \frac{u^2}{2.2:} + \frac{u^3}{3.3:} - ...)$$

From u = r^2 S/4KDt, 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 In 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

$$S = \frac{Q}{4\circledR KD}(-0.5772 - In\frac{r^2 S}{4KDt})$$

Because Q, KD, and S are constant, if we use drawdown observations at a short distance r from the well, a plot of drawdown S versus the logarithm of t forms a straight line (see Figure below). If this line is extended until it intercepts the time-axis where s = 0, the intercept point has the coordinates s = 0 and t = to. Substituting these values into the above Equation gives

$$S = \frac{2.25KDt_0}{r^2}$$

$$KD = \frac{2.30Q}{4\circledR \Delta S} = \text{T}$$

Based on this method of evaluation all the twelve pumping well were analyzed and the results are presented below (figure 20A-2I)

WEEL INDEX PW-1

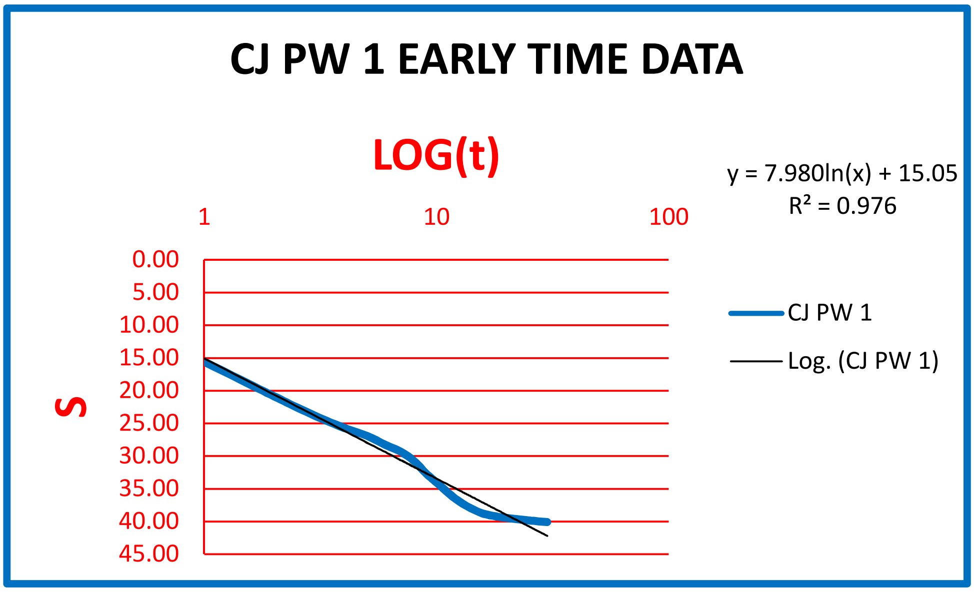

FIGURE 20A: Cooper-Jacob method of solution for constant pumping test -Well PW-01

WEEL INDEX PW-6

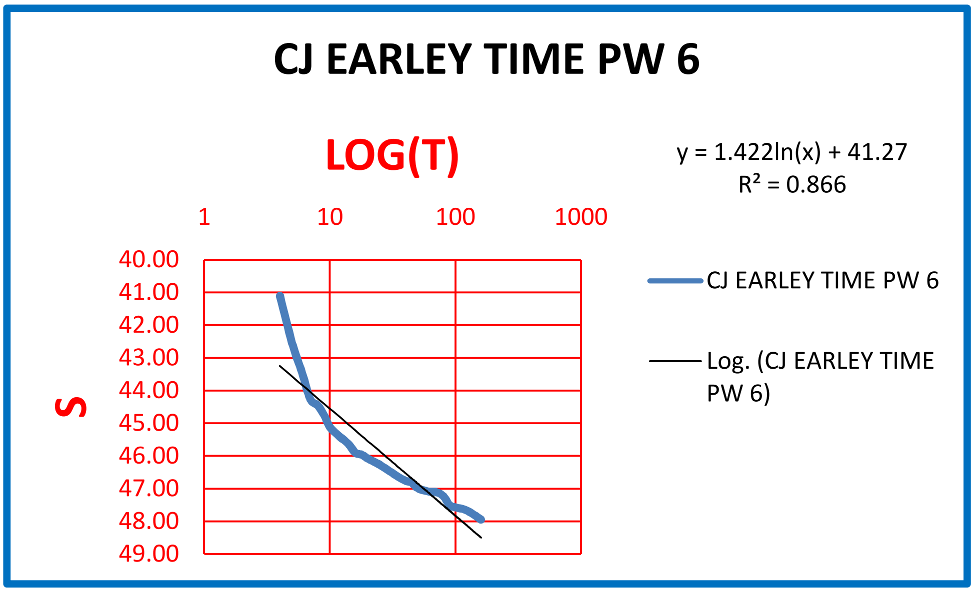

FIGURE 20B:Cooper-Jacob method of solution for constant pumping test -Well PW-6

WELL INDEX PW-2

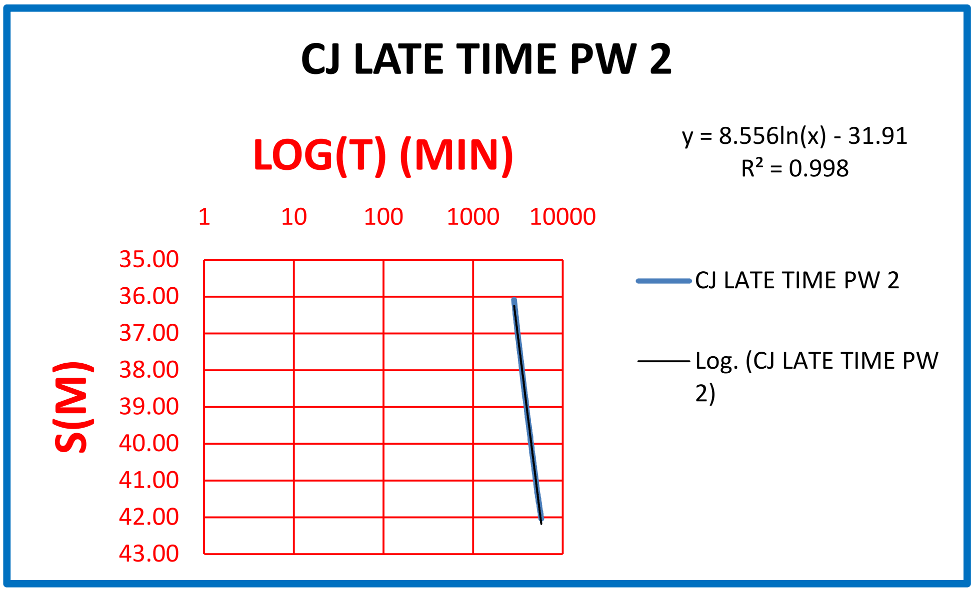

FIGURE 20C :Cooper-Jacob method of solution for constant pumping test 2-Well PW 2

WEEL INDEX PW-4

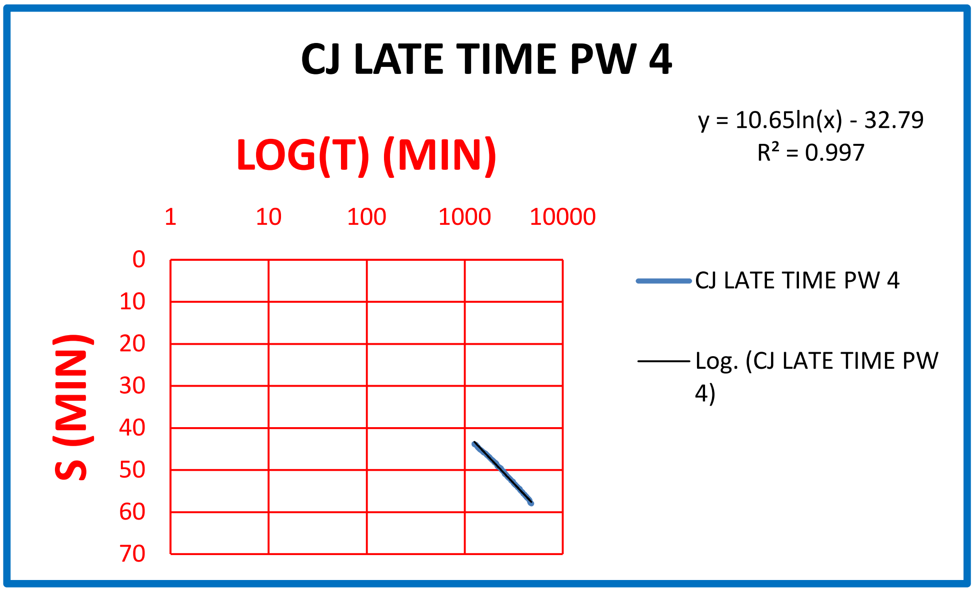

FIGURE 20D : Cooper-Jacob method of solution for constant pumping test -Well PW 4

WEEL INDEX PW-18

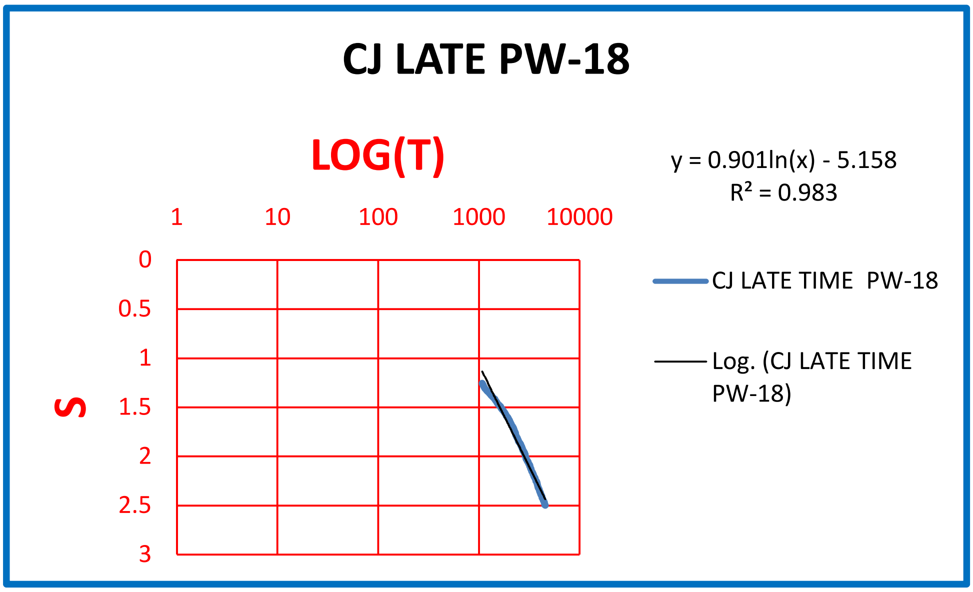

FIGURE 20E :Cooper-Jacob method of solution for constant pumping test -Well PW 18

WEEL INDEX PW-7

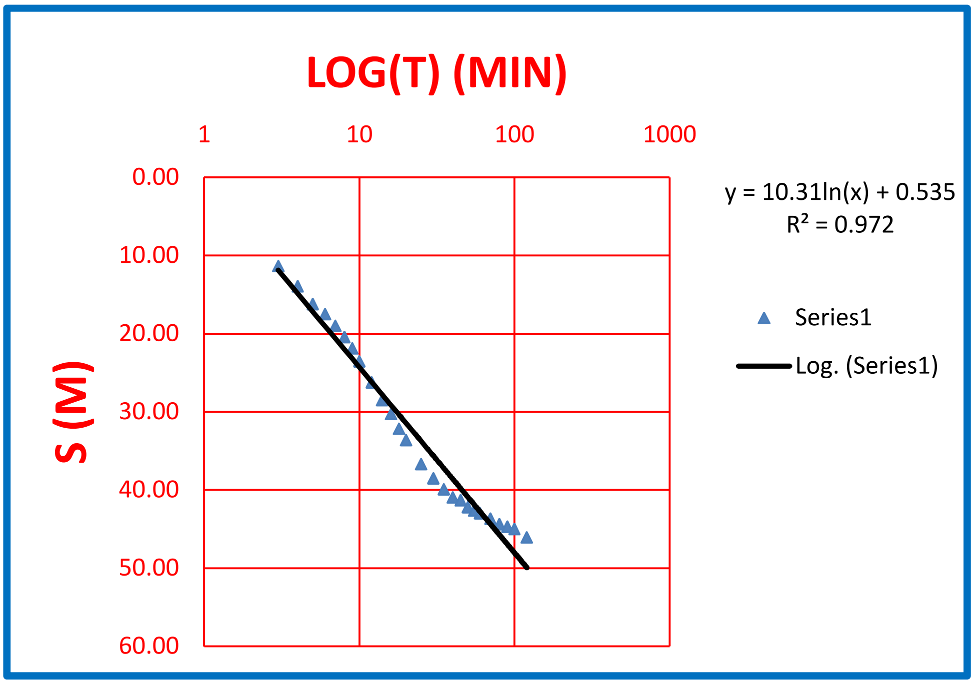

FIGURE 20F : Cooper-Jacob method of solution for constant pumping test -Well PW-7

WELL INDEX SWAWF - 2

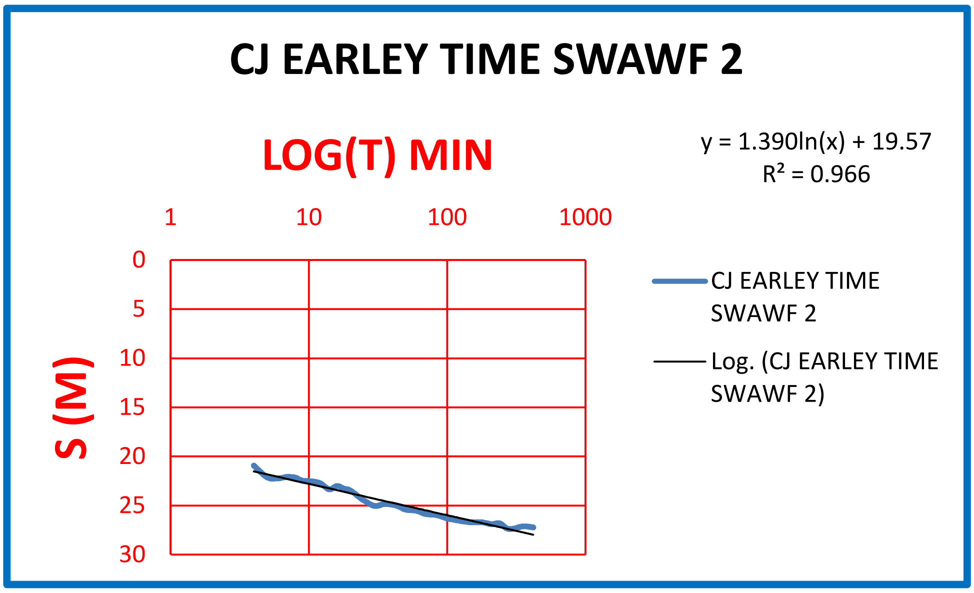

FIGURE 20G : Cooper-Jacob method of solution for constant pumping test -Well SWAWF-2

WELL INDEX SWAWF-4B

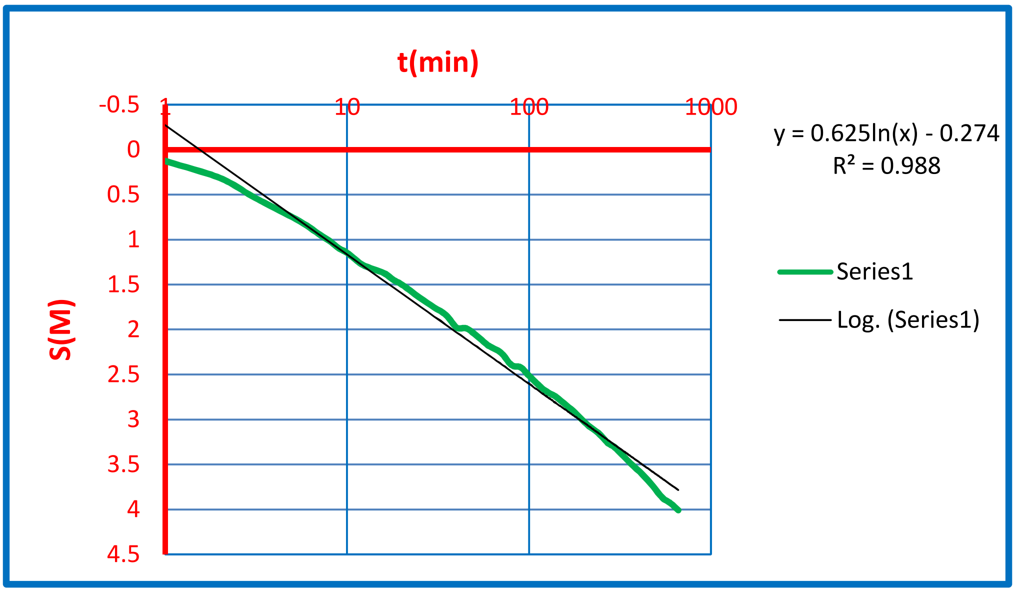

FIGURE 20H : Cooper-Jacob method of solution for constant pumping test -Well SWAWF-4B

WEEL INDEX SWAWF-5

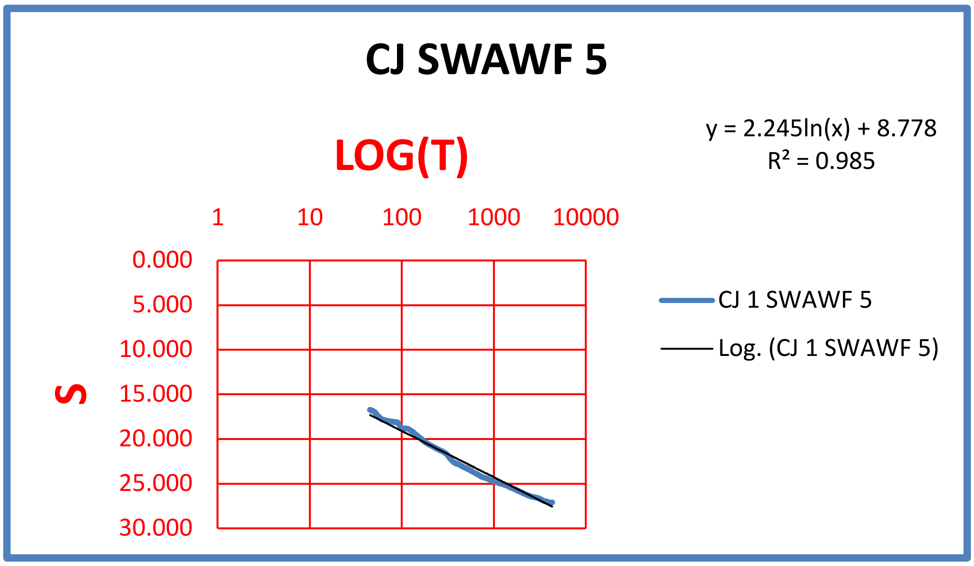

FIGURE 20I : Cooper-Jacob method of solution for constant pumping test 1-Well SWAWF 5

TABLE 5: SUMMERY OF COOPER & JACOB METHOD OF ANALYSIS

No	Well Index	Q (m3/d)	Radius of the well (M)	Best fit line			Estimated sat t =		ΔS	to	Transmissivity Estimated (m2/d)	Cofficent of storativity Estimated	Remark
				Slope	Intersept	R^2	10	100					
1	PW-1	907	0.127	7.98	15.05	0.976	33.4	51.8	18.4	1.51E-01	9	0.1327	
2	PW-6	6807	0.127	1.42	41.27	0.866	44.5	47.8	3.3	5.3x10-14	381	NA	
3	PW-2	5400	0.1524	8.56	-31.91	0.998	-12.23	7.45	19.7	4.18E+01	50	NA	
4	PW-4	10541	0.1778	10.65	-32.79	0.997	-8.29	16.2	24.5	2.18E+01	79	NA	
5	PW-18	12096	0.127	0.9	-5.16	0.983	-3.086	-1.01	2.07	3.08E+02	1068	NA	
6	PW-7	626	0.127	10.31	0.54	0.97	24.25	47.96	23.71	7.56x10-7	5	0.4447	
7	SWAWF-2	4705	0.127	1.39	19.57	0.966	22.77	25.96	3.197	7.56x10-7	269	0.0000197	
8	SWAWF-4B	7776	10.5	0.63	-0.27	0.988	1.1635	2.601	1.44	1.55E+00	990	0.02176	Multiple well test
9	SWAWF-5	7776	0.127	2.25	8.78	0.985	13.94	19.11	5.16	2.00E-02	275	0.5327	
10	PW-3	-	-	-	-	-	-	-	-	-	-	-	Only recovery data is used
11	PW-8	-	-	-	-	-	-	-	-	-	-	-	Only recovery data is used
12	PW-13	-	-	-	-	-	-	-	-	-	-	-	Only recovery data is used

4.5 RECOVERY DATA ANALYSIS

4.5.1 THEIS RECOVERY METHOD OF ANALYSIS

According to Theis (1935), the residual drawdown after a pumping test with a constant discharge is

$$s' = \frac{Q}{4\circledR KD}\{W(u) - W(u)\} \quad \text{where}$$

$$u = \frac{r^2 S}{4KDt} andu' = \frac{r^2 S'}{4KDt'}$$

When u and u’ are sufficiently small , the first equation can be approximated by

$$s' = \frac{Q}{4\circledR KD}(\ln\frac{4KDt}{r^2 S} - \ln\frac{4KDt'}{r^2 S})$$

where
s'= residual drawdown in m

r = distance in m from well to piezometer

KD = transmissivity of the aquifer in m2/d

S' = storativity during recovery, dimensionless

S = storativity during pumping, dimensionless

t = time in days since the start of pumping

t' = time in days since the cessation of pumping

Q = rate of recharge = rate of discharge in m3/d

When **S** and ***S‘*** are constant and equal and KD is constant, the third equation can also be written as

$$s' = \frac{2.30Q}{4\circledR KD}\log\frac{t}{t'}$$

A plot of s’ versus t/t’ on semi-log paper (t/t’ on logarithmic scale) will yield a straight line. The slope of the line is

$$\Delta s' = \frac{2.30Q}{4\circledR KD}$$

where **Δs‘** is the residual drawdown difference per log cycle of t/t’

Based on this method of evaluation all the twelve pumping well were analyzed and the results are presented below (figure 21A-21L)
During this recovery data analysis in all the twelve wells early time data were ignored as they may be the result of well storage.

WELL INDEX PW-1

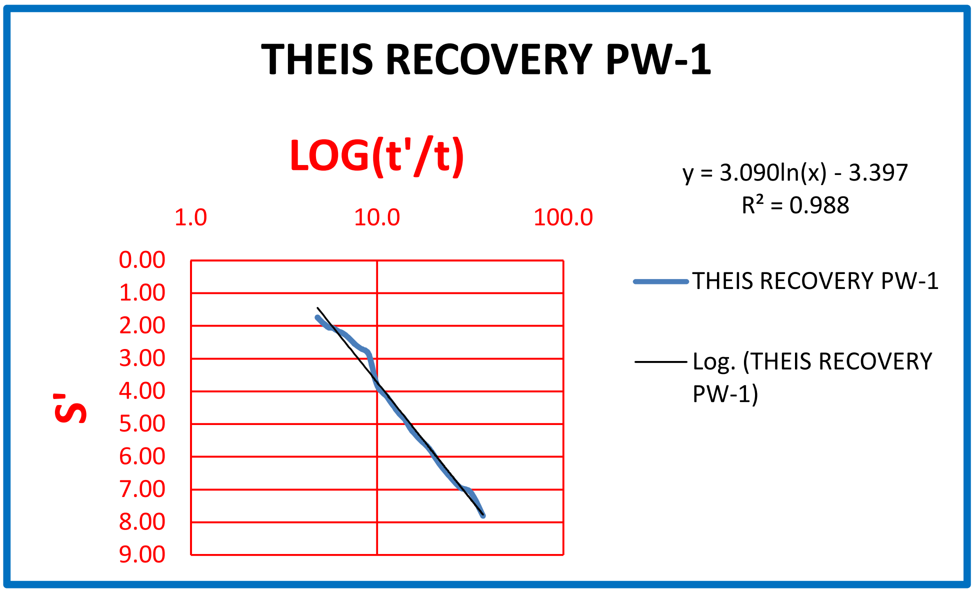

FIGURE 21A: THEIS RECOVERY METHOD FOR RECOVERY TEST

WELL PW 01

WELL INDEX PW-6

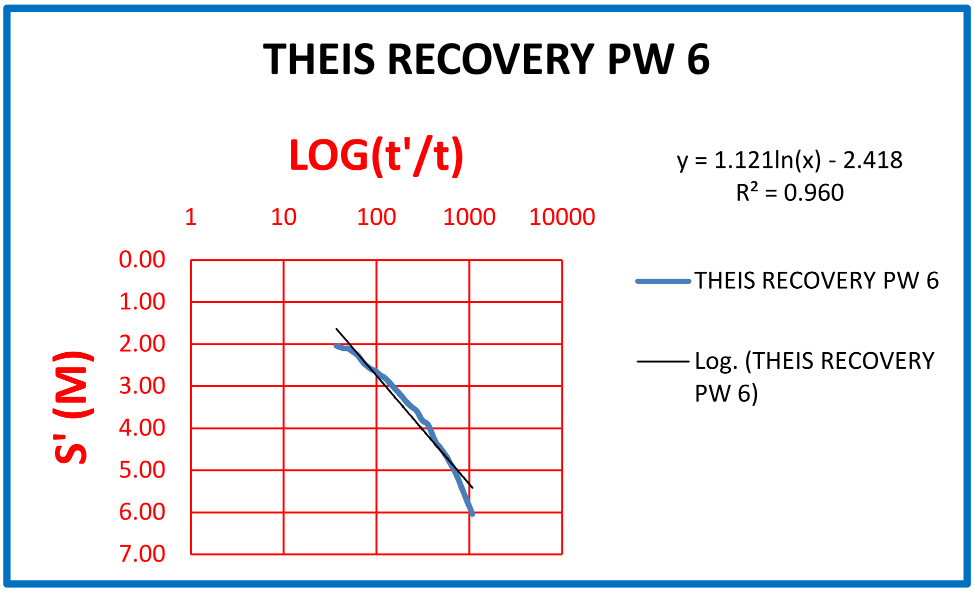

FIGURE 21B: THEIS RECOVERY METHOD FOR RECOVERY TEST

WELL PW 6

WEEL INDEX PW-2

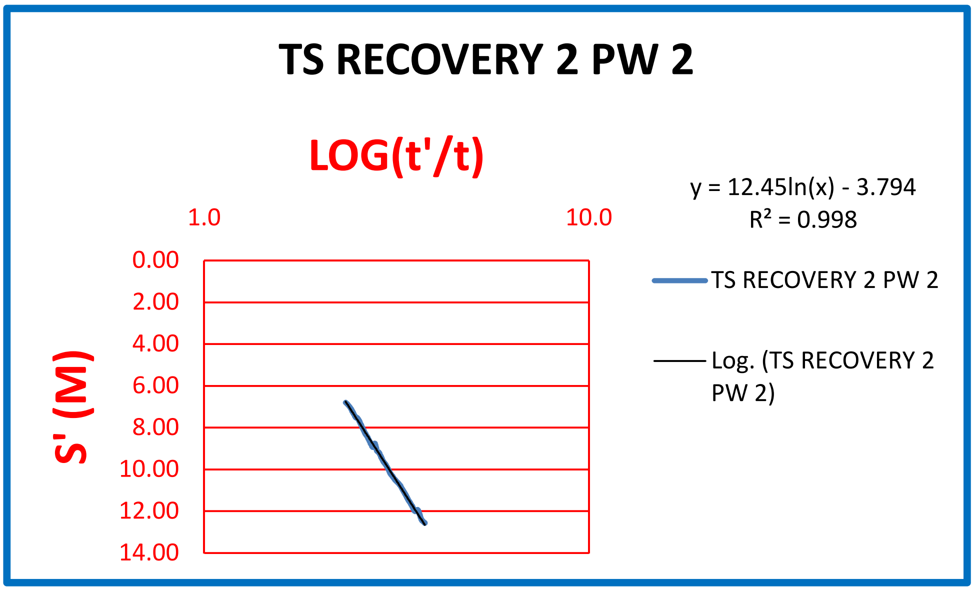

FIGURE 21C: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST 2

WELL PW 2

WEEL INDEX PW-4

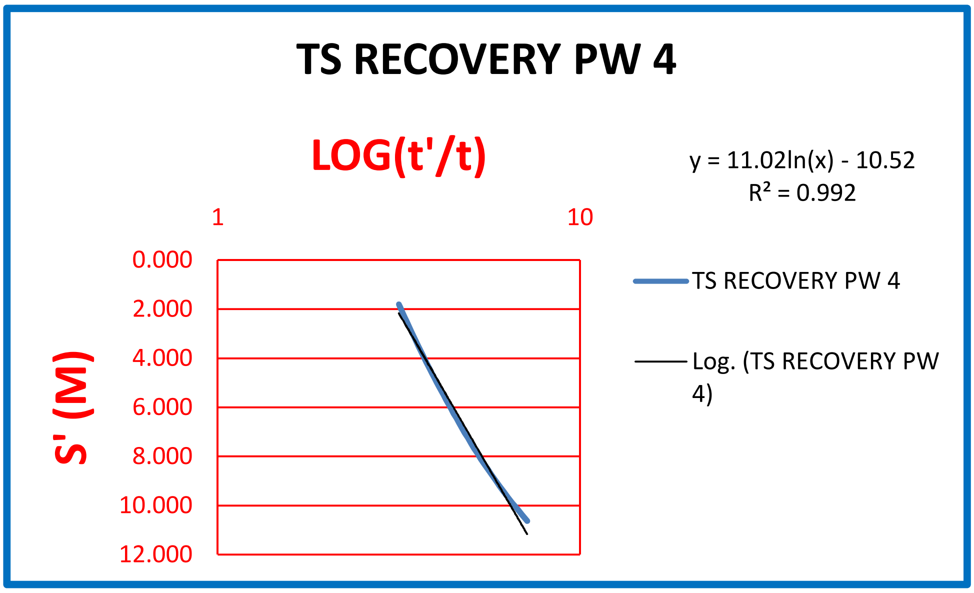

FIGURE 21D: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST WELL PW4

WELL INDEX PW-18

Recovery data were also analyzed using Theis (1935) straight line recovery method & result in a transmissivity of 17190 m2/day (figure 3 below). early time data of this recovery data were also ignored as they may be the result of well storage. Analyzing this recovery test result the graph has a value of intercept (< 1) at zero drawdown which indicates as incomplete recovery of initial head which may be due to the existence of small aquifer volume, which is true as only 38% of the drawdown recovered after 24 hours of recovery observation .Another point observed from this recovery test is that the recovery was very slow (as it takes 24 hours to recover a drawdown of only 1.4m).Due all this reasons this result is ignored as it is not reasonable to calculate the aquifer parameter from this not fully recovered data which has almost horizontal graph that result in smaller value slope to exaggerate our estimation of transmissivity of the aquifer.

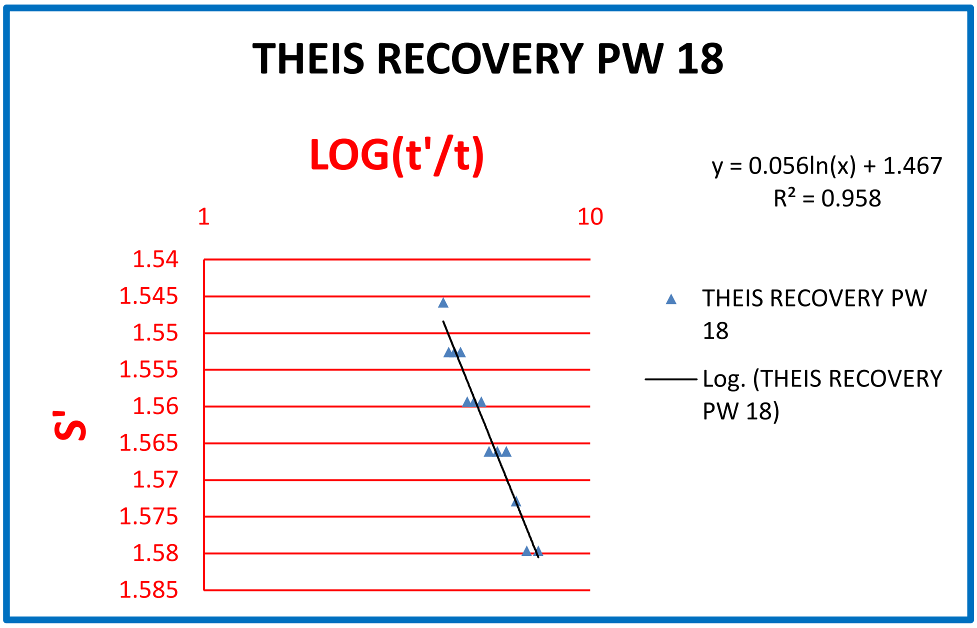

FIGURE 21E: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST WELL PW 18

WEEL INDEX PW-7

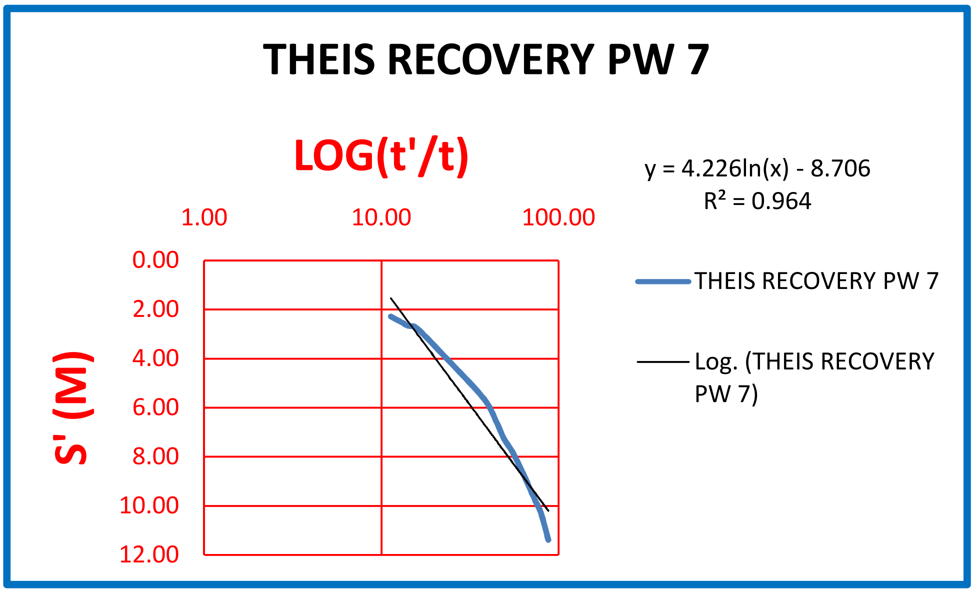

FIGURE 21F: THEIS RECOVERY METHOD FOR RECOVERY TEST

WELL PW 7

WEEL INDEX SWAWF 2

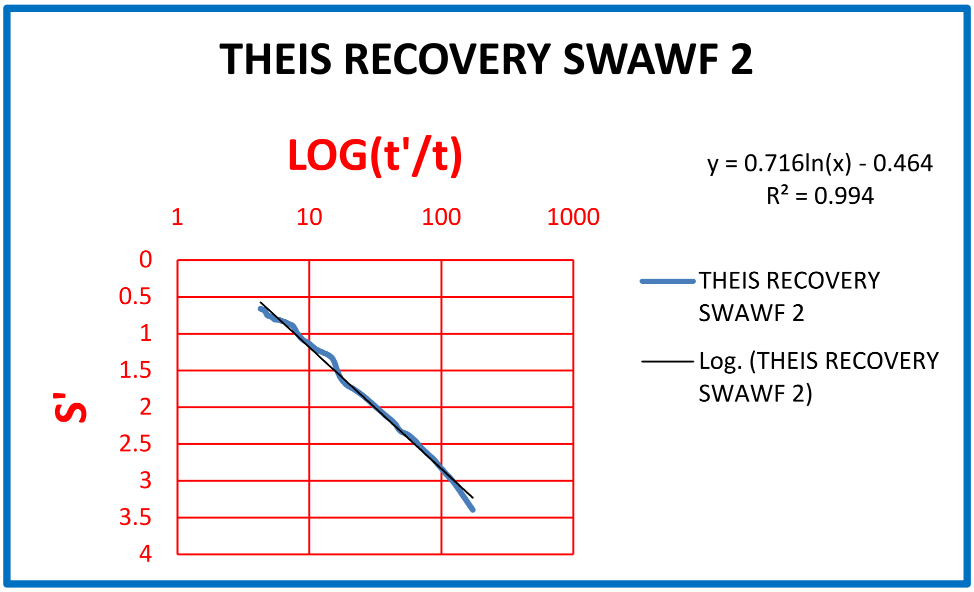

FIGURE 21G: THEIS RECOVERY METHOD FOR RECOVERY TEST

WELL SWAWF 2

WEEL INDEX SWAWF 4B

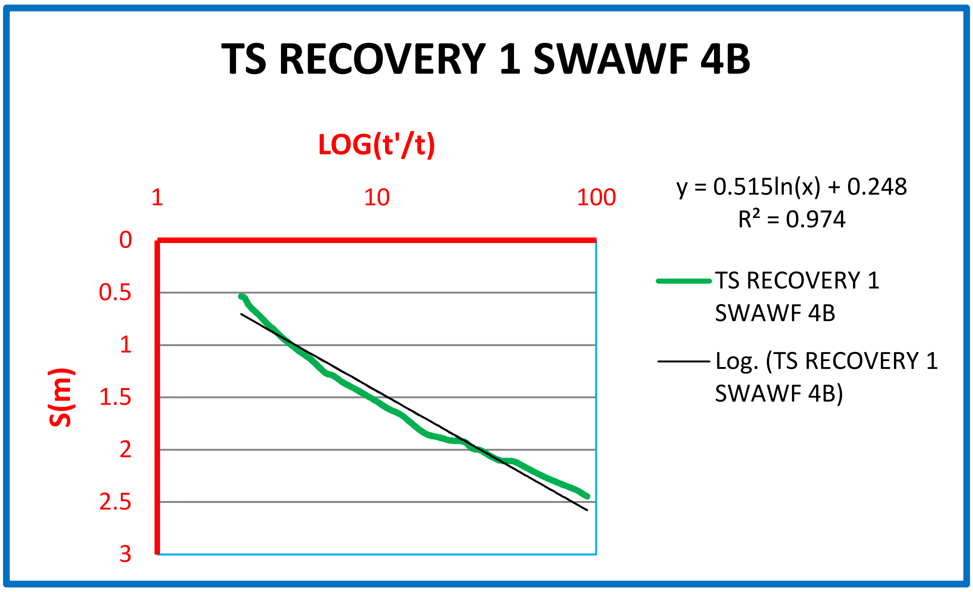

FIGURE 21H: THEIS RECOVERY METHOD FOR RECOVERY TEST

WELL SWAWF 4B

WEEL INDEX SWAWF 5

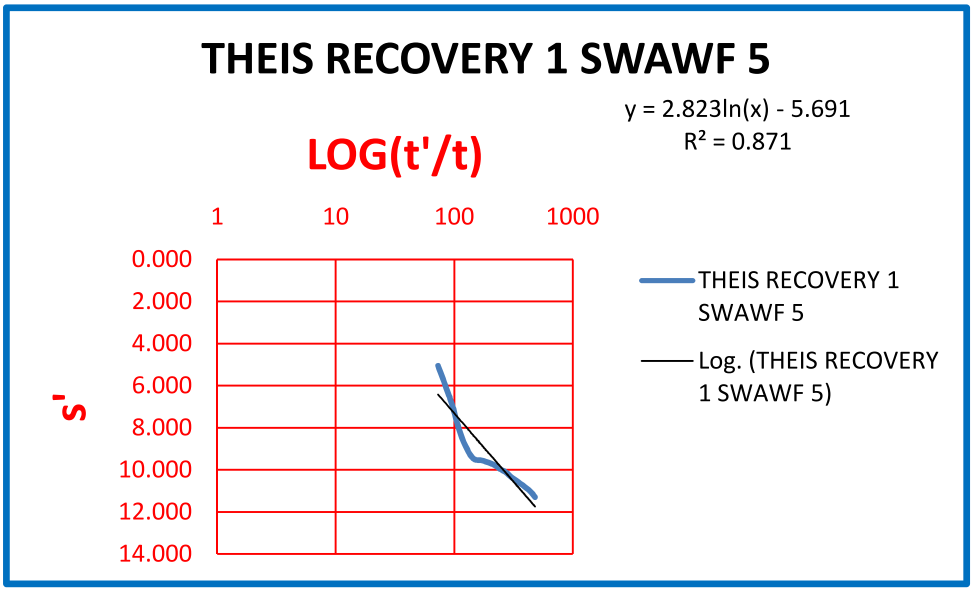

FIGURE 21I: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST 1

WELL SWAWF 5

WEEL INDEX PW-3

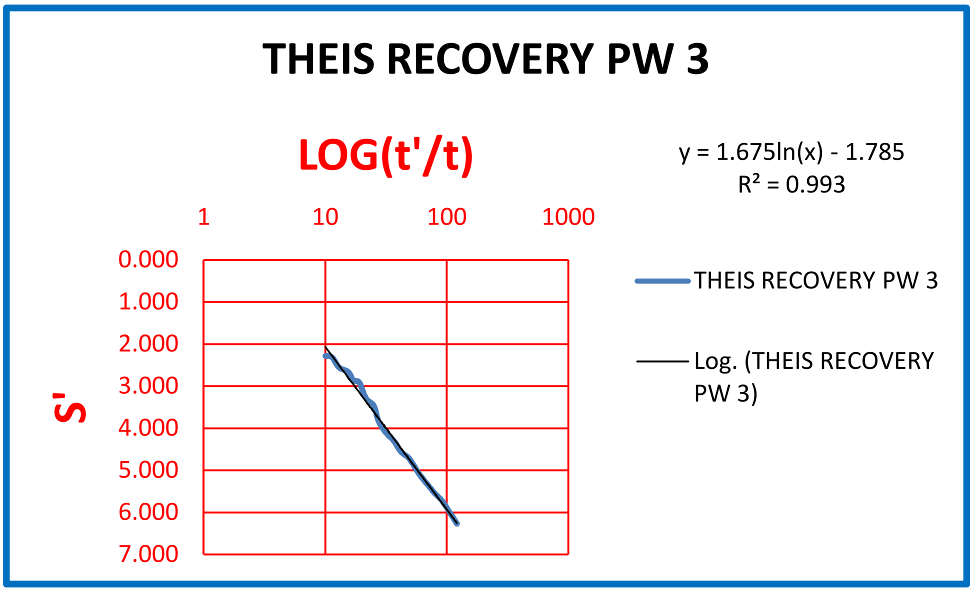

FIGURE 21J: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST

WELL PW 3

WEEL INDEX PW 8 ANALYSIS

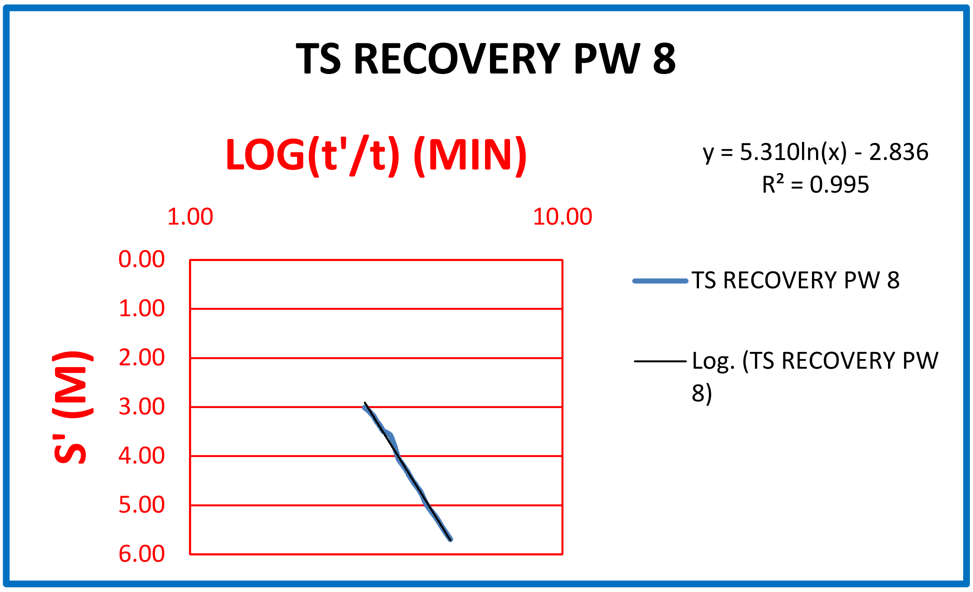

FIGURE 21K: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST

WELL PW 8

WELL INDEX PW 13

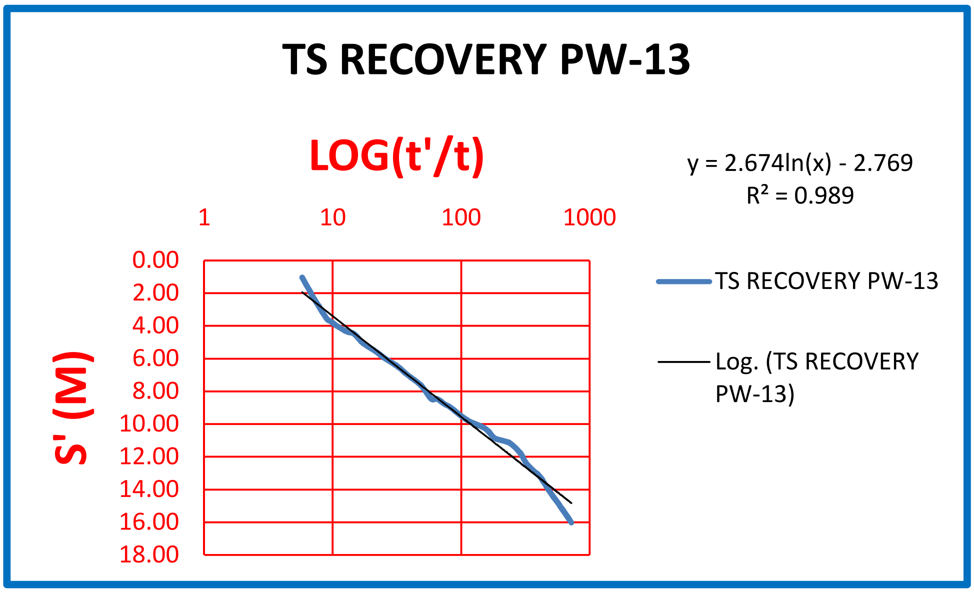

FIGURE 21L: THEIS RECOVERY METHOD FOR RECOVERY PUMP TEST

WELL PW 13

TABLE 6 : SUMMERY OF THEIS RECOVERY METHOD OF ANALYSIS

No	Well Index	Q (m3/d)	Radius of the well (m)	Best fit line			Estimated s at t =		ΔS	Transmissivity Estimated (m2/d)	Remark
				slope	intercept	R^2	10	100			
1	PW-1	907	0.127	3.09	-3.39	0.988	3.71	10.817	7.107	23	
2	PW-6	6807	0.127	1.121	-2.418	0.96	0.16	2.74	2.58	483	
3	PW-2	5400	0.1524	12.45	-3.794	0.998	24.84	53.48	28.64	35	
4	PW-4	10541	0.1778	11.02	-10.52	0.992	14.83	40.17	25.35	76	
5	PW-18	12096	0.127	0.056	1.467	0.958	1.59	1.72	0.128	17190	Ignored
6	PW-7	626	0.127	4.226	-8.706	0.964	1.013	10.73	9.72	12	
7	SWAWF-2	4705	0.127	0.716	-0.464	0.994	1.183	2.83	1.65	523	
8	SWAWF-4B	7776	10.5	0.515	0.248	0.974	1.43	2.62	1.185	1252(GM)	Geometric mean from pump test 1& 2
9	SWAWF-5	7776	0.127	2.823	-5.691	0.871	0.8	7.29	6.49	395(GM)	Geometric mean from pump test 1& 2
10	PW-3	2418	0.127	1.68	-1.79	0.993	2.07	5.92	3.85	115	
11	PW-8	4320	0.1524	5.31	-2.83	0.995	9.38	21.59	12.21	65	
12	PW-13	1901	0.127	2.67	-2.769	0.989	3.38	9.53	6.15	57	

4.6 SUMMERY OF RESULT AND DISCUSSION

WEEL INDEX PW-1 AND 6

For analyzing the data collected from the constant discharge test first a semi-log graph of drawdown versus log time was prepared , both shows a gradual decrease in drawdown. This occurs because the aquifer is gaining water from another source, either because the aquifer is leaky , or because the expanding cone of depression has intercepted a source of recharge , such as river .This is an encouraging sign for the wells as a sustainable water source , and the transmissivity value was estimated using the data before the leakage is observed.

As far as concerning PW-1 the reason for recharge effect seen during the test is assumed to be due to the expanding cone of depression has intercepted a river which is found at a distance of 309m from it or this recharge is assumed to happen due to conducting the test at the wrong time of the year (condition too wet) as the test was done on June 24, 2010 which is the time of summer in Addis Ababa. While for PW-6 the reason for recharge effect seen during the test is assumed to be due to the expanding cone of depression has intercepted a river which is found at a distance of 280m from it .

WELL INDEX PW-2 , PW-4 & PW-18

The data collected from the above three wells show a drawdown with a gradual increase as the pumping continues. This indicates that the aquifer properties away from the bore holes are poorer than those closer to this wells. 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 the shallow part 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) calculation of the transmissivity has been done using the late time data.

WEEL INDEX PW-7 , SWAWF-2 & SWAWF-4B

For analyzing the data collected from the constant discharge test for this wells first a semi-log graph of drawdown versus log time was prepared , which shows a flat curve but not strictly horizontal that continues to increase at a reduced rate. This is the case that will happen when the recharge is insufficient to match the discharge & transmissivity value was estimated using the data before the leakage is observed. As far as concerning well PW-7 & SWAWF-2 the reason for recharge effect seen during the test is assumed to be due to the expanding cone of depression has intercepted a river which is found at a distance of 20m from them .

WEEL INDEX SWAWF-5

The first constant pumping test show a sudden increase in drawdown at the 45 minute which may due to from the dewatering of an important fracture or the interception of a hydraulic barrier. Such behaviors is of serious concern & indicates that the well may dry up after heavy usage or during the dry season. All is not lost, however, as the well may still be usable, at a lower pumping rate. As this early data may show false draw down, calculation of the aquifer properties were made using the late time data.

WELL INDEX PW 3 , PW 8 & 13

The data collected from the constant pump test of this three wells show significant up & down values with sudden increase in drawdown for many times throughout the test which limits the ability to much theoretical curves to the data sets , so the data from this tests are discarded in this evaluation. This is one of the disadvantage of single well test, as there is no data to be taken from observation well which left as only one option to analyze the recovery data without any other comparison or confirmation.

TABLE 7 : SUMMERY OF RESULTS

No	Well Index	Transmissivity to be evaluated (m2/day).	TRANSMISSIVITY EVALUATED (m2/day) USING			GEOMETRIC MEAN OF TRANSMISSIVITY EVALUATED	STORATIVITY EVALUATED		GEOMETRIC MEAN OF STORATIVITY EVALUATED	TRANDMISSIVITY % DECREASE & INCREASE
			COOPER - JACOB	THEIS RECOVERY	THEIS		COOPER - JACOB	THEIS		
1	WF01-PW1	86.7	9	23	7	11	0.1393	0.2	0.1669	-766
2	WF01-PW2	203	50	35	43	42	—	—	—	-481
3	WF01-PW3	575	—	115	—	115	—	—	—	-500
4	WF01-PW4	96.7	79	76	67	74	—	—	—	-131
5	WF01-PW6	1590	381	483	246	356	—	—	—	-446
6	WF01-PW7	26.5	5	12	5	7	0.44	0.21	0.3056	-391
7	WF01-PW8	106	—	65	—	65	—	—	—	-163
8	WF01-PW13	166	—	57	—	57	—	—	—	-291
9	WF01-PW18	16200	1068	—	802	925	—	—	—	-1750
10	SWAWF2	58.3	269	523	300	348	1.9700E-05	—	1.9700E-05	597
11	SWAWF4B	12900	990	1252	728	1031	0.022	0.034	0.0273	-1251
12	SWAWF5	34400	275	395	159	258	0.53	—	0.5300	-13317

5. CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

Owing to the high costs of aquifer tests, the number that can be performed in most groundwater studies has to be restricted. Nevertheless, one can perform an aquifer test without using piezometers, thereby cutting costs, although one must then accept a certain, sometimes appreciable, error. To distinguish such tests from normal aquifer tests, they are called single-well tests. In these tests, measurements are only taken inside the pumped well.

Analyzing and evaluating aquifer-test data is as much an art as a science. It is a science as it is based on theoretical models that the geologist or 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 as different types of aquifers can exhibit similar drawdown behaviors that demand interpretational skills on the part of the geologist or engineer.

As the objective of this research is the analysis hydraulic parameters of the akaki well field aquifer by using data collected from single well test all the data from the twenty four well, which are found in the selected well field 01 were thoroughly analyzed and Evaluated .

During the Evaluation process geological logging were studied, Drawdown versus time graph of each pumping test data were plotted and compared to the theoretical models in order to identify the type of the aquifer for selecting the right method in evaluating the pumping test, after which the required correction of data were made & finally approximation of the transmissivity values were made using excel spread sheet & Aquifer test software which both result in comparable values and based on the result the twelve pump test data results found to have exaggerated values of transmissivity which doesn't even represent the aquifer characteristics of the study area.

The test well drilling results of the study area shows that the main aquifer in this prospective site are scoria, scoraceous & fractured basalt, which are classified as fractured igneous rocks. Freeze et al . (2000) indicates that the values of the Hydraulic conductivity of this rocks ranges between 8x10^{-9} - 3x10^{-4} m/s & as noticed from the result made after the evaluation the transmissivity estimated lies in this range, while the result from the document evaluated takes exaggerated values of highly hydraulic conductive of rocks like permeable basalt & karast lime stone in which such kinds of inaccurate estimation will result in excessive loss of Saturated aquifer thickness of the aquifer that shorten the productive life of the aquifer.

5.2 RECOMMENDATION

1. Conducting aquifer test using a single well test , where well loss is present makes the determination of storativity impossible and also left us with no option for making any comparison of result obtained , so this evaluation thesis recommend the most useful test that includes water level measurement in observation well (multiple well test) has to be conducted to have a correct parameter of the area for a proper management of the groundwater resource.

2. Conducting a step drawdown test is the only reliable means of quantifying the well loss for determination well efficiency, which provides valuable information about the well performance and to make an informed decision regarding the well pumping rate , so this evaluation urge the performing of a step drawdown test as it was ignored in most of the well developed in the study area.

3. Before being used in the analysis, Quality of data has to be assessed and compared with theoretical models which comprise the type of aquifers, outer boundary conditions (bounded aquifer like the case of barriers and recharge boundaries), inner boundaries conditions (those associated with the pumping well like the cases of full or partially penetrating, well loss) and finally the right model has to be selected to analyses the data. If the wrong model is chosen, the hydraulic characteristics calculated for the real aquifer will not be correct Kruseman and de Ridder. (2000). So in this evaluation it is recommended that the determination of groundwater hydraulic parameters has to be done after a proper data quality checking , correction & methods of analysis selection as many errors had been found during the evaluation process like using uncorrected data &

doing the analysis by using only one method for Determination & evaluation of hydraulic characteristics .

4. As the thesis evaluates only the transmissivity of the aquifer of the study area from data collected using single well test. Hence use of existing wells as data observation site to conduct multiple well test , which can be used to define the overall hydraulic parameters (like the determination of storativity &/or specific yield of the area) is recommended as a research topic to strengthen the conclusion reached in this research for proper utilization and management of the ground water resource of the area.

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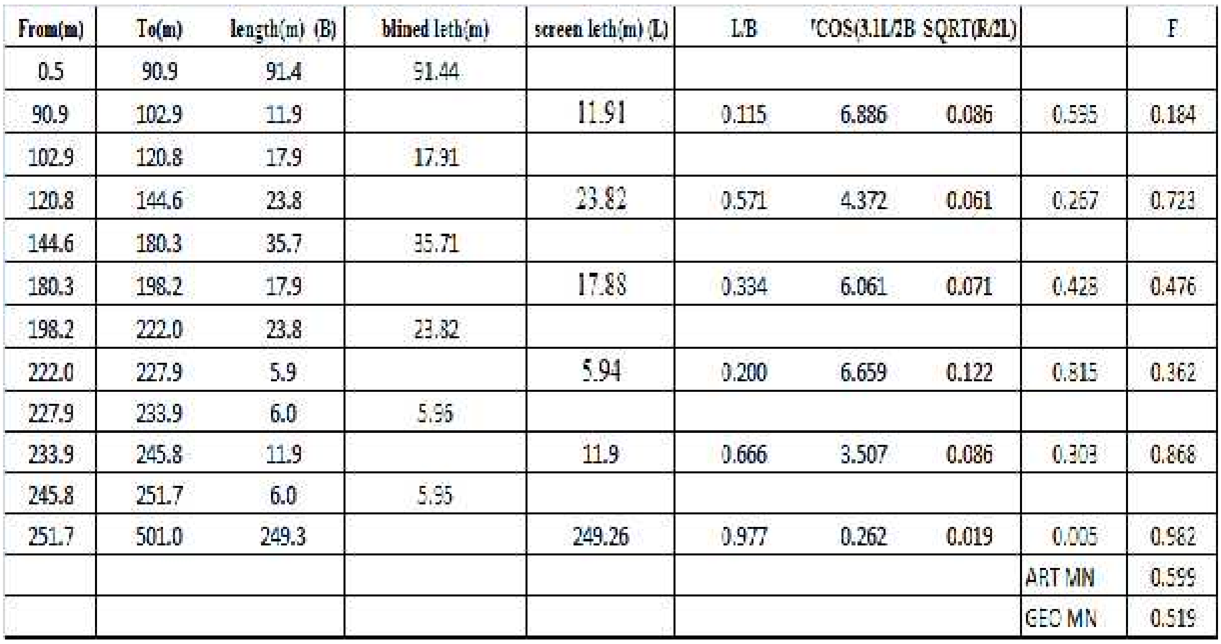
APPENDEX-A

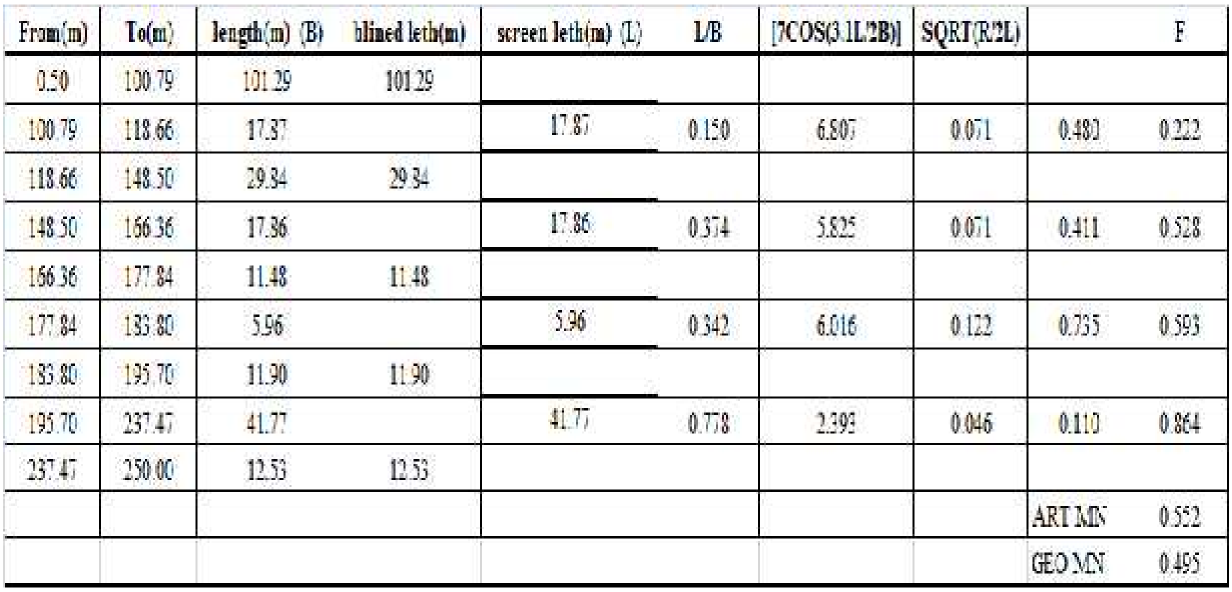
CALCULATION OF CORRECTION FOR PARTIAL PENETRATION,KOZENY(1933) REDUCTION FACTOR

TABLE A1:WELL INDEX PW-1



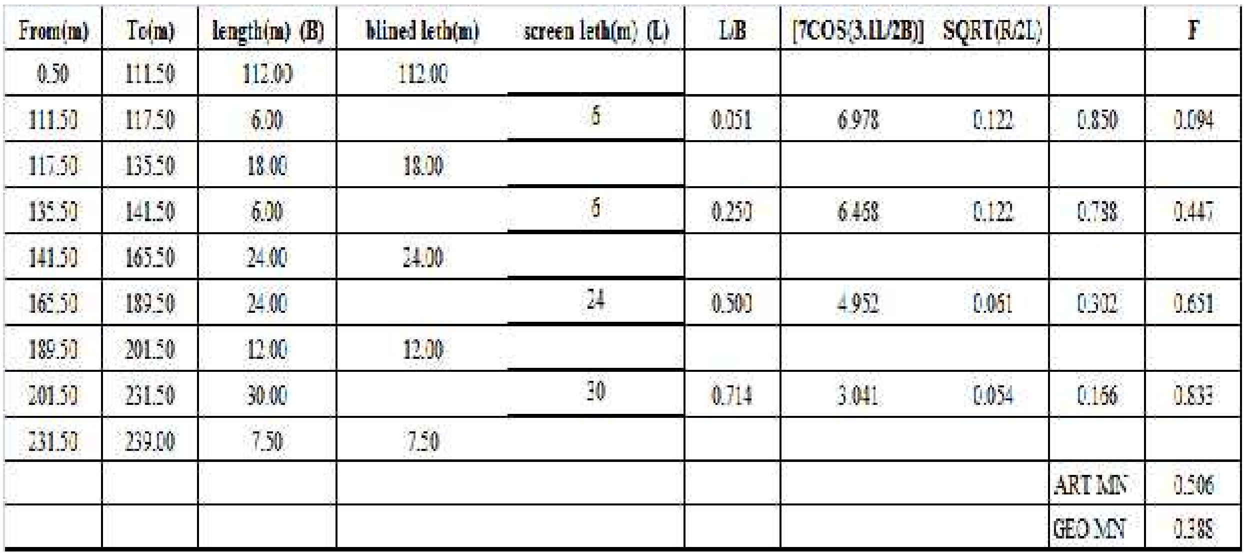
From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	'COS(3.1L/2B	SQRT(R/2L)		F
0.5	90.9	91.4	91.44						
90.9	102.9	11.9		11.91	0.115	6.886	0.086	0.535	0.184
102.9	120.8	17.9	17.91						
120.8	144.6	23.8		23.82	0.571	4.372	0.061	0.257	0.723
144.6	180.3	35.7	35.71						
180.3	198.2	17.9		17.88	0.334	6.061	0.071	0.428	0.476
198.2	222.0	23.8	23.82						
222.0	227.9	5.9		5.94	0.200	6.659	0.122	0.815	0.362
227.9	233.9	6.0	5.96						
233.9	245.8	11.9		11.9	0.666	3.507	0.086	0.303	0.868
245.8	251.7	6.0	5.95						
251.7	501.0	249.3		249.26	0.977	0.262	0.019	0.005	0.982
								ART MN	0.599
								GEO MN	0.519

TABLE A2:WELL INDEX PW-2



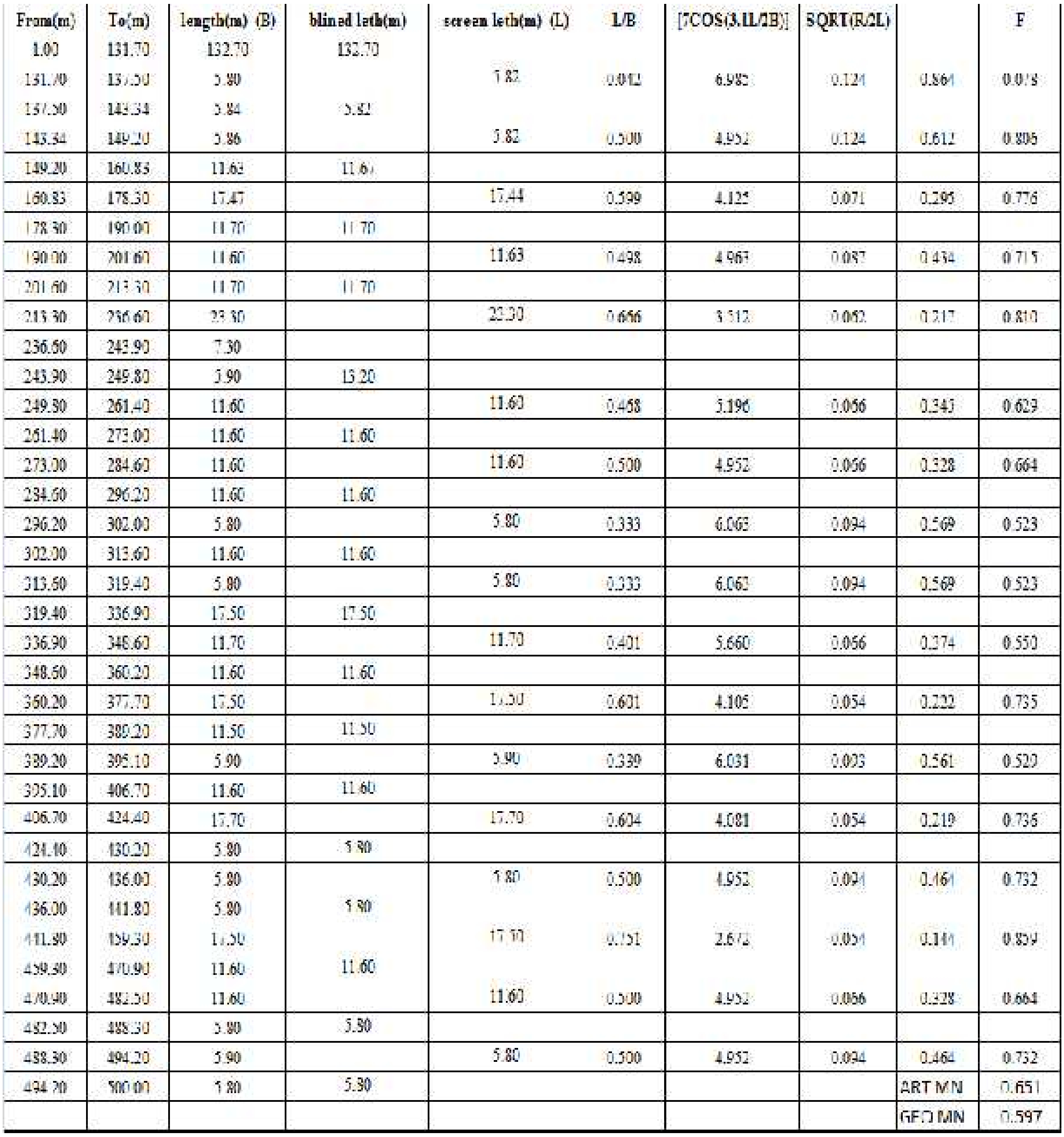
From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.50	100.79	101.29	101.29						
100.79	118.66	17.87		17.87	0.150	6.807	0.071	0.480	0.222
118.66	148.50	29.84	29.84						
148.50	166.36	17.86		17.86	0.374	5.825	0.071	0.411	0.528
166.36	177.84	11.48	11.48						
177.84	183.80	5.96		5.96	0.342	6.016	0.122	0.735	0.593
183.80	195.70	11.90	11.90						
195.70	237.47	41.77		41.77	0.778	2.393	0.046	0.110	0.864
237.47	250.00	12.53	12.53						
								ART MN	0.552
								GEO MN	0.495

TABLE A3:WELL INDEX PW-3



From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.50	111.50	112.00	112.00						
111.50	117.50	6.00		6	0.051	6.978	0.122	0.850	0.094
117.50	135.50	18.00	18.00						
135.50	141.50	6.00		6	0.250	6.468	0.122	0.738	0.447
141.50	165.50	24.00	24.00						
165.50	189.50	24.00		24	0.500	4.952	0.061	0.302	0.651
189.50	201.50	12.00	12.00						
201.50	231.50	30.00		30	0.714	3.041	0.054	0.166	0.833
231.50	239.00	7.50	7.50						
								ART MN	0.506
								GEO MN	0.388

TABLE A4:WELL INDEX PW-4



From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
1.00	131.70	132.70	132.70						
131.70	137.50	5.80		5.82	0.042	6.982	0.124	0.864	0.078
137.50	143.34	5.84	5.82						
143.34	149.20	5.86		5.82	0.500	4.952	0.124	0.612	0.806
149.20	160.83	11.63	11.63						
160.83	178.30	17.47		17.44	0.599	4.125	0.071	0.295	0.776
178.30	190.00	11.70	11.70						
190.00	201.60	11.60		11.63	0.498	4.963	0.087	0.434	0.715
201.60	213.30	11.70	11.70						
213.30	236.60	23.30		23.30	0.666	3.512	0.062	0.217	0.810
236.50	243.90	7.30							
243.90	249.80	5.90	13.20						
249.30	261.40	11.60		11.60	0.458	5.196	0.056	0.343	0.629
261.40	273.00	11.60	11.60						
273.00	284.60	11.60		11.60	0.500	4.952	0.056	0.328	0.664
284.60	296.20	11.60	11.60						
296.20	302.00	5.80		5.80	0.333	6.063	0.094	0.569	0.523
302.00	313.60	11.60	11.60						
313.50	319.40	5.80		5.80	0.333	6.062	0.094	0.569	0.523
319.40	336.90	17.50	17.50						
336.90	348.60	11.70		11.70	0.401	5.660	0.056	0.274	0.550
348.50	360.20	11.60	11.60						
360.20	377.70	17.50		17.50	0.601	4.105	0.054	0.222	0.735
377.70	389.20	11.50	11.50						
389.20	395.10	5.90		5.90	0.339	6.031	0.093	0.561	0.520
395.10	406.70	11.60	11.60						
406.70	424.40	17.70		17.70	0.604	4.081	0.054	0.219	0.736
424.40	430.20	5.80	5.80						
430.20	436.00	5.80		5.80	0.500	4.952	0.094	0.464	0.732
436.00	441.80	5.80	5.80						
441.80	459.30	17.50		17.50	0.751	2.672	0.054	0.144	0.859
459.30	470.90	11.60	11.60						
470.90	482.50	11.60		11.60	0.500	4.952	0.066	0.328	0.664
482.50	488.30	5.80	5.80						
488.30	494.20	5.90		5.80	0.500	4.952	0.094	0.464	0.732
494.20	500.00	5.80	5.80					ART MN	0.651
								GEO MN	0.597

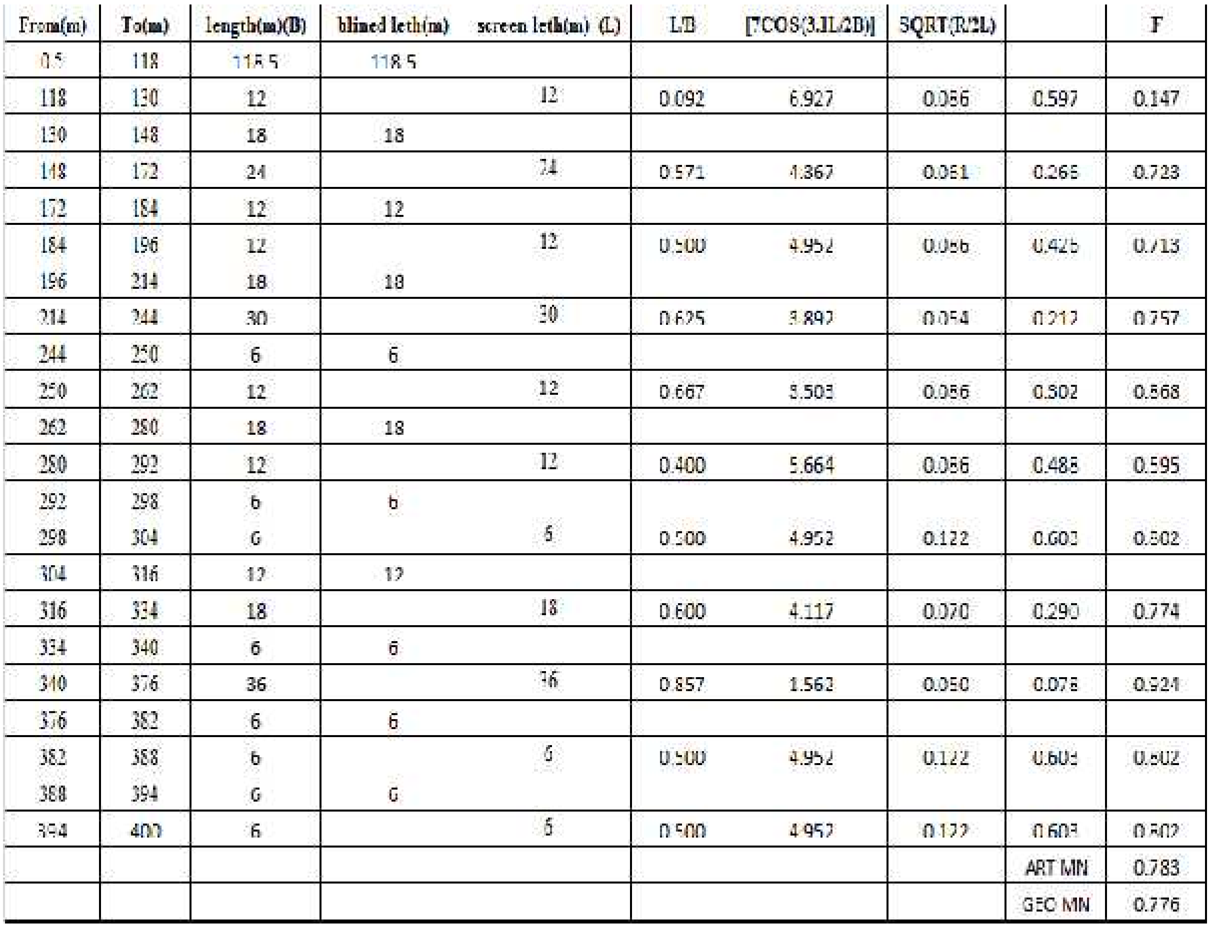
TABLEA5:WELL INDEX PW-6

From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.50	109.00	109.50	109.50						
109.00	115.00	6.00		6.00	0.052	6.977	0.122	0.850	0.096
115.00	127.00	12.00	12.00						
127.00	133.00	6.00		6.00	0.333	6.063	0.122	0.738	0.279
133.00	157.00	24.00	24.00						
157.00	187.00	30.00		30.00	0.556	4.502	0.054	0.245	0.692
187.00	199.00	12.00	12.00						
199.00	211.00	12.00		12.00	0.500	4.952	0.086	0.426	0.713
211.00	229.00	18.00	18.00						
229.00	241.00	12.00		12.00	0.400	5.664	0.086	0.488	0.595
241.00	259.00	18.00	18.00						
259.00	277.00	18.00		18.00	0.500	4.952	0.070	0.348	0.674
277.00	283.00	6.00	6.00						
283.00	532.00	249.00		249.00	0.976	0.264	0.019	0.005	0.981
								ART MN	0.619
								GEO MN	0.524

TABLEA6:WELL INDEX PW-8

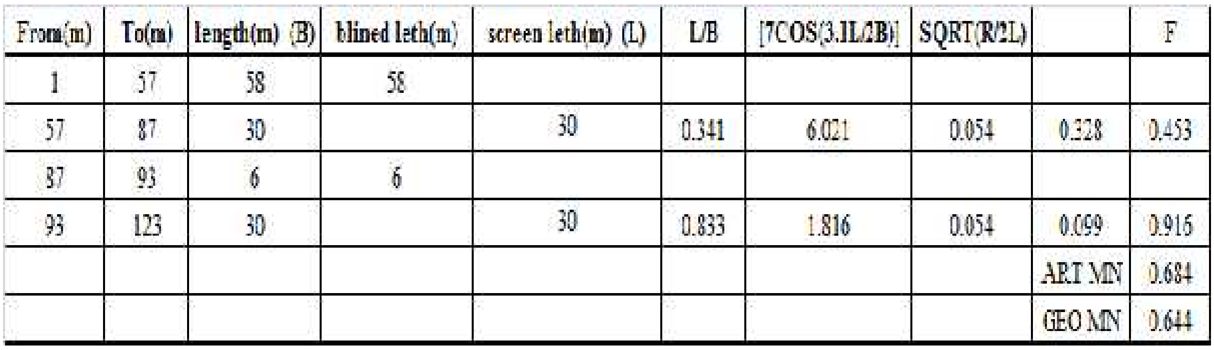
From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.65	88.00	88.66	83.66						
88.00	118.00	30.00		30.00	0.253	6.456	0.054	0.352	0.342
113.00	142.00	24.00	24.00						
142.00	160.00	18.00		18.00	0.429	5.474	0.070	0.385	0.594
160.00	172.00	12.00	12.00						
172.00	184.00	12.00		12.00	0.500	4.952	0.086	0.426	0.713
184.00	214.00	30.00	30.00						
214.00	244.00	30.00		30.00	0.500	4.952	0.054	0.270	0.635
244.00	250.00	6.00	6.00						
250.00	483.70	233.70		233.70	0.975	0.281	0.020	0.005	0.980
								ART MN	0.653
								GEO MN	0.618

TABLEA7:WELL INDEX PW -13



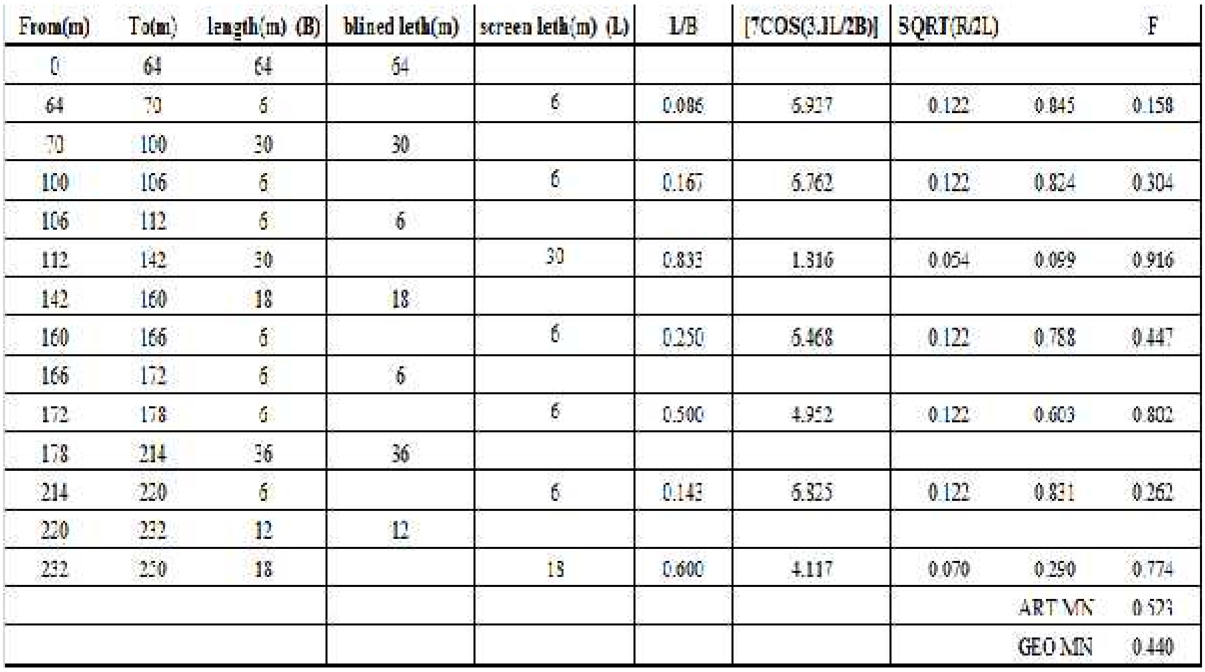
From(m)	To(m)	length(m)(B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0.5	118	118.5	118.5						
118	130	12		12	0.092	6.927	0.066	0.597	0.147
130	148	18	18						
148	172	24		24	0.571	4.367	0.051	0.266	0.723
172	184	12	12						
184	196	12		12	0.500	4.952	0.066	0.425	0.713
196	214	18	18						
214	244	30		30	0.625	3.892	0.054	0.212	0.757
244	250	6	6						
250	262	12		12	0.667	3.503	0.066	0.502	0.568
262	280	18	18						
280	292	12		12	0.400	5.664	0.066	0.488	0.595
292	298	6	6						
298	304	6		6	0.500	4.952	0.122	0.603	0.502
304	316	12	12						
316	334	18		18	0.600	4.117	0.070	0.290	0.774
334	340	6	6						
340	376	36		36	0.857	1.563	0.050	0.078	0.924
376	382	6	6						
382	388	6		6	0.500	4.952	0.122	0.603	0.502
388	394	6	6						
394	400	6		6	0.500	4.952	0.122	0.603	0.502
								ART MN	0.783
								GEO MN	0.776

TABLEA8:WELL INDEX PW -18



From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
1	57	58	58						
57	87	30		30	0.341	6.021	0.054	0.328	0.453
87	93	6	6						
93	123	30		30	0.833	1.816	0.054	0.099	0.916
								ART MN	0.684
								GEO MN	0.644

TABLEA9:WELL INDEX SWAWF -5



From(m)	To(m)	length(m) (B)	blined leth(m)	screen leth(m) (L)	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F
0	64	64	64						
64	70	6		6	0.086	6.927	0.122	0.845	0.158
70	100	30	30						
100	106	6		6	0.167	6.762	0.122	0.824	0.304
106	112	6	6						
112	142	30		30	0.833	1.316	0.054	0.099	0.916
142	160	18	18						
160	166	6		6	0.250	6.468	0.122	0.788	0.447
166	172	6	6						
172	178	6		6	0.500	4.952	0.122	0.603	0.802
178	214	36	36						
214	220	6		6	0.143	6.325	0.122	0.831	0.262
220	232	12	12						
232	250	18		18	0.600	4.117	0.070	0.290	0.774
								ART MN	0.523
								GEO MN	0.440

APPENDEX B

TABLES OF STEP, CONSTANT & RECOVERY PUMPING TEST RAW DATA , CORRECTION FOR PARTIAL PENETRATION & UNCONFINED CORRECTION

TABLE B1: DATA OF WELL INDEX PW-1

WELL INDEX PW -1				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**	UNC CORR
0	21.67	0	0.00	
1	48.12	26.45	15.85	15.59
2	57.28	35.61	21.34	20.86
3	62.47	40.8	24.45	23.83
4	65.72	44.05	26.40	25.67
5	67.83	46.16	27.66	26.86
6	70.26	48.59	29.12	28.23
7	72.15	50.48	30.25	29.30
8	74.7	53.03	31.78	30.72
9	78.08	56.41	33.81	32.61
10	80.58	58.91	35.30	34.00
12	84.97	63.3	37.93	36.43
14	87.65	65.98	39.54	37.91
16	89.25	67.58	40.50	38.78
18	89.94	68.27	40.91	39.16
20	90.4	68.73	41.19	39.42
25	91.1	69.43	41.61	39.80
30	91.55	69.88	41.88	40.04
35	91.87	70.2	42.07	40.22
40	92.18	70.51	42.26	40.39
45	92.4	70.73	42.39	40.51
50	92.6	70.93	42.51	40.62
60	92.76	71.09	42.60	40.71
70	92.92	71.25	42.70	40.79
80	93.27	71.6	42.91	40.98
90	93.4	71.73	42.99	41.05
100	93.56	71.89	43.08	41.14
120	93.78	72.11	43.21	41.26
140	94	72.33	43.35	41.38
160	94.22	72.55	43.48	41.50
180	94.52	72.85	43.66	41.67
210	94.62	72.95	43.72	41.72
240	94.75	73.08	43.80	41.79
270	94.88	73.21	43.87	41.86
300	95.11	73.44	44.01	41.99

WELL INDEX PW -1				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**	UNC CORR
330	95.23	73.56	44.08	42.05
360	95.33	73.66	44.14	42.11
420	95.5	73.83	44.24	42.20
480	95.65	73.98	44.33	42.28
540	95.8	74.13	44.42	42.36
600	95.94	74.27	44.51	42.44
660	96.08	74.41	44.59	42.51
720	96.12	74.45	44.62	42.54
780	96.27	74.6	44.71	42.62
840	96.35	74.68	44.75	42.66
900	96.47	74.8	44.83	42.73
960	96.57	74.9	44.89	42.78
1020	96.65	74.98	44.93	42.82
1080	96.7	75.03	44.96	42.85
1140	96.78	75.11	45.01	42.89
1200	96.82	75.15	45.04	42.92
1260	96.87	75.2	45.07	42.94
1320	96.94	75.27	45.11	42.98
1380	96.99	75.32	45.14	43.01
1440	97.03	75.36	45.16	43.03
1500	97.05	75.38	45.17	43.04
1560	97.11	75.44	45.21	43.07
1620	97.2	75.53	45.26	43.12
1680	97.25	75.58	45.29	43.15
1740	97.19	75.52	45.26	43.12
1800	97.25	75.58	45.29	43.15
1860	97.37	75.7	45.37	43.21
1920	97.39	75.72	45.38	43.23
1980	97.4	75.73	45.38	43.23
2040	97.48	75.81	45.43	43.27
2100	97.52	75.85	45.46	43.30
2160	97.58	75.91	45.49	43.33
2220	97.6	75.93	45.50	43.34
2280	97.62	75.95	45.52	43.35

WELL INDEX PW -1				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**	**UNCON CORR**
2340	97.65	75.98	45.53	43.37
2400	97.66	75.99	45.54	43.37
2460	97.65	75.98	45.53	43.37
2520	97.69	76.02	45.56	43.39
2580	97.74	76.07	45.59	43.42
2640	97.74	76.07	45.59	43.42
2700	97.76	76.09	45.60	43.43
2760	97.82	76.15	45.64	43.46
2820	97.83	76.16	45.64	43.46
2880	97.86	76.19	45.66	43.48
2940	97.87	76.2	45.67	43.49
3000	97.91	76.24	45.69	43.51
3060	97.96	76.29	45.72	43.53
3120	97.99	76.32	45.74	43.55
3180	98.08	76.41	45.79	43.60
3240	98.04	76.37	45.77	43.58
3300	98.05	76.38	45.77	43.58
3360	98.05	76.38	45.77	43.58
3420	98.04	76.37	45.77	43.58
3480	98.08	76.41	45.79	43.60
3540	98.1	76.43	45.80	43.61
3600	98.12	76.45	45.82	43.62
3660	98.15	76.48	45.83	43.64
3720	98.18	76.51	45.85	43.65
3780	98.22	76.55	45.88	43.68
3840	98.26	76.59	45.90	43.70
3900	98.27	76.6	45.90	43.70
3960	98.25	76.58	45.89	43.69
4020	98.24	76.57	45.89	43.69
4080	98.24	76.57	45.89	43.69
4140	98.24	76.57	45.89	43.69
4200	98.27	76.6	45.90	43.70
4260	98.3	76.63	45.92	43.72
4320	98.32	76.65	45.93	43.73

WELL INDEX PW -1

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR	UNCON CORR
0	98.32	76.65	#DIV/0!	45.93	
1	94.2	72.53	4321.0	43.47	41.49
2	89.15	67.48	2161.0	40.44	38.73
3	83.84	62.17	1441.0	37.26	35.81
4	78.22	56.55	1081.0	33.89	32.69
5	75.75	54.08	865.0	32.41	31.31
6	73.21	51.54	721.0	30.89	29.89
7	71.81	50.14	618.1	30.05	29.10
8	68.92	47.25	541.0	28.32	27.48
9	67.14	45.47	481.0	27.25	26.47
10	66.2	44.53	433.0	26.69	25.94
12	63.2	41.53	361.0	24.89	24.24
14	60.55	38.88	309.6	23.30	22.73
16	58.15	36.48	271.0	21.86	21.36
18	56.52	34.85	241.0	20.88	20.43
20	54.45	32.78	217.0	19.64	19.24
25	50.15	28.48	173.8	17.07	16.76
30	46.42	24.75	145.0	14.83	14.60
35	44.39	22.72	124.4	13.62	13.42
40	42.15	20.48	109.0	12.27	12.12
45	41.76	20.09	97.0	12.04	11.89
50	40.38	18.71	87.4	11.21	11.08
60	38.28	16.61	73.0	9.95	9.85
70	37.85	16.18	62.7	9.70	9.60
80	37.5	15.83	55.0	9.49	9.39
90	36.74	15.07	49.0	9.03	8.95
100	36.2	14.53	44.2	8.71	8.63
120	34.8	13.13	37.0	7.87	7.80
140	33.59	11.92	31.9	7.14	7.09
160	33.34	11.67	28.0	6.99	6.94
180	32.85	11.18	25.0	6.70	6.65
210	32.1	10.43	21.6	6.25	6.21
240	31.32	9.65	19.0	5.78	5.75
270	30.85	9.18	17.0	5.50	5.47
300	30.4	8.73	15.4	5.23	5.20
330	29.82	8.15	14.1	4.88	4.86
360	29.46	7.79	13.0	4.67	4.65
420	28.65	6.98	11.3	4.18	4.16
480	28.05	6.38	10.0	3.82	3.81
540	26.45	4.78	9.0	2.86	2.86
600	26.18	4.51	8.2	2.70	2.70
660	25.92	4.25	7.5	2.55	2.54
720	25.6	3.93	7.0	2.36	2.35
780	25.39	3.72	6.5	2.23	2.22
840	25.27	3.6	6.1	2.16	2.15
900	25.12	3.45	5.8	2.07	2.06
960	25.1	3.43	5.5	2.06	2.05
1020	24.93	3.26	5.2	1.95	1.95
1080	24.77	3.1	5.0	1.86	1.85
1140	24.58	2.91	4.8	1.74	1.74

TABLE B2: DATA OF WELL INDEX PW-2

WELL INDEX PW -2				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
0	21.23	0	0.00	
1	42.58	21.35	11.78	11.48
2	46.16	24.93	13.76	13.35
3	48.02	26.79	14.79	14.31
4	48.68	27.45	15.15	14.65
5	49.22	27.99	15.45	14.93
6	49.7	28.47	15.71	15.17
7	50.18	28.95	15.98	15.42
8	50.41	29.18	16.10	15.54
9	50.72	29.49	16.28	15.70
10	50.96	29.73	16.41	15.82
12	51.45	30.22	16.68	16.07
14	51.82	30.59	16.88	16.26
16	52.18	30.95	17.08	16.44
18	52.52	31.29	17.27	16.62
20	52.87	31.64	17.46	16.80
25	53.52	32.29	17.82	17.13
30	54.1	32.87	18.14	17.42
35	54.59	33.36	18.41	17.67
40	55.03	33.8	18.65	17.89
45	55.48	34.25	18.90	18.12
50	55.81	34.58	19.08	18.29
55	56.14	34.91	19.27	18.46
60	56.43	35.2	19.43	18.60
70	57.06	35.83	19.77	18.92
80	57.64	36.41	20.09	19.21
90	58.24	37.01	20.43	19.51
100	58.78	37.55	20.72	19.79
120	59.48	38.25	21.11	20.14
140	60.29	39.06	21.56	20.54
160	61.01	39.78	21.95	20.90
180	61.72	40.49	22.35	21.26
210	62.75	41.52	22.92	21.77
240	63.51	42.28	23.33	22.14
270	64.34	43.11	23.79	22.56
300	65.06	43.83	24.19	22.91
330	65.76	44.53	24.58	23.26
360	66.5	45.27	24.98	23.62
420	67.72	46.49	25.66	24.22
480	68.91	47.68	26.31	24.80
540	69.98	48.75	26.91	25.32
600	71.05	49.82	27.50	25.84

WELL INDEX PW -2

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
660	72	50.77	28.02	26.30
720	72.9	51.67	28.52	26.74
780	73.85	52.62	29.04	27.20
840	74.75	53.52	29.54	27.63
900	75.55	54.32	29.98	28.02
960	76.32	55.09	30.40	28.38
1020	77.08	55.85	30.82	28.75
1080	78.1	56.87	31.39	29.23
1140	78.56	57.33	31.64	29.45
1200	79.2	57.97	31.99	29.76
1260	79.96	58.73	32.41	30.12
1320	80.29	59.06	32.60	30.27
1380	80.6	59.37	32.77	30.42
1440	80.95	59.72	32.96	30.59
1500	81.67	60.44	33.36	30.93
1560	82.44	61.21	33.78	31.29
1620	83.11	61.88	34.15	31.60
1680	83.73	62.5	34.49	31.89
1740	84.31	63.08	34.81	32.17
1800	84.94	63.71	35.16	32.46
1860	85.49	64.26	35.47	32.72
1920	86.1	64.87	35.80	33.00
1980	86.6	65.37	36.08	33.23
2040	87.25	66.02	36.44	33.54
2100	87.6	66.37	36.63	33.70
2160	88.18	66.95	36.95	33.97
2220	88.62	67.39	37.19	34.17
2280	89.12	67.89	37.47	34.40
2340	89.6	68.37	37.73	34.62
2400	90.07	68.84	37.99	34.84
2460	90.52	69.29	38.24	35.05
2520	90.95	69.72	38.48	35.24
2580	91.43	70.2	38.74	35.46
2640	91.68	70.45	38.88	35.58
2700	91.94	70.71	39.03	35.70
2760	92.15	70.92	39.14	35.79
2820	92.37	71.14	39.26	35.89
2880	92.79	71.56	39.49	36.09
2940	93.24	72.01	39.74	36.29
3000	93.74	72.51	40.02	36.52
3060	94.13	72.9	40.23	36.70
3120	94.58	73.35	40.48	36.90

WELL INDEX PW -2

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
3180	94.95	73.72	40.69	37.07
3240	95.31	74.08	40.89	37.23
3300	95.71	74.48	41.11	37.41
3360	96.02	74.79	41.28	37.55
3420	96.4	75.17	41.49	37.73
3480	96.72	75.49	41.66	37.87
3540	97.07	75.84	41.86	38.03
3600	97.4	76.17	42.04	38.18
3660	97.74	76.51	42.23	38.33
3720	98.07	76.84	42.41	38.48
3780	98.43	77.2	42.61	38.64
3840	98.7	77.47	42.76	38.76
3900	98.97	77.74	42.91	38.88
4020	99.62	78.39	43.26	39.17
4080	99.92	78.69	43.43	39.31
4140	100.2	78.97	43.58	39.43
4200	100.41	79.18	43.70	39.53
4260	100.7	79.47	43.86	39.66
4320	100.93	79.7	43.99	39.76
4380	101.21	79.98	44.14	39.88
4440	101.47	80.24	44.29	40.00
4500	101.72	80.49	44.42	40.11
4560	102.01	80.78	44.58	40.24
4620	102.22	80.99	44.70	40.33
4680	102.43	81.2	44.81	40.43
4740	102.71	81.48	44.97	40.55
4800	102.9	81.67	45.07	40.63
4860	103.15	81.92	45.21	40.74
4920	103.38	82.15	45.34	40.85
4980	103.61	82.38	45.47	40.95
5040	103.83	82.6	45.59	41.05
5100	104.05	82.82	45.71	41.14
5160	104.32	83.09	45.86	41.26
5220	104.53	83.3	45.97	41.35
5280	104.7	83.47	46.07	41.43
5340	104.86	83.63	46.16	41.50
5400	105.05	83.82	46.26	41.58
5460	105.22	83.99	46.35	41.66
5520	105.43	84.2	46.47	41.75
5580	105.58	84.35	46.55	41.82
5640	105.72	84.49	46.63	41.88
5700	105.95	84.72	46.76	41.98
5760	106.07	84.84	46.82	42.03

WELL INDEX PW -2

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR	UNCON CORR
0	106.07	84.84	#DIV/0!	46.82	42.03
1	86.8	65.57	5761.0	36.19	33.33
2	82.11	60.88	2881.0	33.60	31.13
3	80.47	59.24	1921.0	32.70	30.36
4	79.8	58.57	1441.0	32.33	30.04
5	79.19	57.96	1153.0	31.99	29.75
6	78.86	57.63	961.0	31.81	29.60
7	78.55	57.32	823.9	31.64	29.45
8	78.25	57.02	721.0	31.47	29.31
9	78.03	56.8	641.0	31.35	29.20
10	77.79	56.56	577.0	31.22	29.09
12	77.1	55.87	481.0	30.84	28.76
14	76.98	55.75	412.4	30.77	28.70
16	76.72	55.49	361.0	30.63	28.58
18	76.39	55.16	321.0	30.44	28.42
20	76.19	54.96	289.0	30.33	28.32
25	75.57	54.34	231.4	29.99	28.02
30	75.1	53.87	193.0	29.73	27.80
35	74.45	53.22	165.6	29.37	27.49
40	74.32	53.09	145.0	29.30	27.42
45	74.03	52.8	129.0	29.14	27.28
50	73.77	52.54	116.2	29.00	27.16
55	73.52	52.29	105.7	28.86	27.04
60	73.28	52.05	97.0	28.73	26.92
70	72.71	51.48	83.3	28.41	26.65
80	72.11	50.88	73.0	28.08	26.36
90	71.74	50.51	65.0	27.88	26.18
100	71.42	50.19	58.6	27.70	26.02
120	70.64	49.41	49.0	27.27	25.64
140	69.91	48.68	42.1	26.87	25.29
160	69.35	48.12	37.0	26.56	25.02
180	68.7	47.47	33.0	26.20	24.70
210	67.85	46.62	28.4	25.73	24.28
240	67.04	45.81	25.0	25.28	23.89
270	66.3	45.07	22.3	24.87	23.52
300	65.78	44.55	20.2	24.59	23.27
330	65.1	43.87	18.5	24.21	22.93
360	64.52	43.29	17.0	23.89	22.64
420	63.41	42.18	14.7	23.28	22.10
480	62.31	41.08	13.0	22.67	21.55
540	61.29	40.06	11.7	22.11	21.04
600	60.38	39.15	10.6	21.61	20.59
660	59.56	38.33	9.7	21.15	20.18
720	58.62	37.39	9.0	20.64	19.71
780	57.8	36.57	8.4	20.18	19.29
840	56.76	35.53	7.9	19.61	18.77
900	56.16	34.93	7.4	19.28	18.47
960	55.35	34.12	7.0	18.83	18.06

WELL INDEX PW -2

Recovery

Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
1020	54.65	33.42	6.6	18.44	17.70
1080	54.02	32.79	6.3	18.10	17.38
1140	53.49	32.26	6.1	17.80	17.11
1200	52.88	31.65	5.8	17.47	16.80
1260	52.29	31.06	5.6	17.14	16.50
1320	51.73	30.5	5.4	16.83	16.21
1380	51.02	29.79	5.2	16.44	15.85
1440	50.43	29.2	5.0	16.12	15.55
1500	49.81	28.58	4.8	15.77	15.23
1560	49.34	28.11	4.7	15.51	14.99
1620	48.8	27.57	4.6	15.22	14.71
1680	48.19	26.96	4.4	14.88	14.40
1740	47.67	26.44	4.3	14.59	14.13
1800	47.29	26.06	4.2	14.38	13.93
1860	47.2	25.97	4.1	14.33	13.88
1920	46.81	25.58	4.0	14.12	13.68
1980	45.45	24.22	3.9	13.37	12.98
2040	44.95	23.72	3.8	13.09	12.72
2100	44.64	23.41	3.7	12.92	12.56
2160	44.3	23.07	3.7	12.73	12.38
2220	43.47	22.24	3.6	12.27	11.95
2280	43.55	22.32	3.5	12.32	11.99
2340	43.02	21.79	3.5	12.03	11.71
2400	42.58	21.35	3.4	11.78	11.48
2460	42.1	20.87	3.3	11.52	11.23
2520	41.65	20.42	3.3	11.27	10.99
2580	41.22	19.99	3.2	11.03	10.77
2640	40.95	19.72	3.2	10.88	10.62
2700	40.7	19.47	3.1	10.75	10.49
2760	40.38	19.15	3.1	10.57	10.32
2820	40.08	18.85	3.0	10.40	10.17
2880	39.63	18.4	3.0	10.16	9.93
2940	39.3	18.07	3.0	9.97	9.76
3000	39.02	17.79	2.9	9.82	9.61
3060	38.62	17.39	2.9	9.60	9.40
3120	38.22	16.99	2.8	9.38	9.18
3180	38.05	16.82	2.8	9.28	9.09
3240	37.4	16.17	2.8	8.92	8.75
3300	37.73	16.5	2.7	9.11	8.93
3360	37.48	16.25	2.7	8.97	8.79
3420	37.1	15.87	2.7	8.76	8.59
3480	36.8	15.57	2.7	8.59	8.43
3540	36.55	15.32	2.6	8.46	8.30
3600	36.25	15.02	2.6	8.29	8.14
3660	35.92	14.69	2.6	8.11	7.96
3720	35.63	14.4	2.5	7.95	7.81
3780	35.3	14.07	2.5	7.77	7.63
3840	35.11	13.88	2.5	7.66	7.53
3900	35.05	13.82	2.5	7.63	7.50
4020	34.57	13.34	2.4	7.36	7.24
4080	34.31	13.08	2.4	7.22	7.11
4140	34.13	12.9	2.4	7.12	7.01
4200	33.98	12.75	2.4	7.04	6.93
4260	33.85	12.62	2.4	6.97	6.86
4320	33.73	12.5	2.3	6.90	6.79

TABLE B3: DATA OF WELL INDEX PW-3

WELL INDEX PW -3				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
0	21.83	0		
1	45.2	23.37	11.83	11.675
2	85	63.17	31.97	30.858
3	86.9	65.07	32.93	31.752
4	87.8	65.97	33.39	32.174
5	87.5	65.67	33.23	32.033
6	87.8	65.97	33.39	32.174
7	87.8	65.97	33.39	32.174
8	87.5	65.67	33.23	32.033
9	87.9	66.07	33.44	32.221
10	87.4	65.57	33.18	31.987
12	87.9	66.07	33.44	32.221
14	87.2	65.37	33.08	31.893
16	87.2	65.37	33.08	31.893
18	87.2	65.37	33.08	31.893
20	86.9	65.07	32.93	31.752
25	86.5	64.67	32.73	31.564
30	86.6	64.77	32.78	31.611
35	87.5	65.67	33.23	32.033
40	87.8	65.97	33.39	32.174
45	87.2	65.37	33.08	31.893
50	87.7	65.87	33.34	32.127
55	87.9	66.07	33.44	32.221
60	87.92	66.09	33.45	32.231
70	88	66.17	33.49	32.268
80	88	66.17	33.49	32.268
90	89.1	67.27	34.04	32.784

WELL INDEX PW -3				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
100	89	67.17	33.99	32.74
120	89.3	67.47	34.15	32.88
140	90.8	68.97	34.90	33.58
160	90.5	68.67	34.75	33.44
180	90.9	69.07	34.96	33.63
210	91.7	69.87	35.36	34.00
270	92.07	70.24	35.55	34.17
300	92.5	70.67	35.77	34.37
360	92.25	70.42	35.64	34.26
420	92.72	70.89	35.88	34.48
480	92.99	71.16	36.01	34.60
540	92.99	71.16	36.01	34.60
600	92.99	71.16	36.01	34.60
660	92.99	71.16	36.01	34.60
720	91.94	70.11	35.48	34.11
780	91.1	69.27	35.06	33.72
840	90.89	69.06	34.95	33.62
900	91.55	69.72	35.28	33.93
960	91.88	70.05	35.45	34.08
1020	91.1	69.27	35.06	33.72
1080	91.7	69.87	35.36	34.00
1140	91.37	69.54	35.19	33.85
1200	91.36	69.53	35.19	33.84
1260	90.63	68.8	34.82	33.50
1320	90.63	68.8	34.82	33.50
1380	90.25	68.42	34.63	33.32
1440	90.48	68.65	34.74	33.43

WELL INDEX PW -3

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR	UNCON CORR
0	90.48	68.65	#DIV/0!	34.74	
1	50.4	28.57	1441	14.46	14.23
2	47.1	25.27	721	12.79	12.61
3	43.6	21.77	481	11.02	10.89
4	40.1	18.27	361	9.25	9.15
5	38.4	16.57	289	8.39	8.31
6	37.2	15.37	241	7.78	7.71
7	36.5	14.67	207	7.42	7.36
8	35.9	14.07	181	7.12	7.07
9	35.4	13.57	161	6.87	6.82
10	34.9	13.07	145	6.61	6.57
12	34.3	12.47	121	6.31	6.27
14	33.7	11.87	104	6.01	5.97
16	33.2	11.37	91	5.75	5.72
18	32.9	11.07	81	5.60	5.57
20	32.6	10.77	73	5.45	5.42
25	31.9	10.07	59	5.10	5.07
30	31.2	9.37	49	4.74	4.72
35	30.9	9.07	42	4.59	4.57
40	30.4	8.57	37	4.34	4.32
45	30.1	8.27	33	4.19	4.17
50	29.8	7.97	30	4.03	4.02
55	29.4	7.57	27	3.83	3.82
60	28.7	6.87	25	3.48	3.46
70	28.35	6.52	22	3.30	3.29
80	27.6	5.77	19	2.92	2.91
90	27.5	5.67	17	2.87	2.86
100	27.1	5.27	15	2.67	2.66
120	26.9	5.07	13	2.57	2.56
140	26.4	4.57	11	2.31	2.31
160	26.36	4.53	10	2.29	2.29

TABLE B4: DATA OF WELL INDEX PW-4

WELL INDEX PW -4				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
0.00	37.38			
1.00	56.24	18.86	12.28	12.11
2.00	73.00	35.62	23.19	22.61
3.00	75.13	37.75	24.58	23.92
4.00	76.38	39.00	25.39	24.69
5.00	76.89	39.51	25.72	25.01
6.00	77.58	40.20	26.17	25.43
7.00	77.94	40.56	26.40	25.65
8.00	78.30	40.92	26.64	25.87
9.00	78.55	41.17	26.80	26.03
10.00	78.96	41.58	27.07	26.28
12.00	79.35	41.97	27.32	26.52
14.00	79.61	42.23	27.49	26.67
16.00	80.01	42.63	27.75	26.92
18.00	80.19	42.81	27.87	27.03
20.00	80.64	43.26	28.16	27.31
25.00	81.15	43.77	28.49	27.62
30.00	81.49	44.11	28.72	27.82
35.00	81.86	44.48	28.96	28.05
40.00	82.15	44.77	29.15	28.23
45.00	82.69	45.31	29.50	28.56
50.00	83.70	46.32	30.15	29.17
55.00	84.00	46.62	30.35	29.35
60.00	84.20	46.82	30.48	29.48
70.00	84.27	46.89	30.53	29.52
80.00	84.88	47.50	30.92	29.89
90.00	85.34	47.96	31.22	30.17
100.00	85.70	48.32	31.46	30.39
110.00	86.36	48.98	31.89	30.79
120.00	87.54	50.16	32.65	31.50
140.00	87.54	50.16	32.65	31.50
160.00	88.44	51.06	33.24	32.05
180.00	88.04	51.77	33.70	32.47

WELL INDEX PW -4				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
210	89.86	52.48	34.16	32.90
240	90.78	53.4	34.76	33.46
270	91.72	54.34	35.38	34.02
300	92.42	55.04	35.83	34.44
360	93.83	56.45	36.75	35.29
420	95.86	58.48	38.07	36.50
480	96.86	59.48	38.72	37.10
540	98.03	60.65	39.48	37.80
600	98.97	61.59	40.10	38.36
660	99.71	62.33	40.58	38.80
720	101.43	64.05	41.70	39.82
780	101.95	64.57	42.04	40.13
840	102.61	65.23	42.46	40.52
900	103.28	65.9	42.90	40.91
960	104.17	66.79	43.48	41.44
1020	105.42	68.04	44.29	42.17
1080	106.01	68.63	44.68	42.52
1140	106.71	69.33	45.13	42.93
1200	107.29	69.91	45.51	43.27
1260	108.19	70.81	46.10	43.80
1320	108.71	71.33	46.44	44.11
1380	109.67	72.29	47.06	44.67
1440	110.39	73.01	47.53	45.09
1500	110.96	73.58	47.90	45.42
1560	111.53	74.15	48.27	45.75
1620	111.91	74.53	48.52	45.97
1680	112.54	75.16	48.93	46.34
1740	113.06	75.68	49.27	46.64
1800	113.61	76.23	49.63	46.96
1860	114.22	76.84	50.02	47.32
1920	114.7	77.32	50.34	47.60
1980	115.17	77.79	50.64	47.87
2040	115.76	78.38	51.03	48.21
2100	116.08	78.7	51.23	48.40
2160	117.1	79.72	51.90	48.99
2220	117.45	80.07	52.13	49.19
2280	117.7	80.32	52.29	49.33
2340	118.09	80.71	52.54	49.56
2400	118.8	81.42	53.00	49.97

WELL INDEX PW -4				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
2460	119.2	81.82	53.26	50.20
2520	119.52	82.14	53.47	50.38
2580	120.46	83.08	54.09	50.92
2640	120.65	83.27	54.21	51.03
2700	121.2	83.82	54.57	51.35
2760	121.62	84.24	54.84	51.59
2820	121.99	84.61	55.08	51.80
2880	122.29	84.91	55.28	51.97
2940	122.71	85.33	55.55	52.21
3000	123.18	85.8	55.86	52.48
3060	123.35	85.97	55.97	52.58
3120	123.64	86.26	56.16	52.75
3180	124.34	86.96	56.61	53.15
3240	124.62	87.24	56.79	53.31
3300	124.98	87.6	57.03	53.51
3360	125.25	87.87	57.20	53.67
3420	125.56	88.18	57.41	53.84
3480	125.91	88.53	57.63	54.04
3540	126.21	88.83	57.83	54.21
3600	126.47	89.09	58.00	54.36
3660	126.71	89.33	58.15	54.50
3720	127.3	89.92	58.54	54.83
3780	127.55	90.17	58.70	54.98
3840	127.8	90.42	58.86	55.12
3900	128.07	90.69	59.04	55.27
3960	128.55	91.17	59.35	55.54
4020	128.73	91.35	59.47	55.65
4080	128.96	91.58	59.62	55.78
4140	129.37	91.99	59.89	56.01
4200	129.61	92.23	60.04	56.15
4260	129.82	92.44	60.18	56.26
4320	130.29	92.91	60.48	56.53
4380	130.48	93.1	60.61	56.64
4440	130.64	93.26	60.71	56.73
4500	130.95	93.57	60.91	56.90
4560	131.33	93.95	61.16	57.12
4620	131.71	94.33	61.41	57.33
4680	132.36	94.98	61.83	57.70
4740	132.64	95.26	62.01	57.86
4800	132.8	95.42	62.12	57.95

WELL INDEX PW -4

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR	UNCON CORR
1	91.13	53.75	4801.00	34.99	33.67
2	94.84	57.46	2401.00	37.41	35.89
3	94.81	57.43	1601.00	37.38	35.87
4	94.42	57.04	1201.00	37.13	35.64
5	94.07	56.69	961.00	36.90	35.43
6	93.74	56.36	801.00	36.69	35.23
7	93.45	56.07	686.71	36.50	35.06
8	93.18	55.80	601.00	36.32	34.90
9	92.94	55.56	534.33	36.17	34.76
10	92.70	55.32	481.00	36.02	34.61
12	92.31	54.93	401.00	35.76	34.38
14	91.94	54.56	343.86	35.52	34.16
16	91.61	54.23	301.00	35.31	33.96
18	91.29	53.91	267.67	35.09	33.76
20	90.62	53.24	241.00	34.66	33.36
25	90.36	52.98	193.00	34.49	33.20
30	89.78	52.40	161.00	34.11	32.86
35	89.24	51.86	138.14	33.76	32.53
40	88.77	51.39	121.00	33.46	32.25
45	88.31	50.93	107.67	33.16	31.97
50	87.79	50.41	97.00	32.81	31.65
55	87.49	50.11	88.27	32.62	31.47
60	87.10	49.72	81.00	32.37	31.23
70	86.37	48.99	69.57	31.89	30.79
80	85.71	48.33	61.00	31.46	30.39
90	85.09	47.71	54.33	31.06	30.02
100	84.55	47.17	49.00	30.71	29.69
120	83.40	46.02	41.00	29.96	28.99
140	82.42	45.04	35.29	29.32	28.39
160	81.46	44.08	31.00	28.69	27.80
180	80.59	43.21	27.67	28.13	27.28
210	79.79	42.41	23.86	27.61	26.79
240	78.32	40.94	21.00	26.65	25.88
270	77.28	39.90	18.78	25.97	25.24
300	76.30	38.92	17.00	25.34	24.64

WELL INDEX PW -4					
Recovery					
Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
360	74.46	37.08	14.33	24.14	23.51
420	72.78	35.40	12.43	23.05	22.47
480	71.21	33.83	11.00	22.02	21.50
540	69.71	32.33	9.89	21.05	20.57
600	68.31	30.93	9.00	20.14	19.70
660	66.99	29.61	8.27	19.27	18.87
720	65.73	28.35	7.67	18.45	18.08
780	64.54	27.16	7.15	17.68	17.35
840	63.39	26.01	6.71	16.93	16.62
900	62.29	24.91	6.33	16.22	15.93
960	61.24	23.86	6.00	15.53	15.27
1020	60.20	22.82	5.71	14.86	14.62
1080	59.20	21.82	5.44	14.21	13.99
1140	58.23	20.85	5.21	13.57	13.37
1200	57.32	19.94	5.00	12.98	12.80
1260	56.41	19.03	4.81	12.39	12.22
1320	55.52	18.14	4.64	11.81	11.66
1380	54.68	17.30	4.48	11.26	11.13
1440	53.88	16.50	4.33	10.74	10.62
1500	53.11	15.73	4.20	10.24	10.13
1560	52.38	15.00	4.08	9.77	9.66
1620	51.65	14.27	3.96	9.29	9.20
1680	50.94	13.56	3.86	8.83	8.74
1740	50.25	12.87	3.76	8.38	8.30
1800	49.59	12.21	3.67	7.95	7.88
1860	48.91	11.53	3.58	7.51	7.45
1920	48.28	10.90	3.50	7.09	7.04
1980	47.64	10.26	3.42	6.68	6.63
2040	47.04	9.66	3.35	6.29	6.25
2100	46.44	9.06	3.29	5.90	5.86
2160	45.88	8.50	3.22	5.53	5.50
2220	45.34	7.96	3.16	5.18	5.15
2280	44.79	7.41	3.11	4.82	4.80
2340	44.28	6.90	3.05	4.49	4.47
2400	43.78	6.40	3.00	4.17	4.15
2460	43.28	5.90	2.95	3.84	3.83
2520	42.80	5.42	2.90	3.53	3.51
2580	42.32	4.94	2.86	3.22	3.20
2640	41.86	4.48	2.82	2.91	2.90
2700	41.41	4.03	2.78	2.62	2.62
2760	40.99	3.61	2.74	2.35	2.34
2820	40.56	3.18	2.70	2.07	2.06
2880	40.16	2.78	2.67	1.81	1.80

TABLE B5: DATA OF WELL INDEX PW-6

WELL INDEX PW -6				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
0	8.43	0	0.00	
1	49.45	41.02	25.38	24.77
2	64.8	56.37	34.88	33.72
3	73.4	64.97	40.20	38.66
4	77.7	69.27	42.86	41.11
5	80.25	71.82	44.44	42.55
6	81.85	73.42	45.43	43.46
7	83.3	74.87	46.32	44.28
8	83.62	75.19	46.52	44.46
9	84.15	75.72	46.85	44.75
10	84.8	76.37	47.25	45.12
12	85.32	76.89	47.57	45.41
14	85.7	77.27	47.81	45.63
16	86.2	77.77	48.12	45.91
18	86.3	77.87	48.18	45.96
20	86.5	78.07	48.30	46.08
25	86.85	78.42	48.52	46.27
30	87.2	78.77	48.74	46.47
35	87.5	79.07	48.92	46.64
40	87.72	79.29	49.06	46.76
45	87.82	79.39	49.12	46.82
50	88.12	79.69	49.31	46.99
60	88.3	79.87	49.42	47.09
70	88.34	79.91	49.44	47.11
80	88.55	80.12	49.57	47.23
90	89.05	80.62	49.88	47.51
100	89.17	80.74	49.96	47.57
120	89.3	80.87	50.04	47.65
140	86.6	81.14	50.20	47.80
160	89.84	81.41	50.37	47.95
180	90.12	81.69	50.54	48.10
210	90.35	81.92	50.69	48.23
240	90.38	81.95	50.71	48.25
270	90.41	81.98	50.72	48.27

WELL INDEX PW -6				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
300	90.43	82	50.74	48.28
330	90.57	82.14	50.82	48.36
360	90.59	82.16	50.84	48.37
420	90.59	82.16	50.84	48.37
480	90.6	82.17	50.84	48.37
540	90.8	82.37	50.97	48.48
600	90.99	82.56	51.08	48.59
660	91.02	82.59	51.10	48.61
720	91.5	83.07	51.40	48.88
780	91.9	83.47	51.65	49.10
840	91.85	83.42	51.61	49.07
900	91.7	83.27	51.52	48.99
960	91.85	83.42	51.61	49.07
1020	91.9	83.47	51.65	49.10
1080	92.25	83.82	51.86	49.29
1140	92.3	83.87	51.89	49.32
1200	92.5	84.07	52.02	49.43
1260	92.59	84.16	52.07	49.48
1320	92.77	84.34	52.18	49.58
1440	92.81	84.38	52.21	49.61
1500	92.83	84.4	52.22	49.62
1560	92.85	84.42	52.23	49.63
1620	92.85	84.42	52.23	49.63
1680	92.85	84.42	52.23	49.63
1740	92.86	84.43	52.24	49.63
1800	92.86	84.43	52.24	49.63
1860	92.86	84.43	52.24	49.63
1920	92.86	84.43	52.24	49.63
1980	92.87	84.44	52.25	49.64
2040	92.87	84.44	52.25	49.64
2100	92.87	84.44	52.25	49.64
2160	92.87	84.44	52.25	49.64
2220	92.88	84.45	52.25	49.64
2280	92.88	84.45	52.25	49.64
2340	92.88	84.45	52.25	49.64
2400	92.88	84.45	52.25	49.64

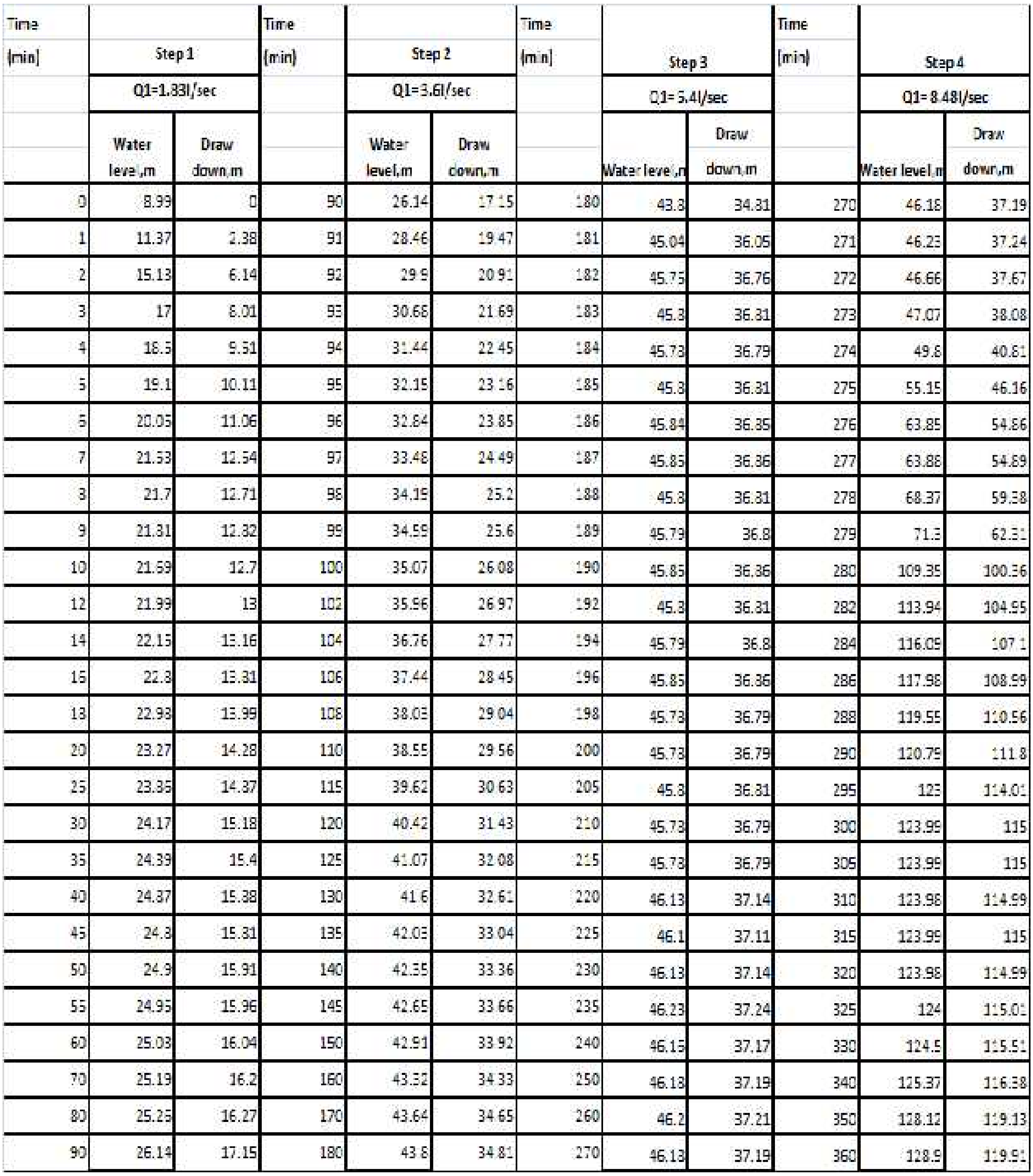
WELL INDEX PW -6

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
2460	92.88	84.45	52.25	49.64
2520	92.89	84.46	52.26	49.65
2580	92.89	84.46	52.26	49.65
2640	92.9	84.47	52.26	49.66
2700	92.9	84.47	52.26	49.66
2760	92.9	84.47	52.26	49.66
2820	92.91	84.48	52.27	49.66
2880	92.92	84.49	52.28	49.67
2940	92.92	84.49	52.28	49.67
3000	92.78	84.35	52.19	49.59
3060	92.84	84.41	52.23	49.62
3120	92.85	84.42	52.23	49.63
3180	92.87	84.44	52.25	49.64
3240	92.83	84.4	52.22	49.62
3300	92.74	84.31	52.17	49.57
3360	92.76	84.33	52.18	49.58
3420	92.69	84.26	52.13	49.54
3480	92.61	84.18	52.09	49.49
3540	92.64	84.21	52.10	49.51
3600	92.58	84.15	52.07	49.48
3660	92.52	84.09	52.03	49.44
3720	92.44	84.01	51.98	49.40
3780	92.3	83.87	51.89	49.32
3840	92.49	84.06	52.01	49.43
3900	92.57	84.14	52.06	49.47
3960	92.72	84.29	52.15	49.56
4020	92.85	84.42	52.23	49.63
4080	92.87	84.44	52.25	49.64
4140	92.9	84.47	52.26	49.66
4200	93.08	84.65	52.38	49.76
4260	92.9	84.47	52.26	49.66
4320	92.93	84.5	52.28	49.67
4320	92.93	84.5	52.28	49.67

WELL INDEX PW -6					
Recovery					
Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
0	92.9	84.5	#DIV/0!	52.28	49.67
1	42.7	34.27	4321	21.20	20.77
2	24.8	16.37	2161	10.13	10.03
3	19.6	11.17	1441	6.91	6.87
4	18.3	9.82	1081	6.08	6.04
5	17.4	8.97	865	5.55	5.52
6	16.7	8.27	721	5.12	5.09
7	16.3	7.82	618	4.84	4.82
8	15.9	7.47	541	4.62	4.60
9	15.7	7.22	481	4.47	4.45
10	15.5	7.02	433	4.34	4.33
12	14.8	6.37	361	3.94	3.93
14	14.6	6.17	310	3.82	3.80
16	14.3	5.82	271	3.60	3.59
18	14.1	5.67	241	3.51	3.50
20	14	5.52	217	3.42	3.40
25	13.6	5.12	174	3.17	3.16
30	13.2	4.81	145	2.98	2.97
35	13	4.56	124	2.82	2.81
40	12.9	4.42	109	2.73	2.73
45	12.7	4.27	97	2.64	2.64
50	12.6	4.2	87	2.60	2.59
60	12.4	3.97	73	2.46	2.45
70	12.1	3.67	63	2.27	2.27
80	12	3.52	55	2.18	2.17
90	11.8	3.4	49	2.10	2.10
100	11.8	3.4	44	2.10	2.10
120	11.7	3.3	37	2.04	2.04

TABLE B6: DATA OF WELL INDEX PW-7



Time (min)	Step 1		Time (min)	Step 2		Time (min)	Step 3		Time (min)	Step 4	
	Q1=1.83l/sec			Q1=3.6l/sec			Q1= 5.4l/sec			Q1= 8.48l/sec	
	Water level,m	Draw down,m		Water level,m	Draw down,m		Water level,m	Draw down,m		Water level,m	Draw down,m
0	8.99	0	90	26.14	17.15	180	43.8	34.81	270	46.18	37.19
1	11.37	2.38	91	28.46	19.47	181	45.04	36.05	271	46.23	37.24
2	15.13	6.14	92	29.9	20.91	182	45.75	36.76	272	46.66	37.67
3	17	8.01	93	30.68	21.69	183	45.3	36.31	273	47.07	38.08
4	18.5	9.51	94	31.44	22.45	184	45.78	36.79	274	49.8	40.81
5	19.1	10.11	95	32.15	23.16	185	45.3	36.31	275	55.15	46.16
6	20.05	11.06	96	32.84	23.85	186	45.84	36.85	276	63.85	54.86
7	21.53	12.54	97	33.48	24.49	187	45.85	36.86	277	63.88	54.89
8	21.7	12.71	98	34.19	25.2	188	45.8	36.81	278	68.37	59.38
9	21.31	12.32	99	34.59	25.6	189	45.79	36.8	279	71.3	62.31
10	21.69	12.7	100	35.07	26.08	190	45.85	36.86	280	109.35	100.36
12	21.99	13	102	35.96	26.97	192	45.8	36.81	282	113.94	104.95
14	22.15	13.16	104	36.76	27.77	194	45.79	36.8	284	116.09	107.1
16	22.3	13.31	106	37.44	28.45	196	45.85	36.86	286	117.98	108.99
18	22.98	13.99	108	38.03	29.04	198	45.78	36.79	288	119.55	110.56
20	23.27	14.28	110	38.55	29.56	200	45.78	36.79	290	120.79	111.8
25	23.36	14.37	115	39.62	30.63	205	45.8	36.81	295	123	114.01
30	24.17	15.18	120	40.42	31.43	210	45.78	36.79	300	123.99	115
35	24.39	15.4	125	41.07	32.08	215	45.78	36.79	305	123.99	115
40	24.37	15.38	130	41.6	32.61	220	46.13	37.14	310	123.98	114.99
45	24.3	15.31	135	42.03	33.04	225	46.1	37.11	315	123.99	115
50	24.9	15.91	140	42.35	33.36	230	46.13	37.14	320	123.98	114.99
55	24.95	15.96	145	42.65	33.66	235	46.23	37.24	325	124	115.01
60	25.03	16.04	150	42.91	33.92	240	46.16	37.17	330	124.5	115.51
70	25.19	16.2	160	43.32	34.33	250	46.18	37.19	340	125.37	116.38
80	25.26	16.27	170	43.64	34.65	260	46.2	37.21	350	128.12	119.13
90	26.14	17.15	180	43.8	34.81	270	46.18	37.19	360	128.9	119.91

WELL INDEX PW -7

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
0	8.8	0	0.00	
1	17.2	8.4	5.06	5.03
2	24.35	15.55	9.36	9.26
3	27.84	19.04	11.46	11.31
4	32.31	23.51	14.15	13.93
5	36.22	27.42	16.51	16.20
6	38.43	29.63	17.84	17.48
7	41.05	32.25	19.41	18.99
8	43.57	34.77	20.93	20.44
9	46.07	37.27	22.44	21.87
10	48.98	40.18	24.19	23.53
12	53.75	44.95	27.06	26.23
14	57.78	48.98	29.49	28.50
16	60.93	52.13	31.38	30.27
18	64.31	55.51	33.42	32.15
20	66.95	58.15	35.01	33.62
25	72.5	63.7	38.35	36.68
30	75.84	67.04	40.36	38.52
35	78.38	69.58	41.89	39.90
40	80.3	71.5	43.04	40.95
45	80.98	72.18	43.45	41.32
50	82.6	73.8	44.43	42.20
55	83.42	74.62	44.92	42.64
60	84.04	75.24	45.29	42.97
70	85.33	76.53	46.07	43.67
80	86.65	77.85	46.87	44.38
90	87.24	78.44	47.22	44.70
100	87.79	78.99	47.55	45.00
120	89.78	80.98	48.75	46.06
270	99.79	90.99	54.78	51.38
300	100.31	91.51	55.09	51.66
330	100.47	91.67	55.19	51.74
360	100.3	91.5	55.08	51.65
420	100.58	91.78	55.25	51.80
480	101.63	92.83	55.88	52.35
540	102	93.2	56.11	52.55
600	102.72	93.92	56.54	52.93
660	102.85	94.05	56.62	52.99
720	103.2	94.4	56.83	53.18
780	103.6	94.8	57.07	53.39
840	103.9	95.1	57.25	53.54
900	104.17	95.37	57.41	53.69
960	104.32	95.52	57.50	53.76
1020	104.48	95.68	57.60	53.85
1080	104.62	95.82	57.68	53.92
1140	104.75	95.95	57.76	53.99
1200	104.89	96.09	57.85	54.06
1260	105.07	96.27	57.95	54.16
1320	105.12	96.32	57.98	54.18
1380	105.18	96.38	58.02	54.21

WELL INDEX PW -7				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**	**UNCON CORR**
1440	105.27	96.47	58.07	54.26
1500	105.35	96.55	58.12	54.30
1560	105.39	96.59	58.15	54.32
1620	105.48	96.68	58.20	54.37
1680	105.61	96.81	58.28	54.44
1740	105.78	96.98	58.38	54.53
1800	105.92	97.12	58.47	54.60
1860	106.1	97.3	58.57	54.70
1920	106.11	97.31	58.58	54.70
1980	106.25	97.45	58.66	54.77
2040	106.31	97.51	58.70	54.80
2100	106.44	97.64	58.78	54.87
2160	106.62	97.82	58.89	54.97
2220	106.82	98.02	59.01	55.07
2280	106.93	98.13	59.07	55.13
2340	106.88	98.08	59.04	55.10
2400	106.87	98.07	59.04	55.10
2460	107.05	98.25	59.15	55.19
2520	107.15	98.35	59.21	55.24
2580	107.31	98.51	59.30	55.33
2640	107.42	98.62	59.37	55.38
2700	107.46	98.66	59.39	55.40
2760	107.39	98.59	59.35	55.37
2820	106.94	98.14	59.08	55.13
2880	106.83	98.03	59.01	55.08
2940	106.78	97.98	58.98	55.05
3000	106.52	97.72	58.83	54.91
3060	106.58	97.78	58.86	54.95
3120	106.67	97.87	58.92	54.99
3180	106.74	97.94	58.96	55.03
3240	106.76	97.96	58.97	55.04
3300	106.17	97.37	58.62	54.73
3360	106.22	97.42	58.65	54.76
3420	106.25	97.45	58.66	54.77
3480	106.31	97.51	58.70	54.80
3540	106.35	97.55	58.73	54.83
3600	106.43	97.63	58.77	54.87
3660	106.46	97.66	58.79	54.88
3720	106.55	97.75	58.85	54.93
3780	106.53	97.73	58.83	54.92
3840	106.7	97.9	58.94	55.01
3900	106.72	97.92	58.95	55.02
3960	106.75	97.95	58.97	55.03
4020	106.78	97.98	58.98	55.05
4080	106.78	97.98	58.98	55.05
4140	106.8	98	59.00	55.06
4200	106.88	98.08	59.04	55.10
4260	106.87	98.07	59.04	55.10
4320	106.89	98.09	59.05	55.11

WELL INDEX PW -7

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR	UNCON CORR
0	106.89	98.09	#DIV/0!	59.05	
1	101.39	92.59	4321.00	55.74	52.23
2	97.49	88.69	2161.00	53.39	50.17
3	92.02	83.22	1441.00	50.10	47.26
4	87.33	78.53	1081.00	47.28	44.75
5	83.56	74.76	865.00	45.01	42.72
6	79.6	70.8	721.00	42.62	40.57
7	76	67.2	618.14	40.45	38.60
8	73.08	64.28	541.00	38.70	37.00
9	70.37	61.57	481.00	37.07	35.51
10	67.95	59.15	433.00	35.61	34.17
12	63.68	54.88	361.00	33.04	31.80
14	60.03	51.23	309.57	30.84	29.77
16	55	46.2	271.00	27.81	26.94
18	51.83	43.03	241.00	25.90	25.15
20	49.13	40.33	217.00	24.28	23.61
25	46.4	37.6	173.80	22.64	22.06
30	44.2	35.4	145.00	21.31	20.80
35	38.98	30.18	124.43	18.17	17.80
40	34.75	25.95	109.00	15.62	15.35
45	29.77	20.97	97.00	12.62	12.44
50	27.95	19.15	87.40	11.53	11.38
55	26.12	17.32	79.55	10.43	10.30
60	25.12	16.32	73.00	9.82	9.72
70	23.3	14.5	62.71	8.73	8.64
80	21.9	13.1	55.00	7.89	7.82
90	20.94	12.14	49.00	7.31	7.25
100	19.72	10.92	44.20	6.57	6.52
120	18.07	9.27	37.00	5.58	5.55
270	13.74	4.94	17.00	2.97	2.96
300	13.29	4.49	15.40	2.70	2.69
330	13.23	4.43	14.09	2.67	2.66
360	13	4.2	13.00	2.53	2.52
420	12.6	3.8	11.29	2.29	2.28

TABLE B7: DATA OF WELL INDEX PW-8

WELL INDEX PW -8			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
0	17.5	0	0.00
1	66.8	49.3	32.19
2	73.8	56.3	36.76
3	76.79	59.29	38.72
4	76.77	59.27	38.70
5	76.76	59.26	38.70
6	76.74	59.24	38.68
7	76.73	59.23	38.68
8	76.73	59.23	38.68
9	76.72	59.22	38.67
10	76.71	59.21	38.66
12	76.71	59.21	38.66
14	76.7	59.2	38.66
16	76.7	59.2	38.66
18	76.7	59.2	38.66
20	76.71	59.21	38.66
25	76.75	59.25	38.69
30	76.77	59.27	38.70
35	76.77	59.27	38.70
40	76.78	59.28	38.71
45	76.78	59.28	38.71
50	76.78	59.28	38.71
55	76.79	59.29	38.72
60	76.79	59.29	38.72
70	76.81	59.31	38.73
80	76.81	59.31	38.73
90	76.81	59.31	38.73
100	76.81	59.31	38.73
120	76.82	59.32	38.74
140	76.82	59.32	38.74
160	76.82	59.32	38.74
180	76.83	59.33	38.74
210	76.83	59.33	38.74
240	76.84	59.34	38.75
270	76.86	59.36	38.76

WELL INDEX PW -8			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
300	76.88	59.38	38.78
360	94.85	77.35	50.51
420	94.88	77.38	50.53
480	94.9	77.4	50.54
540	94.95	77.45	50.57
600	94.95	77.45	50.57
660	94.97	77.47	50.59
720	95	77.5	50.61
780	95.05	77.55	50.64
840	95.08	77.58	50.66
900	95.12	77.62	50.69
960	95.14	77.64	50.70
1020	95.14	77.64	50.70
1080	95.15	77.65	50.71
1140	95.15	77.65	50.71
1200	95.16	77.66	50.71
1260	95.18	77.68	50.73
1320	95.18	77.68	50.73
1380	95.16	77.66	50.71
1440	95.18	77.68	50.73
1500	95.18	77.68	50.73
1560	95.19	77.69	50.73
1620	97.45	79.95	52.21
1680	97.6	80.1	52.31
1740	98.3	80.8	52.76
1800	98.72	81.22	53.04
1860	99.25	81.75	53.38
1920	100.48	82.98	54.19
1980	101.4	83.9	54.79
2040	101.45	83.95	54.82
2100	101.55	84.05	54.88
2160	101.57	84.07	54.90
2220	101.6	84.1	54.92
2280	101.62	84.12	54.93
2340	101.65	84.15	54.95
2400	98.6	81.1	52.96

WELL INDEX PW -8

Constant Test

Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
2460	98.5	81	52.89
2520	98.5	81	52.89
2580	98.74	81.24	53.05
2640	98.96	81.46	53.19
2700	98.93	81.43	53.17
2760	99	81.5	53.22
2820	99.05	81.55	53.25
2880	99.18	81.68	53.34
2940	99.25	81.75	53.38
3000	99.25	81.75	53.38
3060	99.28	81.78	53.40
3120	99.3	81.8	53.42
3180	99.33	81.83	53.43
3240	99	81.5	53.22
3300	99.1	81.6	53.28
3360	99.1	81.6	53.28
3420	99.1	81.6	53.28
3480	99.2	81.7	53.35
3540	99.15	81.65	53.32
3600	99.2	81.7	53.35
3660	99.25	81.75	53.38
3720	99.3	81.8	53.42
3780	99.35	81.85	53.45
3840	99.4	81.9	53.48
3900	99.45	81.95	53.51
3960	99.53	82.03	53.57
4020	99.58	82.08	53.60
4080	99.6	82.1	53.61
4140	99.63	82.13	53.63
4260	99.74	82.24	53.70
4200	99.65	82.15	53.64
4320	99.8	82.3	53.74
4380	99.82	82.32	53.75
4440	99.83	82.33	53.76
4500	99.85	82.35	53.77
4560	99.86	82.36	53.78

WELL INDEX PW -8

Recovery

Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
0	99.86	82.4	#DIV/0!	53.81	
1	64.9	47.4	4561.00	30.95	29.92
2	56.5	39	2281.00	25.47	24.77
3	52.5	35	1521.00	22.86	22.29
4	50.5	33	1141.00	21.55	21.05
6	50.1	32.6	761.00	21.29	20.80
7	50	32.5	652.43	21.22	20.74
8	49.6	32.1	571.00	20.96	20.49
9	49.2	31.7	507.67	20.70	20.24
10	48.9	31.4	457.00	20.50	20.05
12	48.3	30.8	381.00	20.11	19.68
14	47.8	30.3	326.71	19.79	19.37
16	47.4	29.9	286.00	19.52	19.12
18	47	29.5	254.33	19.26	18.87
20	46.7	29.2	229.00	19.07	18.68
25	46	28.5	183.40	18.61	18.24
30	45.4	27.9	153.00	18.22	17.86
35	44.9	27.4	131.29	17.89	17.55
40	44.4	26.9	115.00	17.57	17.23
45	43.8	26.3	102.33	17.17	16.86
50	43.3	25.8	92.20	16.85	16.54
55	42.9	25.4	83.91	16.59	16.29
60	42.5	25	77.00	16.33	16.04
70	41.5	24	66.14	15.67	15.41
80	40.7	23.2	58.00	15.15	14.90
90	40.1	22.6	51.67	14.76	14.52
100	39.6	22.1	46.60	14.43	14.21
120	38.4	20.9	39.00	13.65	13.45
140	37.6	20.1	33.57	13.13	12.94
160	36.8	19.3	29.50	12.60	12.43
180	36.4	18.9	26.33	12.34	12.18

WELL INDEX PW -8

Recovery

Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
210	35.6	18.1	22.71	11.82	11.67
240	34.9	17.4	20.00	11.36	11.22
270	34.4	16.9	17.89	11.04	10.91
300	33.7	16.2	16.20	10.58	10.46
360	32.8	15.3	13.67	9.99	9.88
420	31.5	14	11.86	9.14	9.05
480	31.3	13.8	10.50	9.01	8.92
540	31.2	13.7	9.44	8.95	8.86
600	31	13.5	8.60	8.82	8.73
660	30.8	13.3	7.91	8.68	8.60
720	29.9	12.4	7.33	8.10	8.03
780	28.4	10.9	6.85	7.12	7.06
840	28	10.5	6.43	6.86	6.81
900	27.7	10.2	6.07	6.66	6.61
960	27.3	9.82	5.75	6.41	6.37
1020	27	9.47	5.47	6.18	6.14
1080	26.6	9.1	5.22	5.94	5.90
1140	26.3	8.77	5.00	5.73	5.69
1200	26	8.47	4.80	5.53	5.50
1260	25.7	8.15	4.62	5.32	5.29
1320	25.4	7.9	4.45	5.16	5.13
1380	25.2	7.65	4.30	5.00	4.97
1440	24.8	7.3	4.17	4.77	4.74
1500	24.6	7.07	4.04	4.62	4.59
1560	24.4	6.85	3.92	4.47	4.45
1620	24.1	6.6	3.81	4.31	4.29
1680	23.9	6.4	3.71	4.18	4.16
1740	23.7	6.2	3.62	4.05	4.03
1800	23.3	5.81	3.53	3.79	3.78
1860	23	5.51	3.45	3.60	3.58
1920	22.9	5.42	3.38	3.54	3.53
1980	22.9	5.36	3.30	3.50	3.49
2040	22.7	5.2	3.24	3.40	3.38
2100	22.6	5.06	3.17	3.30	3.29
2160	22.4	4.9	3.11	3.20	3.19
2220	22.3	4.79	3.05	3.13	3.12
2280	22.2	4.7	3.00	3.07	3.06
2340	22.1	4.63	2.95	3.02	3.01

TABLE B8: DATA OF WELL INDEX PW-13

WELL INDEX PW -13			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
0	40.42	0	
1	96.2	55.78	51.45
2	100.38	59.96	54.96
3	100.53	60.11	55.09
4	99.96	59.54	54.61
5	100.16	59.74	54.78
6	100	59.58	54.64
7	99.98	59.56	54.63
8	100.16	59.74	54.78
9	99.77	59.35	54.45
10	99.98	59.56	54.63
12	100.23	59.81	54.84
14	99.97	59.55	54.62
16	100.25	59.83	54.85
90	105.8	65.38	59.44
100	106.32	65.9	59.86
120	106.78	66.36	60.24
140	105.79	65.37	59.43
160	105.94	65.52	59.55
180	105.9	65.48	59.52
210	106.36	65.94	59.89
240	106.1	65.68	59.68
270	106.58	66.16	60.07
300	106.6	66.18	60.09
330	105.82	65.4	59.45
360	105.75	65.33	59.40
420	105.99	65.57	59.59
480	106.06	65.64	59.65
540	106.08	65.66	59.67
600	106.02	65.6	59.62
660	105.98	65.56	59.58
720	105.84	65.42	59.47
780	105.79	65.37	59.43
840	105.77	65.35	59.41
900	105.91	65.49	59.53
960	105.87	65.45	59.49
1020	104.92	64.5	58.72
1080	104.96	64.54	58.75

WELL INDEX PW -13			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
1140	104.72	64.3	58.55
1200	105.75	65.33	59.40
1260	106.01	65.59	59.61
1320	105.95	65.53	59.56
1380	105.96	65.54	59.57
1440	105.97	65.55	59.58
1500	105.9	65.48	59.52
1560	105.73	65.31	59.38
1620	105.78	65.36	59.42
1680	105.78	65.36	59.42
1740	106.59	66.17	60.08
1800	105.9	65.48	59.52
1860	105.9	65.48	59.52
1920	105.86	65.44	59.49
1980	105.9	65.48	59.52
2040	105.92	65.5	59.53
2100	105.7	65.28	59.35
2160	105.92	65.5	59.53
2220	105.92	65.5	59.53
2280	105.92	65.5	59.53
2340	105.92	65.5	59.53
2400	105.92	65.5	59.53
2460	105.92	65.5	59.53
2520	105.92	65.5	59.53
2580	105.92	65.5	59.53
2640	105.92	65.5	59.53
2700	105.92	65.5	59.53
2760	105.92	65.5	59.53
2820	105.92	65.5	59.53
2880	105.92	65.5	59.53

WELL INDEX PW -13					
Recovery					
Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**	**UNCON CORR**
0	105.92	65.5	#DIV/0!	51.09	47.46
1	86.5	46.08	2881.00	35.94	34.15
2	74.95	34.53	1441.00	26.93	25.92
3	65.5	25.08	961.00	19.56	19.03
4	61.44	21.02	721.00	16.40	16.02
5	59.95	19.53	577.00	15.23	14.91
6	58.8	18.38	481.00	14.34	14.05
7	57.7	17.28	412.43	13.48	13.23
8	57.15	16.73	361.00	13.05	12.81
9	56.6	16.18	321.00	12.62	12.40
10	55.77	15.35	289.00	11.97	11.77
12	54.98	14.56	241.00	11.36	11.18
14	54.74	14.32	206.71	11.17	11.00
16	54.54	14.12	181.00	11.01	10.84
18	53.95	13.53	161.00	10.55	10.40
20	53.64	13.22	145.00	10.31	10.16
25	53.21	12.79	116.20	9.98	9.84
30	52.67	12.25	97.00	9.56	9.43
35	52.1	11.68	83.29	9.11	8.99
40	51.76	11.34	73.00	8.85	8.74
45	51.4	10.98	65.00	8.56	8.46
50	51.4	10.98	58.60	8.56	8.46
60	50.34	9.92	49.00	7.74	7.65
70	49.8	9.38	42.14	7.32	7.24
80	49.36	8.94	37.00	6.97	6.91
90	48.9	8.48	33.00	6.61	6.55
100	48.59	8.17	29.80	6.37	6.32
120	48.1	7.68	25.00	5.99	5.94
140	47.6	7.18	21.57	5.60	5.56
160	47.24	6.82	19.00	5.32	5.28
180	46.9	6.48	17.00	5.05	5.02
210	46.22	5.8	14.71	4.52	4.50
240	46.05	5.63	13.00	4.39	4.36
270	46.81	5.37	11.67	4.19	4.16
300	45.53	5.11	10.60	3.99	3.96
330	45.25	4.83	9.73	3.77	3.75
360	45.01	4.59	9.00	3.58	3.56
420	44.06	3.64	7.86	2.84	2.83
480	43.25	2.83	7.00	2.21	2.20
540	42.44	2.02	6.33	1.58	1.57
600	41.76	1.34	5.80	1.05	1.04

TABLE B9: DATA OF WELL INDEX PW-18

WELL INDEX PW -18			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**
0	0	0.000	0.000
1	1.04	0.707	0.706
2	1.11	0.755	0.754
3	1.14	0.775	0.774
4	1.15	0.782	0.781
5	1.16	0.789	0.788
6	1.17	0.796	0.794
7	1.17	0.796	0.794
8	1.18	0.802	0.801
9	1.18	0.802	0.801
10	1.19	0.809	0.808
12	1.19	0.809	0.808
14	1.2	0.816	0.815
16	1.2	0.816	0.815
18	1.21	0.823	0.822
20	1.21	0.823	0.822
25	1.22	0.830	0.828
30	1.23	0.836	0.835
35	1.23	0.836	0.835
40	1.24	0.843	0.842
45	1.24	0.843	0.842
50	1.25	0.850	0.849
55	1.25	0.850	0.849
60	1.26	0.857	0.855
70	1.26	0.857	0.855
80	1.27	0.864	0.862
90	1.28	0.870	0.869
100	1.28	0.870	0.869
120	1.29	0.877	0.876
140	1.3	0.884	0.883
160	1.32	0.898	0.896
180	1.34	0.911	0.910
210	1.37	0.932	0.930
240	1.39	0.945	0.943
270	1.41	0.959	0.957

WELL INDEX PW -18			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**
300	1.42	0.966	0.964
360	1.44	0.979	0.977
420	1.46	0.993	0.991
480	1.5	1.020	1.018
540	1.53	1.040	1.038
600	1.56	1.061	1.059
660	1.6	1.088	1.086
720	1.64	1.115	1.113
780	1.67	1.136	1.133
840	1.71	1.163	1.160
900	1.76	1.197	1.194
960	1.78	1.210	1.208
1020	1.83	1.244	1.241
1080	1.85	1.258	1.255
1140	1.92	1.306	1.302
1200	1.96	1.333	1.329
1260	1.99	1.353	1.350
1320	2.03	1.380	1.377
1380	2.06	1.401	1.397
1440	2.09	1.421	1.417
1500	2.13	1.448	1.444
1560	2.17	1.476	1.471
1620	2.19	1.489	1.485
1680	2.23	1.516	1.512
1740	2.26	1.537	1.532
1800	2.29	1.557	1.553
1860	2.33	1.584	1.580
1920	2.36	1.605	1.600
1980	2.39	1.625	1.620
2040	2.43	1.652	1.647
2100	2.47	1.680	1.674
2160	2.5	1.700	1.694
2220	2.54	1.727	1.722
2280	2.58	1.754	1.749
2340	2.64	1.795	1.789
2400	2.67	1.816	1.809

WELL INDEX PW -18

Constant Test

Time(MIN)	Water level(M)	Drawdown (m)	PP CORR
2460	2.71	1.84	1.84
2520	2.74	1.86	1.86
2580	2.76	1.88	1.87
2640	2.8	1.90	1.90
2700	2.83	1.92	1.92
2760	2.87	1.95	1.94
2820	2.89	1.97	1.96
2880	2.93	1.99	1.98
2940	2.98	2.03	2.02
3000	3.01	2.05	2.04
3060	3.03	2.06	2.05
3120	3.06	2.08	2.07
3180	3.08	2.09	2.09
3240	3.12	2.12	2.11
3300	3.15	2.14	2.13
3360	3.18	2.16	2.15
3420	3.2	2.18	2.17
3480	3.23	2.20	2.19
3600	3.28	2.23	2.22
3660	3.31	2.25	2.24
3720	3.33	2.26	2.25
3780	3.36	2.28	2.27
3840	3.4	2.31	2.30
3900	3.43	2.33	2.32
3960	3.45	2.35	2.34
4020	3.48	2.37	2.36
4080	3.5	2.38	2.37
4140	3.53	2.40	2.39
4200	3.55	2.41	2.40
4260	3.58	2.43	2.42
4320	3.6	2.45	2.44
4380	3.62	2.46	2.45
4440	3.64	2.48	2.46
4500	3.68	2.50	2.49
4560	3.69	2.51	2.50

WELL INDEX PW -18

Recovery

Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**
0	3.69	#DIV/0!	2.509	
1	2.68	4561	1.822	1.816
2	2.63	2281	1.788	1.782
3	2.61	1521	1.775	1.769
4	2.6	1141	1.768	1.762
5	2.59	913	1.761	1.755
6	2.59	761	1.761	1.755
7	2.58	652	1.754	1.749
8	2.58	571	1.754	1.749
9	2.57	508	1.748	1.742
10	2.57	457	1.748	1.742
12	2.56	381	1.741	1.735
14	2.56	327	1.741	1.735
16	2.56	286	1.741	1.735
18	2.55	254	1.734	1.728
20	2.55	229	1.734	1.728
25	2.54	183	1.727	1.722
30	2.54	153	1.727	1.722
35	2.53	131	1.720	1.715
40	2.52	115	1.714	1.708
45	2.51	102	1.707	1.701
50	2.5	92	1.700	1.694
55	2.49	84	1.693	1.688
60	2.48	77	1.686	1.681
70	2.47	66	1.680	1.674
80	2.46	58	1.673	1.667
90	2.45	52	1.666	1.661
100	2.44	47	1.659	1.654

WELL INDEX PW -18				
Recovery				
Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**
120	2.44	39	1.659	1.654
140	2.43	34	1.652	1.647
160	2.42	30	1.646	1.640
180	2.41	26	1.639	1.634
210	2.41	23	1.639	1.634
240	2.41	20	1.639	1.634
270	2.4	18	1.632	1.627
300	2.39	16	1.625	1.620
330	2.38	15	1.618	1.613
360	2.37	14	1.612	1.607
420	2.37	12	1.612	1.607
480	2.36	11	1.605	1.600
540	2.36	9	1.605	1.600
600	2.35	9	1.598	1.593
660	2.34	8	1.591	1.586
720	2.33	7	1.584	1.580
780	2.33	7	1.584	1.580
840	2.32	6	1.578	1.573
900	2.31	6	1.571	1.566
960	2.31	6	1.571	1.566
1020	2.31	5	1.571	1.566
1080	2.3	5	1.564	1.559
1140	2.3	5	1.564	1.559
1200	2.3	5	1.564	1.559
1260	2.29	5	1.557	1.553
1320	2.29	4	1.557	1.553
1380	2.29	4	1.557	1.553
1440	2.28	4	1.550	1.546

TABLE B10: DATA OF WELL INDEX SWAWF-2

step 1 Q=28l/s		step 2 Q=34l/s		step 3 Q=38l/s		step 4 Q=43l/s	
Time, min	Drawdown, m	Time, min	Drawdown, m	Time, min	Drawdown, m	Time, min	Drawdown, m
0	0	120	50.52	240	62.32	360	74.76
1	44.2	121	53.4	241	64.95	361	87.18
2	44.36	122	56.3	242	66.8	362	92.05
3	44.53	123	57.8	243	67.99	363	93.42
4	44.85	124	58.6	244	68.53	364	93.45
5	45.01	125	59.1	245	69.03	365	93.56
6	45.18	126	59.25	246	69.39	366	93.67
7	45.5	127	59.52	247	69.9	367	93.76
8	45.52	128	59.72	248	70.43	368	94.17
9	45.8	129	59.94	249	70.76	369	94.47
10	45.94	130	60.09	250	70.87	370	94.66
12	46.3	132	60.26	252	71.23	372	94.93
14	46.63	134	60.62	254	71.37	374	95.46
16	47.06	136	60.67	256	71.5	376	96.1
18	47.3	138	60.7	258	71.7	378	96.4
20	47.55	140	60.79	260	71.76	380	96.94
25	47.92	145	60.92	265	71.88	385	97.56
30	48.32	150	61.05	270	72.27	390	98.43
35	48.6	155	61.17	275	73.3	395	98.94
40	48.9	160	61.25	280	73.48	400	99.49
45	49.1	165	61.33	285	73.62	405	99.97
50	49.21	170	61.42	290	73.7	410	100.44
55	49.33	175	61.38	295	73.76	415	100.86
60	49.44	180	61.56	300	73.8	420	101.26
70	49.7	190	61.65	310	73.87	430	101.44
80	49.95	200	61.78	320	74.24	440	101.6
90	50.12	210	61.9	330	74.43	450	101.99
100	50.25	220	62	340	74.6	460	102.46
120	50.52	240	62.32	360	74.76	480	102.46

SWAWF 2

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
0	9.45	0	0.00	
2	61.3	51.85	16.80	
3	69.5	60.05	19.46	2.66
4	74	64.55	20.91	1.46
5	77.73	68.28	22.12	1.21
6	78	68.55	22.21	0.09
7	77.55	68.1	22.06	-0.15
8	77.8	68.35	22.15	0.08
9	78.79	69.34	22.47	0.32
10	78.86	69.41	22.49	0.02
12	79.47	70.02	22.69	0.20
14	81.48	72.03	23.34	0.65
16	80.42	70.97	22.99	-0.34
18	81.32	71.87	23.29	0.29
20	81.83	72.38	23.45	0.17
25	85	75.55	24.48	1.03
30	86.72	77.27	25.04	0.56
35	86.14	76.69	24.85	-0.19
40	86.3	76.85	24.90	0.05
45	86.98	77.53	25.12	0.22
50	87.88	78.43	25.41	0.29
60	88.22	78.77	25.52	0.11
70	89.3	79.85	25.87	0.35
80	89.46	80.01	25.92	0.05
90	90	80.55	26.10	0.17
100	90.7	81.25	26.33	0.23
120	91.3	81.85	26.52	0.19
140	91.8	82.35	26.68	0.16
160	91.85	82.4	26.70	0.02
180	91.89	82.44	26.71	0.01
210	92.45	83	26.89	0.18
240	92.2	82.75	26.81	-0.08
270	93.8	84.35	27.33	0.52
300	93.9	84.45	27.36	0.03
360	93.12	83.67	27.11	-0.25
420	93.51	84.06	27.24	0.13
480	94	84.55	27.39	0.16
540	94.1	84.65	27.43	0.03
600	94.12	84.67	27.43	0.01
660	94.2	84.75	27.46	0.03
720	94.32	84.87	27.50	0.04
780	94.8	85.35	27.65	0.16
840	95.1	85.65	27.75	0.10
900	95.4	85.95	27.85	0.10
960	95.6	86.15	27.91	0.06
1020	95.72	86.27	27.95	0.04
1080	95.83	86.38	27.99	0.04
1140	95.92	86.47	28.02	0.03
1200	95.76	86.31	27.96	-0.05
1260	95.83	86.38	27.99	0.02

SWAWF 2

Constant Test

Time(MIN)	Water level(M)	Drawdown(m)	PP CORR	UNCON CORR
1320	95.91	86.46	28.01	0.03
1380	96.5	87.05	28.20	0.19
1440	96.53	87.08	28.21	0.01
1500	96.61	87.16	28.24	0.03
1560	96.65	87.2	28.25	0.01
1620	96.49	87.04	28.20	-0.05
1680	96.69	87.24	28.27	0.06
1740	96.82	87.37	28.31	0.04
1800	96.8	87.35	28.30	-0.01
1860	96.82	87.37	28.31	0.01
1920	96.85	87.4	28.32	0.01
1980	96.87	87.42	28.32	0.01
2040	96.89	87.44	28.33	0.01
2100	96.9	87.45	28.33	0.00
2160	96.94	87.49	28.35	0.01
2220	97.03	87.58	28.38	0.03
2280	97.11	87.66	28.40	0.03
2340	97.15	87.7	28.41	0.01
2400	97.2	87.75	28.43	0.02
2460	97.5	88.05	28.53	0.10
2520	97.53	88.08	28.54	0.01
2580	97.65	88.2	28.58	0.04
2640	97.7	88.25	28.59	0.02
2700	97.72	88.27	28.60	0.01
2760	97.75	88.3	28.61	0.01
2820	97.84	88.39	28.64	0.03
2880	97.85	88.4	28.64	0.00
2940	97.8	88.35	28.63	-0.02
3000	97.88	88.43	28.65	0.03
3060	97.92	88.47	28.66	0.01
3120	97.65	88.2	28.58	-0.09
3180	97.62	88.17	28.57	-0.01
3240	97.69	88.24	28.59	0.02
3300	97.75	88.3	28.61	0.02
3360	97.8	88.35	28.63	0.02
3420	98	88.55	28.69	0.06
3480	98.05	88.6	28.71	0.02
3540	98.12	88.67	28.73	0.02
3600	98.24	88.79	28.77	0.04
3660	98.3	88.85	28.79	0.02
3720	98.42	88.97	28.83	0.04
3840	98.4	88.95	28.82	-0.01
3900	98.45	89	28.84	0.02
3960	98.48	89.03	28.85	0.01
4020	98.52	89.07	28.86	0.01
4080	98.61	89.16	28.89	0.03
4140	98.73	89.28	28.93	0.04
4200	98.81	89.36	28.95	0.03
4260	98.82	89.37	28.96	0.00
4320	98.84	89.39	28.96	0.01

SWAWF 2

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR
0	98.84	89.39	#DIV/0!	28.96
2	34.4	24.95	2161	8.08
3	32.5	23.05	1441	7.47
4	30.7	21.25	1081	6.89
5	29.05	19.6	865	6.35
6	28	18.55	721	6.01
7	26.8	17.35	618	5.62
8	26.1	16.65	541	5.39
9	25.25	15.8	481	5.12
10	24.92	15.47	433	5.01
12	23.4	13.95	361	4.52
14	22.55	13.1	310	4.24
16	21.9	12.45	271	4.03
18	21.35	11.9	241	3.86
20	20.9	11.45	217	3.71
25	19.93	10.48	174	3.40
30	19.3	9.85	145	3.19
35	18.77	9.32	124	3.02
40	18.42	8.97	109	2.91
45	18.1	8.65	97	2.80
50	17.8	8.35	87	2.71
60	17.4	7.95	73	2.58
70	17	7.55	63	2.45
80	16.75	7.3	55	2.37
90	16.62	7.17	49	2.32
100	16.29	6.84	44	2.22
120	15.92	6.47	37	2.10
140	15.6	6.15	32	1.99
160	15.32	5.87	28	1.90
180	15.1	5.65	25	1.83
210	14.85	5.4	22	1.75
240	14.67	5.22	19	1.69
270	14.33	4.88	17	1.58
300	13.7	4.25	15	1.38
330	13.45	4	14	1.30
420	13.2	3.75	11	1.22
480	13	3.55	10	1.14
540	12.85	3.4	9	1.09
600	12.6	3.15	8	1.01
660	12.34	2.81	8	0.90
720	12.09	2.72	7	0.87
780	12	2.63	7	0.84
840	11.95	2.58	6	0.83
900	11.9	2.53	6	0.81
960	11.9	2.53	6	0.81
1020	11.8	2.43	5	0.78
1080	11.75	2.38	5	0.76
1140	11.72	2.35	5	0.75
1200	11.51	2.14	5	0.68
1260	11.48	2.11	4	0.68
1320	11.44	2.07	4	0.66

TABLE B11: DATA OF WELL INDEX SWAWF-4B

step 1 Q=38.8l/s		***step 2 Q=569l/s***		***step 3 Q=73.35l/s***		***step 4 Q=90.28l/s***	
Time, min	**DD**	**Time, min**	**DD**	**Time, min**	**DD**	**Time, min**	**DD**
0	0	120	16.7	240	30.78	360	44.52
1	15.15	121	20.83	241	35.25	361	50.45
2	15.25	122	24.95	242	41.15	362	51.98
3	15.45	123	26.35	243	42.15	363	52.48
4	15.75	124	26.43	244	42.27	364	52.82
5	16.05	125	26.43	245	42.42	365	52.88
6	16.15	126	26.22	246	42.55	366	53.12
7	16.37	127	26.15	247	42.78	367	53.25
8	16.31	128	26.35	248	42.89	368	53.33
9	16.36	129	26.55	249	42.94	369	53.34
10	16.46	130	26.6	250	43.01	370	53.35
12	16.46	132	26.53	252	43.09	372	53.39
14	16.47	134	29.1	254	43.18	374	53.4
16	16.47	136	29.5	256	43.34	376	53.39
18	16.48	138	29.74	258	43.45	378	53.62
20	16.48	140	29.81	260	43.46	380	53.68
25	16.49	145	29.94	265	43.49	385	53.73
30	16.5	150	30.01	270	43.56	390	53.74
35	16.51	155	30.09	275	43.65	395	53.74
40	16.52	160	30.15	280	43.66	400	53.74
45	16.53	165	30.27	285	43.7	405	53.74
50	16.54	170	30.25	290	43.77	410	53.81
55	16.54	175	30.34	295	43.8	415	53.95
60	16.6	180	30.45	300	43.93	420	53.95
70	16.68	190	30.46	310	44.15	430	53.98
80	16.68	200	30.61	320	44.17	440	54.08
90	16.69	210	30.64	330	44.25	450	54.05
100	16.69	220	30.7	340	44.38	460	54.05
120	16.7	240	30.78	360	44.52	480	54.05

SWAWF 4B			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
0	7.96	0	0.000
1	8.16	0.2	0.126
2	8.46	0.5	0.315
3	8.78	0.82	0.517
4	8.99	1.03	0.649
5	9.15	1.19	0.750
6	9.3	1.34	0.844
7	9.45	1.49	0.939
8	9.57	1.61	1.014
9	9.7	1.74	1.096
10	9.78	1.82	1.147
12	9.98	2.02	1.273
14	10.07	2.11	1.329
16	10.14	2.18	1.373
18	10.26	2.3	1.449
20	10.34	2.38	1.499
25	10.57	2.61	1.644
30	10.74	2.78	1.751
35	10.88	2.92	1.840
40	11.1	3.14	1.978
45	11.11	3.15	1.985
50	11.21	3.25	2.048
55	11.32	3.36	2.117
60	11.42	3.46	2.180
70	11.54	3.58	2.255
80	11.76	3.8	2.394
90	11.8	3.84	2.419
100	11.95	3.99	2.514
120	12.19	4.23	2.665

SWAWF 4B			
Constant Test			
Time(MIN)	**Water level(M)**	**Drawdown(m)**	**PP CORR**
140	12.32	4.36	2.75
160	12.47	4.51	2.84
180	12.61	4.65	2.93
210	12.82	4.86	3.06
240	12.96	5	3.15
270	13.13	5.17	3.26
300	13.23	5.27	3.32
360	13.49	5.53	3.48
420	13.69	5.73	3.61
480	13.9	5.94	3.74
540	14.1	6.14	3.87
600	14.2	6.24	3.93
660	14.32	6.36	4.01
720	14.44	6.48	4.08
780	14.56	6.6	4.16
840	14.67	6.71	4.23
900	14.75	6.79	4.28
960	14.84	6.88	4.33
1020	14.96	7	4.41
1080	14.99	7.03	4.43
1140	15.11	7.15	4.50
1200	15.19	7.23	4.55
1260	15.25	7.29	4.59
1320	15.29	7.33	4.62
1380	15.36	7.4	4.66
1440	15.72	7.76	4.89

SWAWF 4B

Recovery

Time(MIN)	Water level,m	R-DD(m)	t'/t	PP CORR
0	15.36	7.4	#DIV/0!	4.66
1	10.4	3.45	1441.00	2.17
4	11.1	3.15	361.00	1.98
5	11.18	3.23	289.00	2.03
6	11.2	3.25	241.00	2.05
7	11.45	3.5	206.71	2.21
8	11.68	3.73	181.00	2.35
9	11.73	3.78	161.00	2.38
10	11.78	3.83	145.00	2.41
12	11.8	3.85	121.00	2.43
14	11.91	3.96	103.86	2.49
16	11.83	3.88	91.00	2.44
18	11.73	3.78	81.00	2.38
20	11.67	3.72	73.00	2.34
25	11.54	3.59	58.60	2.26
30	11.41	3.46	49.00	2.18
35	11.3	3.35	42.14	2.11
40	11.29	3.34	37.00	2.10
45	11.22	3.27	33.00	2.06
50	11.13	3.18	29.80	2.00
55	11.1	3.15	27.18	1.98
60	11	3.05	25.00	1.92
70	10.98	3.03	21.57	1.91
80	10.93	2.98	19.00	1.88
90	10.89	2.94	17.00	1.85
100	10.8	2.85	15.40	1.80
120	10.6	2.65	13.00	1.67
140	10.5	2.55	11.29	1.61
160	10.39	2.44	10.00	1.54
180	10.3	2.35	9.00	1.48
210	10.19	2.24	7.86	1.41
240	10.1	2.15	7.00	1.35
270	10	2.05	6.33	1.29
300	9.95	2	5.80	1.26
360	9.75	1.8	5.00	1.13
420	9.63	1.68	4.43	1.06
480	9.51	1.56	4.00	0.98
540	9.41	1.46	3.67	0.92
600	9.3	1.35	3.40	0.85
660	9.22	1.27	3.18	0.80
720	9.13	1.18	3.00	0.74
780	9.05	1.1	2.85	0.69
840	8.99	1.04	2.71	0.66
900	8.92	0.97	2.60	0.61
960	8.82	0.87	2.50	0.55
1020	8.8	0.85	2.41	0.54

TABLE B12: DATA OF WELL INDEX SWAWF-5

SWAWF 5				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**	**UNCON CORR**
0	4.9	0	0.00	
1	14.18	9.28	4.85	4.83
2	14.19	9.29	4.86	4.83
3	14.19	9.29	4.86	4.83
4	4.19	9.29	4.86	4.83
5	14.2	9.3	4.86	4.84
6	14.2	9.3	4.86	4.84
7	14.2	9.3	4.86	4.84
8	14.2	9.3	4.86	4.84
9	14.2	9.3	4.86	4.84
10	14.2	9.3	4.86	4.84
12	14.2	9.3	4.86	4.84
14	14.2	9.3	4.86	4.84
16	14.2	9.3	4.86	4.84
18	14.2	9.3	4.86	4.84
20	14.2	9.3	4.86	4.84
25	14.2	9.3	4.86	4.84
30	14.2	9.3	4.86	4.84
35	18.5	13.6	7.11	7.06
40	20.55	15.65	8.19	8.12
45	37.48	32.58	17.04	16.74
50	37.9	33	17.26	16.95
60	39.51	34.61	18.10	17.76
80	40.1	35.2	18.41	18.06
90		35.4	18.52	18.16
100	41.6	36.7	19.20	18.81
120	41.8	36.9	19.30	18.91
180	44.66	39.76	20.80	20.34
240	46.1	41.2	21.55	21.06
300	47.2	42.3	22.13	21.61
360	49.02	44.12	23.08	22.52
420	49.7	44.8	23.43	22.86
480	50.32	45.42	23.76	23.17
540	50.86	45.96	24.04	23.43
600	51.39	46.49	24.32	23.70
660	51.85	46.95	24.56	23.93
720	52.29	47.39	24.79	24.14
780	52.59	47.69	24.95	24.29
840	52.8	47.9	25.06	24.40
900	53.1	48.2	25.21	24.55
960	53.39	48.49	25.36	24.69
1020	53.54	48.64	25.44	24.76
1080	53.64	48.74	25.50	24.81
1140	53.87	48.97	25.62	24.93
1200	54	49.1	25.68	24.99
1260	54.15	49.25	25.76	25.07
1320	54.3	49.4	25.84	25.14
1380	54.45	49.55	25.92	25.21
1440	54.61	49.71	26.00	25.29

SWAWF 5				
Constant Test				
Time(MIN)	**Water level(M)**	**Drawdown (m)**	**PP CORR**	**UNCON CORR**
1500	54.8	49.9	26.10	25.39
1560	54.98	50.08	26.20	25.48
1620	55.11	50.21	26.26	25.54
1680	55.24	50.34	26.33	25.60
1740	55.37	50.47	26.40	25.67
1800	55.53	50.63	26.48	25.75
1860	55.66	50.76	26.55	25.81
1920	55.8	50.9	26.63	25.88
1980	55.91	51.01	26.68	25.94
2040	56.02	51.12	26.74	25.99
2100	56.2	51.3	26.83	26.08
2160	56.3	51.4	26.89	26.13
2220	56.4	51.5	26.94	26.18
2280	56.5	51.6	26.99	26.23
2340	56.6	51.7	27.04	26.28
2400	56.7	51.8	27.10	26.33
2460	56.77	51.87	27.13	26.36
2520	56.83	51.93	27.16	26.39
2580	56.94	52.04	27.22	26.44
2640	56.99	52.09	27.25	26.47
2700	57	52.1	27.25	26.47
2760	57.02	52.12	27.26	26.48
2820	57.11	52.21	27.31	26.53
2880	57.17	52.27	27.34	26.56
2940	57.17	52.27	27.34	26.56
3000	57.22	52.32	27.37	26.58
3060	57.28	52.38	27.40	26.61
3120	57.38	52.48	27.45	26.66
3180	57.47	52.57	27.50	26.70
3240	57.5	52.6	27.51	26.72
3300	57.6	52.7	27.57	26.77
3360	57.7	52.8	27.62	26.82
3420	57.8	52.9	27.67	26.87
3480	57.89	52.99	27.72	26.91
3540	57.9	53	27.72	26.92
3600	57.96	53.06	27.75	26.95
3660	57.99	53.09	27.77	26.96
3720	58.02	53.12	27.79	26.98
3780	58.06	53.16	27.81	27.00
3840	58.12	53.22	27.84	27.03
3900	58.16	53.26	27.86	27.04
3960	58.25	53.35	27.91	27.09
4020	58.29	53.39	27.93	27.11
4080	58.29	53.39	27.93	27.11
4140	58.27	53.37	27.92	27.10
4200	58.25	53.35	27.91	27.09
4260	58.25	53.35	27.91	27.09
4320	58.25	53.35	27.91	27.09

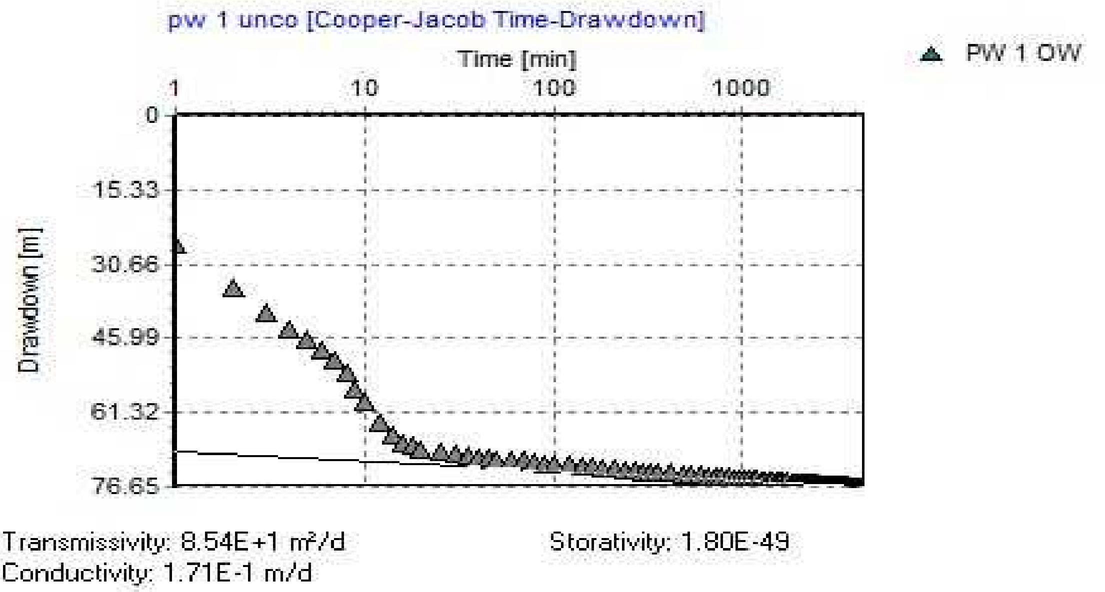
SWAWF 5

Recovery

Time(MIN)	**Water level,m**	**R-DD(m)**	**t'/t**	**PP CORR**
0	53.35	#DIV/0!	27.91	
1	33.49	4321	17.52	17.20
2	30.76	2161	16.09	15.82
3	28.58	1441	14.95	14.72
4	26.98	1081	14.11	13.90
5	24.98	865	13.07	12.89
6	24.05	721	12.58	12.41
7	23.58	618	12.33	12.17
8	22.54	541	11.79	11.64
9	21.86	481	11.43	11.30
10	21.25	433	11.12	10.99
12	20.58	361	10.77	10.64
14	20.06	310	10.49	10.38
16	19.52	271	10.21	10.10
18	19.21	241	10.05	9.94
20	18.85	217	9.86	9.76
25	18.46	174	9.66	9.56
30	18.27	145	9.56	9.46
35	17.11	124	8.95	8.87
40	15.46	109	8.09	8.02
45	13.46	97	7.04	6.99
50	12.02	87	6.29	6.25
60	9.72	73	5.08	5.06

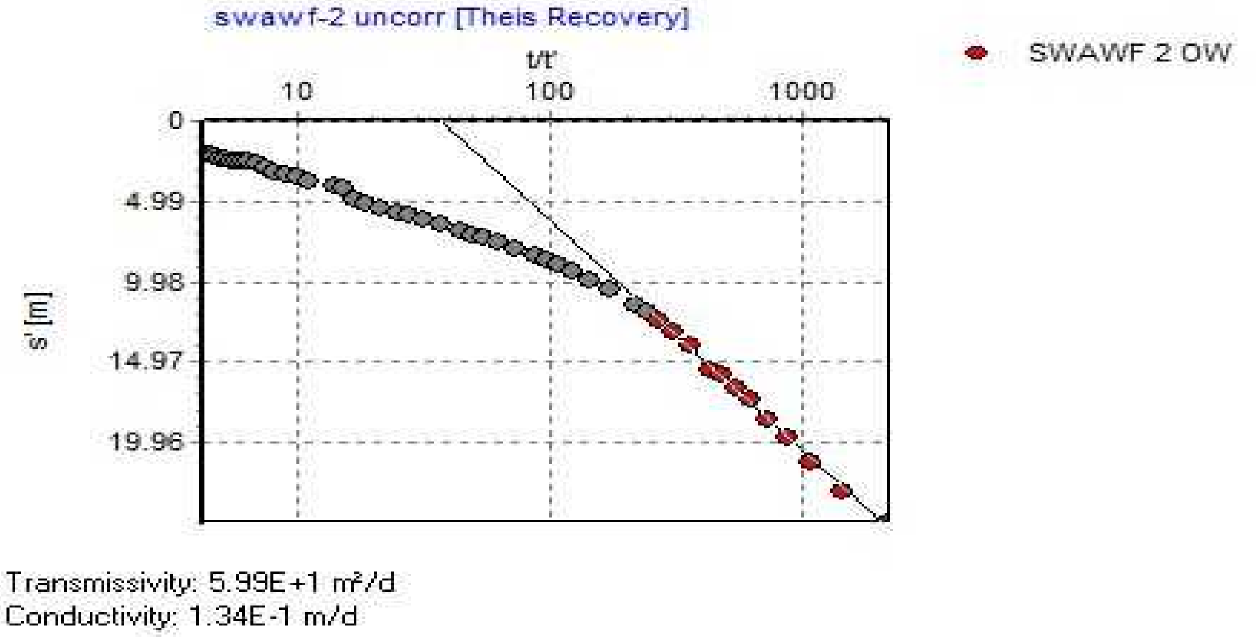
APPENDEX C

ANALYSIS OF THE UNCORRECTED DATA USING AQUIFER TEST V 3.5 SOFTWEAR



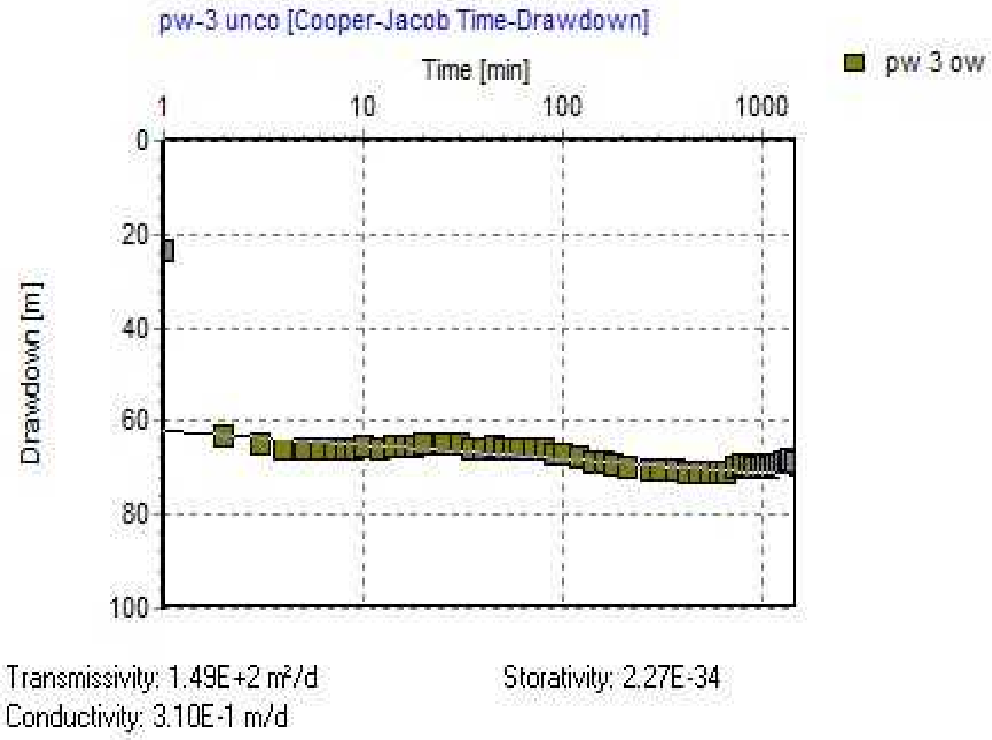
Transmissivity: 8.54E+1 m²/d
Conductivity: 1.71E-1 m/d
Storativity: 1.80E-49

FIGURE C 1: WELL INDEX PW-I ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



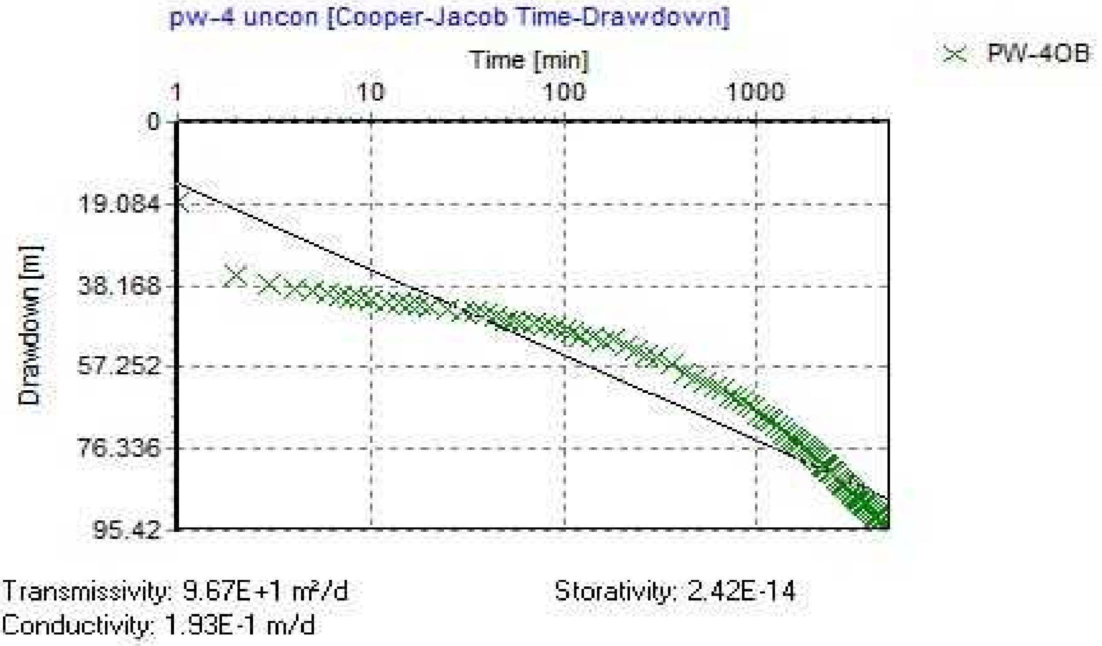
Transmissivity: 5.99E+1 m²/d
Conductivity: 1.34E-1 m/d

FIGURE C 2: WELL INDEX PW-2 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



Transmissivity: 1.49E+2 m²/d
Conductivity: 3.10E-1 m/d
Storativity: 2.27E-34

FIGURE C 3: WELL INDEX PW-3 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



Transmissivity: 9.67E+1 m²/d
Conductivity: 1.93E-1 m/d
Storativity: 2.42E-14

FIGURE C 4: WELL INDEX PW-4 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA

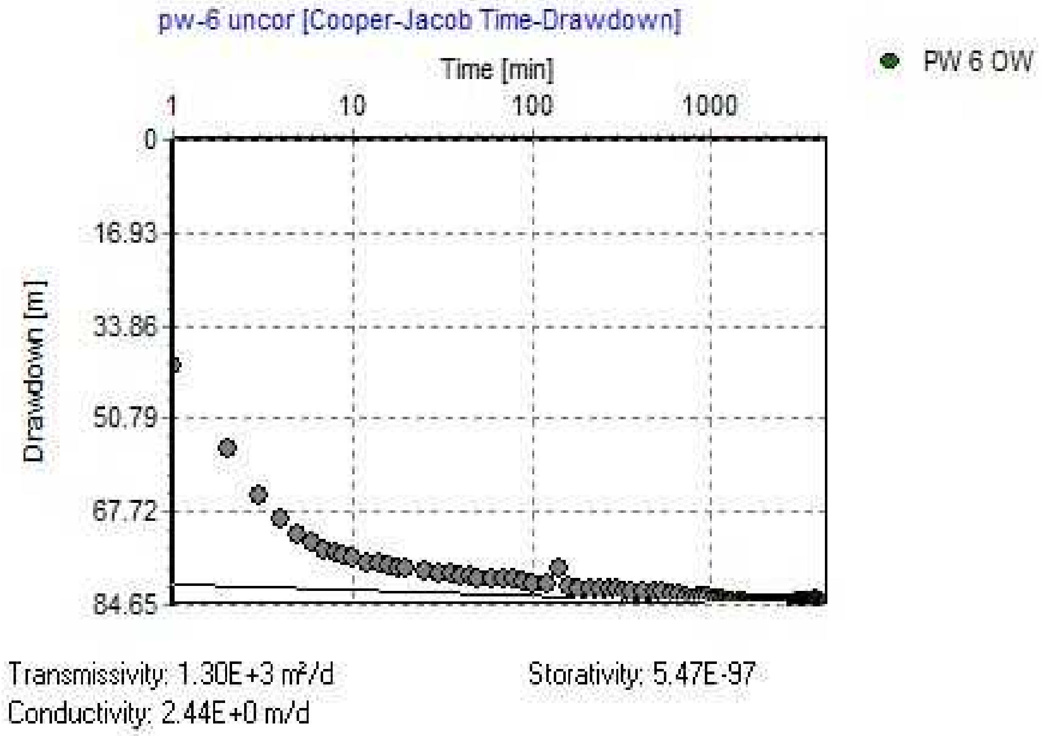


FIGURE C 5: WELL INDEX PW- 6 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA

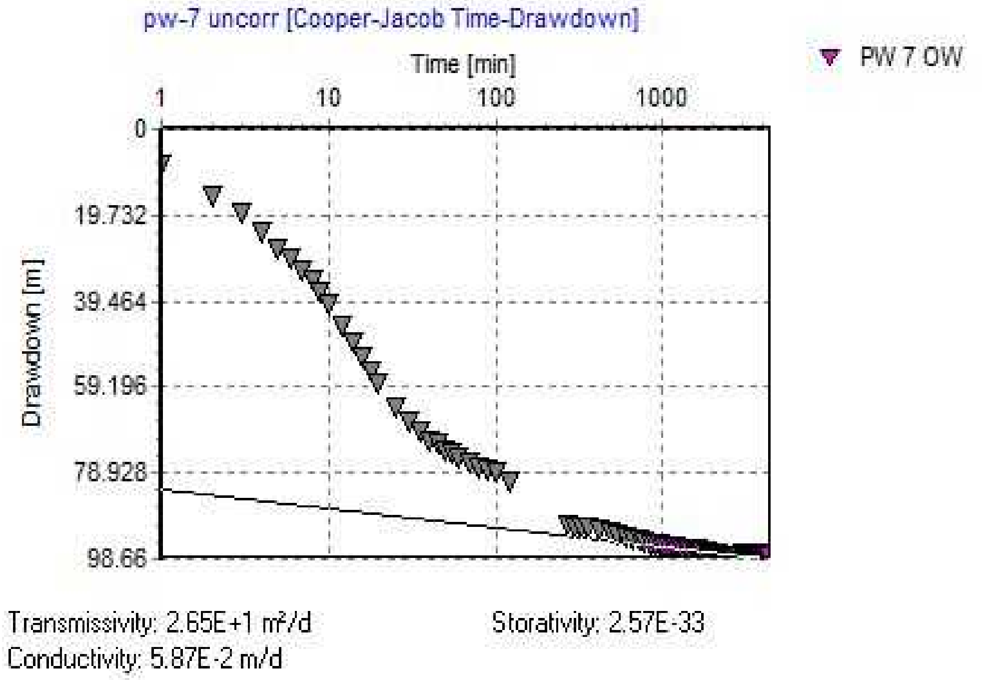
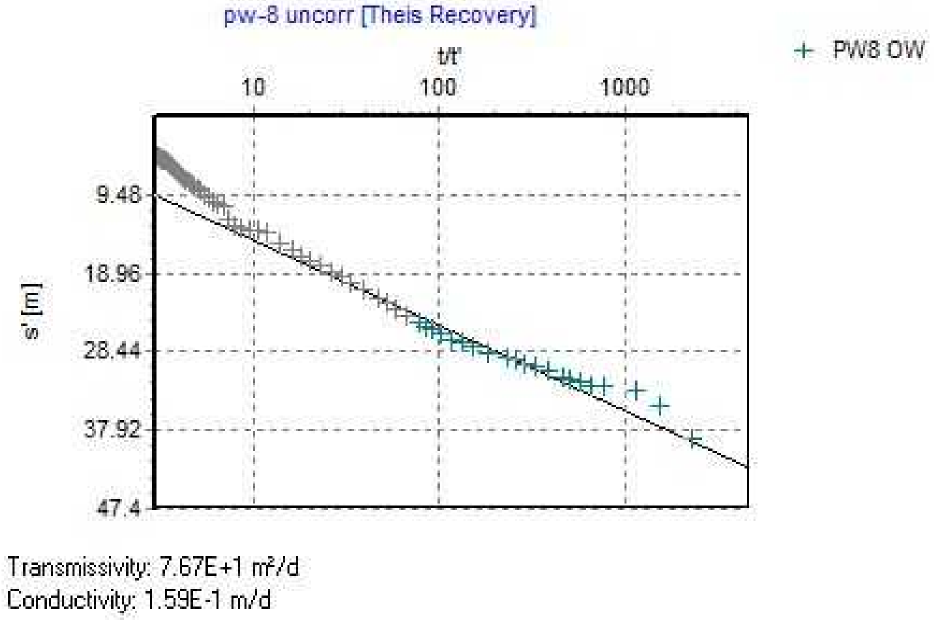
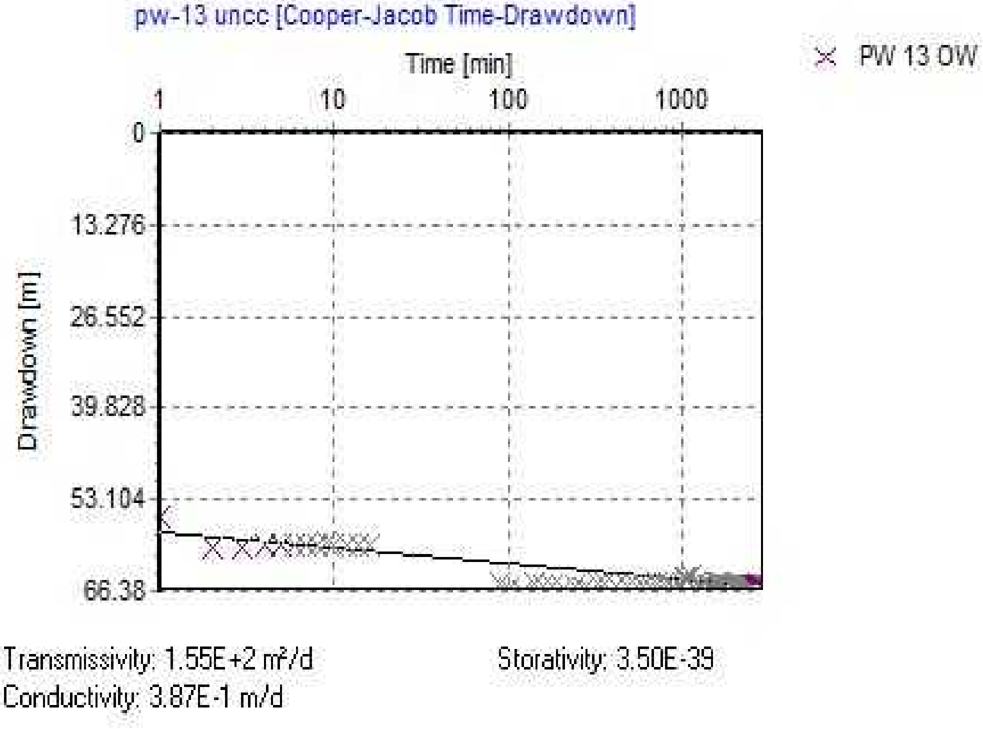


FIGURE C 6: WELL INDEX PW- 7 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



Transmissivity: 7.67E+1 m²/d
Conductivity: 1.59E-1 m/d

FIGURE C 7: WELL INDEX PW- 8 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



Transmissivity: 1.55E+2 m²/d
Storativity: 3.50E-39
Conductivity: 3.87E-1 m/d

FIGURE C 8: WELL INDEX PW- 13 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA

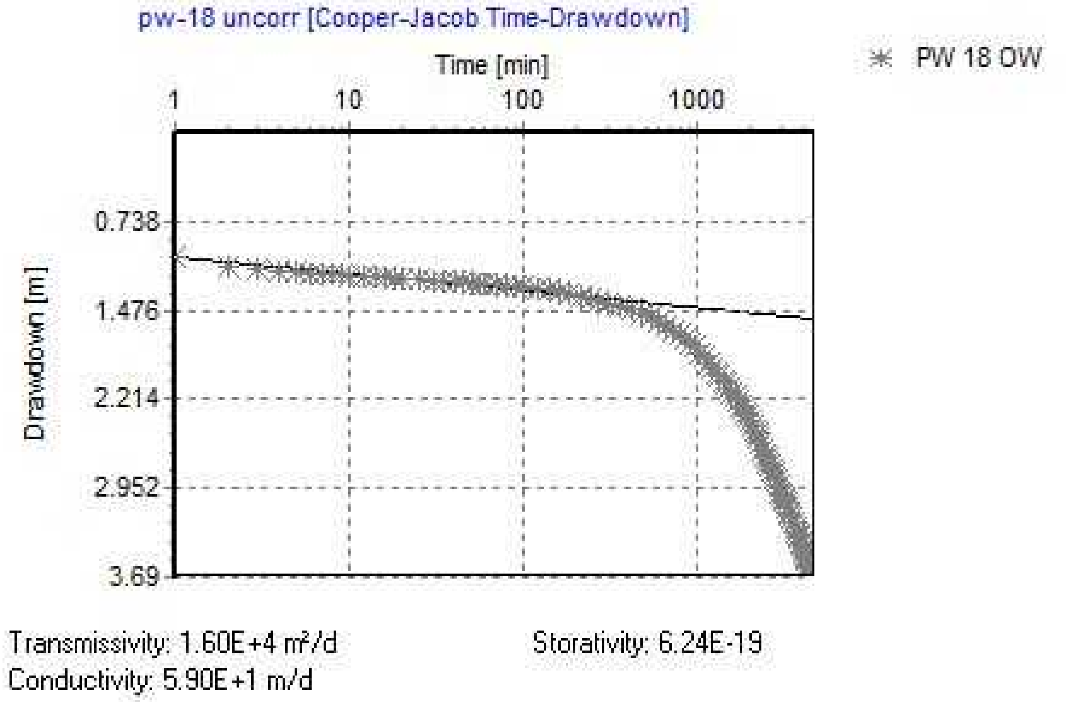


FIGURE C 9: WELL INDEX PW- 18 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA

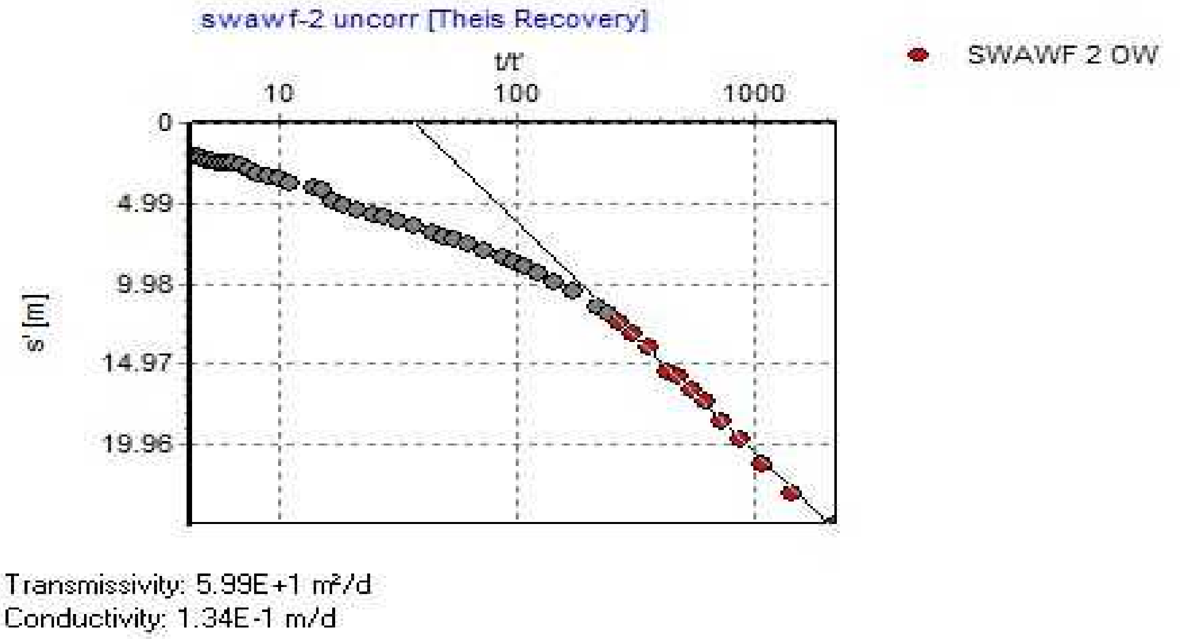
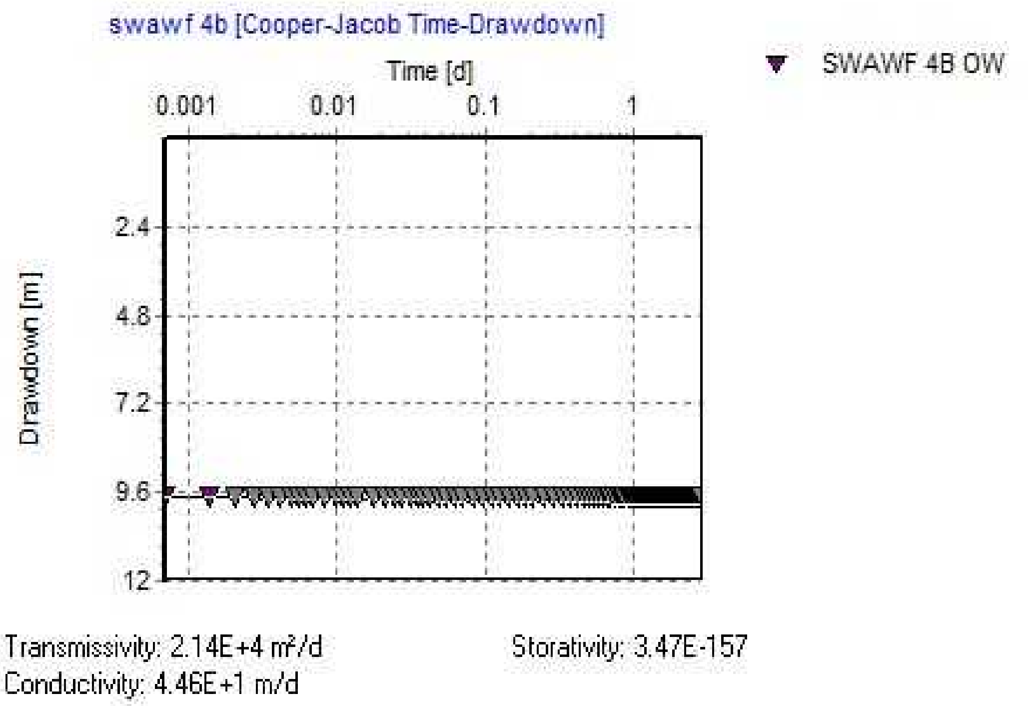


FIGURE C 10: WELL INDEX SWAWF -2 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA

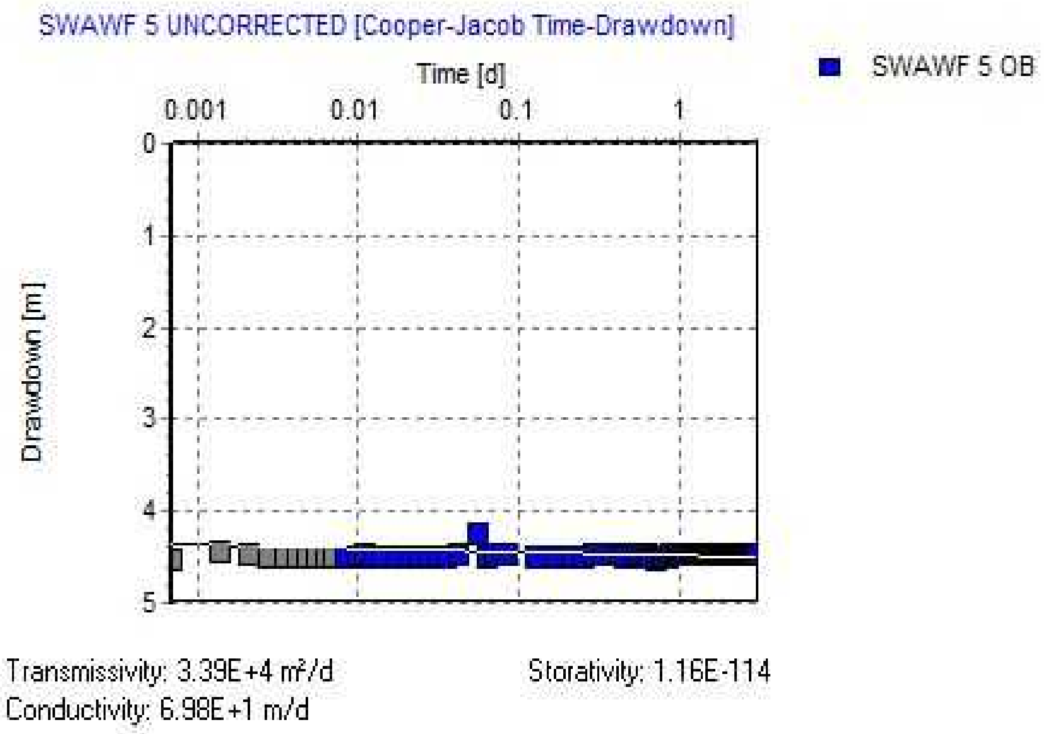


Transmissivity: 2.14E+4 m²/d

Conductivity: 4.46E+1 m/d

Storativity: 3.47E-157

FIGURE C 11: WELL INDEX SWAWF - 4B ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA



Transmissivity: 3.39E+4 m²/d

Conductivity: 6.98E+1 m/d

Storativity: 1.16E-114

FIGURE C 12: WELL INDEX SWAWF - 5 ANALYSIS BY AQUIFER TEST V3.5 USING THE UNCOREECTED DATA