ADDIS ABABA INSTITUTE OF TECHNOLOGY DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING STREAM OF HYDRAULIC ENGINEERING

MASTER FINAL PROJECT ON

EVALUATION OF HYDRAULIC PARAMETERS IN CASE OF AKAKI WELL ON WF02-PW16 AND WF02-PW17 WELLS

BY

SOLOMON LAKE

ID:-GSE/0519/09

ADVISOR NAME

DR. DANEAL.F/SILLASSIE

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Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Evaluation of Hydraulic Parameters In Case of Akaki Wells On

WF02-PW16 AND WF02-PW17 Wells.

By

Solomon Lake

A Project submitted to school of Civil and Environmental Engineering for partial fulfillment of Requirement of Masters of Degree in Civil Engineering

(Stream of Hydraulics Engineering)

Approved By Board of Examiner   Date of Defended 14/10/2021

DR.DANEAL F/SILLASSIE	____________	__________
(ADVISOR)	SIGNATURE	DATE
DR.YENESEW MENGISTE	____________	__________
(EXAMINER)	SIGNATURE	DATE
DR.MEBRUK.M	____________	__________
(CHAIRMAN.DEPARTMENT)	SIGNATURE	DATE

Certification

The undersigned certify that he has read the project entitled: evaluation of hydraulic parameter: in Case of Akaki Phase IIIA on WF02-PW16 and WF02-PW17 Wells and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

………………………………………………

DR. DANEAL F/SILLASSIE

(Advisor)

Declaration

I hereby declare to the Senate of Addis Ababa University that this Project is entirely original work and all other materials are duly acknowledged. This work has not been submitted for academic degree award at any University.

Declaration

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Abstract

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The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. In recent decades it has become apparent in many countries of the world that groundwater is one of the most important natural resources. So far, in Ethiopia, groundwater is mainly utilized for the water supply purposes. It takes care at present of 70% of rural water supply and plays a major role in several of the largest cities (Addis Ababa, Dire Dawa, Mekelle, Bishoftu, and Harari) and a number of medium-sized towns. As capital of Ethiopian, Addis Ababa has seen greater expansions and urbanization than other major city in the country. The primary objective of this project is evaluation of pumping test data to determine the hydraulic parameter of the Akaki phase IIIA bore holes in case of WF02-PW16 and WF02-PW17 by using Theis curve matching method, Cooper Jacob and recovery method on excel sheet and aquifer test software. Akaki well phase IIIA on WF02-16, WF02-17 Wells is located between 8°45' 20" to 9°13' 17" N latitude and 38°34' 3" to 39°4'10" E longitude in Oromiya Regional State, Akaki Kality Sub city south of Addis Ababa about 20 km from the city center. Akaki well field is one of the water supply projects implemented to alleviate the prevailing unsatisfactory water supply situation at the capital city, which is an important service for one of the most water deficit areas of the city-western & central Addis Ababa. The transmissivity values obtained in this project has great variation from the study of WWDSE which accounts for 5 to 100%. These two wells analyses results have overestimated. The overestimated Transmissivity envisions good aquifer with better yield than the capacity of the aquifer.

Key Words: - Addis Ababa Water Supply, Akaki Phase IIIA; Single well test; Transmissivity; Storativity; well Efficiency and well yield.

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List of Abbreviations

AAIT	Addis Ababa Institute of Technology
AAU	Addis Ababa University
AAWSA	Addis Ababa Water Supply and Sewerage Authority
UNESCO	United Nation Educational, Scientific, & Cultural Organization
WWDSE	Water Works Design and Supervision Enterprise
UTM	Universal Transverse Mercator coordinate system
ERA	Ethiopian Road Authority
MOWE	Ministry of Water and energy
SW	Static Water level
WF	Well Field
DD	Drawdown
T	Transmissivity
S	Storativity
Sa	Observed Drawdown
Sc	Corrected Drawdown
Q	Average Pumping Rate

1. Introduction

1.1 Background of the study

The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. We shall retain this classical definition, but we do so in full recognition that the study of groundwater must rest on an understanding of the subsurface water regime in a broader sense. Our approach will be compatible with the traditional emphasis on shallow, saturated, groundwater flow; but it will also encompass the near-surface, unsaturated, soil-moisture regime that plays such an important role in the hydrologic cycle, and it will include the much deeper, saturated regimes that have an important influence on many geologic processes. The study of groundwater is germane to geologists, hydrologists, soil scientists, agricultural engineers, foresters, geographers, ecologists, geotechnical engineers, mining engineers, sanitary engineers, petroleum reservoir analysts, and probably others.

Groundwater is best described as the world's real hidden treasure. Almost everywhere it has made a difference in providing safe drinking water and livelihood security in times of drought. Groundwater is the earth's largest accessible store of fresh water (excluding ice sheets and glaciers) and constitutes about 94% of all fresh water.

The volume of groundwater is almost 100 times that of surface water – about 10,530,000 m3. Groundwater is the most reliable source of supply for potable water and supports a wide array of economic and environmental services. Despite the long history of groundwater extraction throughout civilization, it has only been during recent decades that the use of groundwater has grown exponentially. Estimates of global groundwater abstraction between 1950 and 2000 increased to 1000 km3 of water in 2000 with more than 2 billion people depending on groundwater for their daily supply. Not only have population increases and economic growth laid claim to an ever larger share of groundwater, but the quality of the resource is also increasingly under strain. As use of the resource has increased, so has its value and vulnerability,
forcing 'the hidden treasure' into the spotlight. Major agricultural economies in arid and semi arid regions are sustained by groundwater use. The development of pumps and drilling technologies along with government subsidies has allowed groundwater to become a new frontier in resource exploration.

Ground water has a major influence on rock weathering, stream bank erosion, and the head ward progression of stream channels. In steep terrain, it governs slope stability; in flat terrain, it limits soil compaction and land subsidence. Pumping of ground water can reduce river flows, lower lake levels, and reduce or eliminate discharges to wetlands and springs. It also can influence the sustainability of drinking-water supplies and maintenance of critical ground water-dependent habitats.

So far, in Ethiopia, groundwater is mainly utilized for the water supply purposes. It takes care at present of 70% of rural water supply and plays a major role in several of the largest cities (Addis Ababa, Dire Dawa, Mekelle, Bishoftu, and Harari) and a number of medium-sized towns. As capital of Ethiopian, Addis Ababa has seen greater expansions and urbanization than other major city in the country. Based on the estimated population The Addis Ababa City Administration Council with the help of Addis Ababa Water Supply & Sewerage Authority (AAWSSA) has so far executed some 13 major water supply projects. These are Kebena Mini-Dam, Kechene Mini-Dam, Series of Springs Development, Entoto Water Treatment Plant, Gafarsa-I Dam, Gafarsa-II Dam, Gafarsa-III Dam, Water-I (Legedadi Dam & Water Treatment Plant), Water-IIA (Legedadi Water Treatment Expansion & Rehabilitation of the Existing Legedadi & Gafarsa Water Treatment Plants), Water-IIB (Replacement of the Existing Legedadi Transmission & Major Lines as well as Construction of Service Water Reservoirs), Wells & Springs Development-Emergency, Akaki Town Water Supply and Dire Dam Emergency Projects and Legedadi Deep well developments. Currently, the total coverage of safe water accessible to the residents of Addis Ababa City Administration has reached around 94%. The current total potable water production of the city is reached to some 650,000 m3 per day. The study area of this project is Akaki well field of phase IIIA On WF02-16, WF02-17 wells which is situated south of Addis Ababa.

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 project with the aim of evaluating the exaggerated pumping test results to understanding the hydraulic Parameter of the aquifer which is intended to prolong the productivity of the aquifer and to delay excessive loss of saturated thickness.

1.3 Objective of the project

1.3.1 General objective

The primary objective of this study is evaluation of pumping test data to determine the hydraulic parameter (transmissivity and storativity) of the Akaki phase IIIA On WF02-16, WF02-17 wells.

1.3.2 Specific objective

- To evaluate hydraulic parameter of transmissivity and storativity by using Theis curve matching method, Cooper Jacobi Method and Theis Recovery Method on excels sheet and aquifer test software.
- To compare hydraulic parameter of Transmissivity result with the design value of WWDSE results.

2. Literature Review

2.1. Groundwater Development

In recent decades it has become apparent in many countries of the world that groundwater is one of the most important natural resources. As a source of water supply groundwater has a number of critical advantages when compared with surface water: as a rule it is of higher quality, better protected from possible pollution, less subject to seasonal and perennial fluctuations, and much more uniformly spread over large regions than surface water. Very often groundwater is available in places where there is no surface water. Putting groundwater well fields into operation can be gradual in response to growing water demand while hydro technical facilities for surface water use often require considerable one time investments. In countries with arid and semiarid climate groundwater is widely used for irrigation. About one-third of the landmass is irrigated by groundwater. Out of the total irrigated land in the United States of America, 45% is irrigated by groundwater, 58% in Iran, and 67% in Algeria, and in Libya irrigated farming is wholly based on quality groundwater (UNESCO, 2004). Groundwater has long been regarded as the best water resource for all types of use.

Thus, the stresses on groundwater, both in terms of quality and quantity, are growing rapidly. Over the past two decades there has been a growing worldwide concern about water quality issues and this has led to an increased emphasis on a better understanding of groundwater management. Over the last two decades groundwater development has become a new 'phenomenon' in developing nations. There is a rapid evolution of models from scientific mapping of hydrogeology of an area for specific development projects to value chaining existing hydrogeological knowledge to help policy and decision making in selecting appropriate technology for managed groundwater development, and to devise appropriate climate change adaptation strategies. The model shift around groundwater resources is the fact that groundwater has now become a strategic resource for economic growth, poverty reduction, environmental sustainability, and for climate change adaptation by rural livelihoods.

Ethiopia, as one of the fastest economic growth from the developing countries, has vast water resources which are estimated in 122 billion m3 with an annual groundwater recharge of 28 Billion m3 MoWE (2010). Recent studies indicated that the potential is much greater than this amount.

Groundwater potential in Ethiopia is shaped by complex geological formations and the diversity of the topography, climate and soil as shown in figure 2 below.

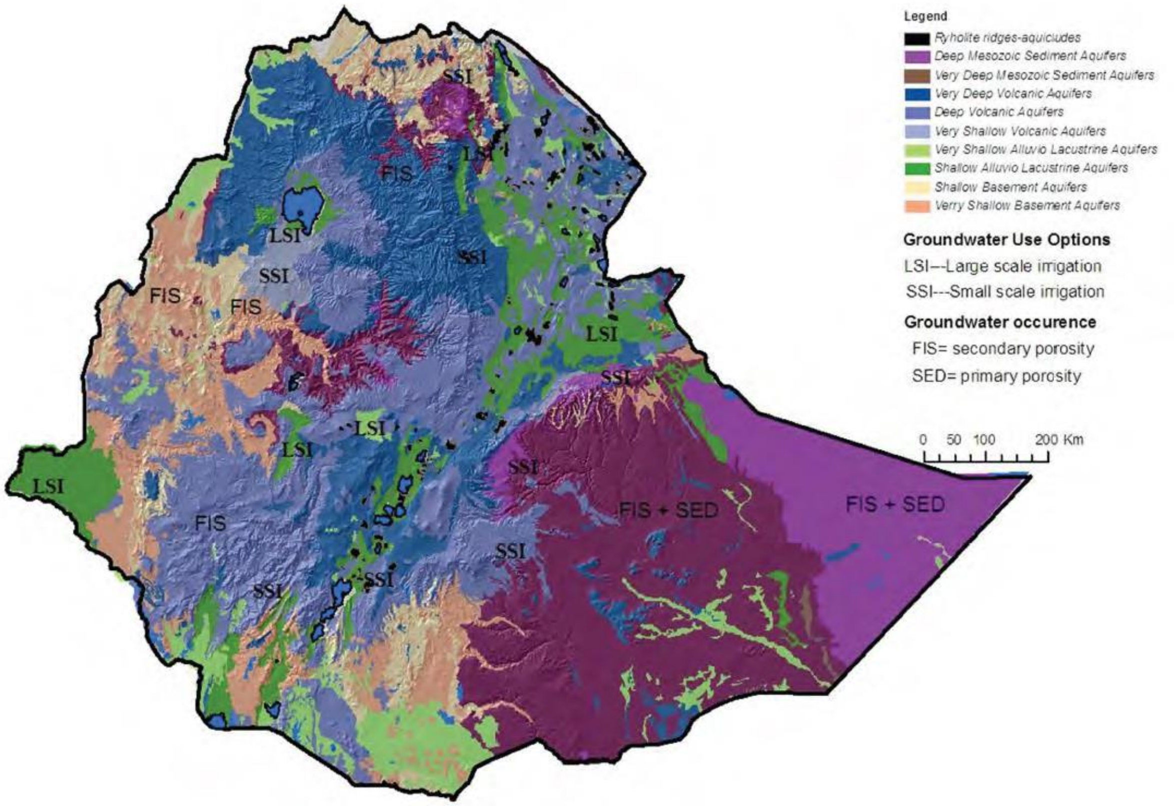

Figure 1.Groundwater occurrence in Ethiopia

Even though agricultural use of groundwater in Ethiopian is low the current capacity to develop groundwater in Ethiopia goes hand in hand with the current very emerging level of groundwater use. Assessment of data from 8,000 boreholes from federal and regional water bureaus indicates that over 80% of groundwater use is for domestic water supply and most of the used wells are shallow wells.

2.2 Groundwater Flow in Addis Ababa and Surrounding Area.

Ground water usually flows toward, and eventually drains into, streams, rivers and lakes. The flow of ground water in aquifers does not always mirror the flow of water on the surface. The most direct and accurate method of determining the direction of groundwater movement is by measuring the elevation of groundwater at multiple locations over the aerial extent of an aquifer. Measurements are plotted on a map of the area and lines are drawn to connect points of equal elevation (equipotential lines). Groundwater moves along a flow path perpendicular to equipotential lines and the direction of movement is from lines of higher value to lines of lower value (i.e., higher to lower elevation or pressure).

Mapping of groundwater flow has been done by different models, mostly for project purposes, though out Addis Ababa as show in figure 3. Comparatively, better hydrogeological figures are assembled in the central and southern part of the city where most of the borehole is concentrated. From this boreholes studies projects were able to gather the groundwater movement direction in Addis Ababa and surrounding region which is predominantly dominated by North-South and East-West flow. Major contribution to the groundwater flow of Addis Ababa come from studies related to the water supply of the city (AAWSA-SEURECA 1991; AAWSA 2000) and academic works (Girma, 1994; Aynalem, 1999; Gizaw, 2002; Demlie, 2007). This project provided an improved understanding of the hydrogeology of the city. Accordingly, SEURECA (1990) stated groundwater flows from Southwest to Southeast in western parts of the city and from East to West in the eastern parts of the city. In some localities, however, the groundwater flow direction changes, mostly towards the nearby streams. In general, the groundwater movement in Addis Ababa is sub parallel to the surface water flow direction and more or less controlled by the topography of the area.

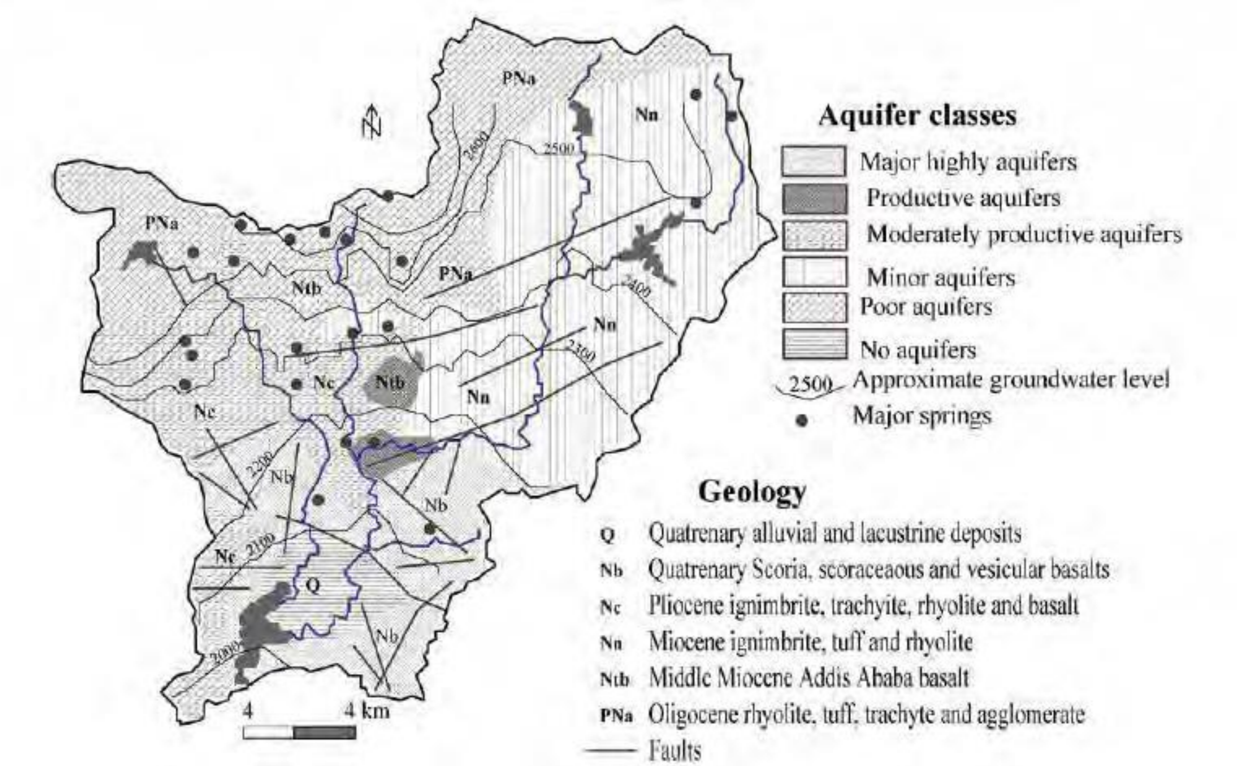

Figure 2.Simplified hydrogeological map of Addis Ababa.

However, construction of groundwater flow direction plots are with errors due to factors influencing groundwater pressure, such as the numbers of wells pumping at any given time and effects from precipitation, groundwater elevations and which in turn affect equipotential surfaces and change in gradients.

2.3 Types of Geological Formations and Aquifers

There are basically four types of geological formations (Aquifers, Aquitard, Aquiclude, and Aquifuge).

2.3.1 Aquifers

An aquifer is a ground-water reservoir composed of geologic units that are saturated with water and sufficiently permeable to yield water in a usable quantity to wells and springs. Sand and gravel deposits, sandstone, limestone, and fractured, crystalline rocks are examples of geological units that form aquifers. Aquifers provide two important functions: (1) they transmit ground water from areas of recharge to areas of discharge, and (2) they provide a storage medium for useable quantities of ground water. The amount of water a material can hold depends upon its porosity. The size and degree of interconnection of those openings (permeability) determine the materials' ability to transmit fluid. Rock beds at the saturated zone that host flowing groundwater are called quifers (from Latin aqua, water; ferre, to bear or carry). Aquifer rocks contain the water in voids—pores and fissures. The size and number of voids and the degree of interconnection between those pores and fissures define the qualities of the aquifers. The same properties define infiltration efficiency and capacity of intake of recharge water.

2.3.2 Aquiclude

Rock strata that prevent passage of groundwater are called aquicludes (from Latin aqua, water; claudere, to close). Aquicludes are important components of groundwater systems because they seal the aquifers and prevent water from infiltrating to great depths. Aquicludes are essential to the formation of springs and shallow accessible aquifers. Aquiclude rocks have low water conductivity caused by a lack of interconnected voids or conduits.

2.4 Types of Aquifers

Most aquifers are of large areal extent and may be visualized as underground storage reservoirs. Water enters a reservoir from natural or artificial recharge; it flows out under the action of gravity or is extracted by wells. Ordinarily, the annual volume of water removed or replaced represents only a small fraction of the total storage capacity. Aquifers may be classed as unconfined or confined, depending on the presence or absence of a water table, while a leaky aquifer represents a combination of the two types.

2.4.1 Unconfined Aquifer

An unconfined aquifer is one in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pump age from wells, and permeability.

Rises and falls in the water table correspond to changes in the volume of water in storage within an aquifer. Contour maps and profiles of the water table can be prepared from elevations of water in wells that tap the aquifer to determine the quantities of water available and their distribution and movement. Relatively this aquifers located at shallow depths are readily tested because test wells and observation wells may be drilled economically to fully penetrate the aquifer. Observation wells may be located short distances from the pumped well; thus, field measurements are easily and quickly made. Long-term pumping is generally not required to obtain usable drawdown measurements. The testing for deeper thin aquifers is similar except for the increased cost of the deeper holes and pump setting.

2.4.2 Confined Aquifers

Confined aquifers, also known as artesian or pressure aquifers, occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. Water enters a confined aquifer in an area where the confining bed rises to the surface; where the confining bed ends underground, the aquifer becomes unconfined. A region supplying water to a confined area is known as a recharge area**;** water may also enter by leakage through a confining bed. Rises and falls of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes. Hence, confined aquifers display only small changes in storage and serve primarily as conduits for conveying water from recharge areas to locations of natural or artificial discharge. Confined aquifer will often be overlain by an unconfined aquifer from which it is separated by a confining laver. The unconfined aquifer should always be cased off in the pumping and observation wells.

If the confined aquifer is not excessively thick, the well should be screened for the entire thickness of the aquifer.

2.4.3 Leaky Aquifer

Aquifers that are completely confined or unconfined occur less frequently than do leaky, or semi-confined, aquifers. These are a common feature in alluvial valleys, plains, or former lake basins where a permeable stratum is overlain or underlain by a semi-pervious Aquitard or semi confining layer. Many areas are underlain by an unconfined aquifer and one or more confined aquifers.

The confining layers may vary from practically impermeable to moderately permeable as compared to the aquifers. In the latter case, interchange of water between aquifers may occur depending on the pressure differences which exist among them. Under such conditions, each aquifer should be pump tested separately. The pumping well should be cased through the untested sections and should be screened through the entire thickness of the tested aquifer. Observation wells and piezometers should be set to conform with the design of the pumping well.

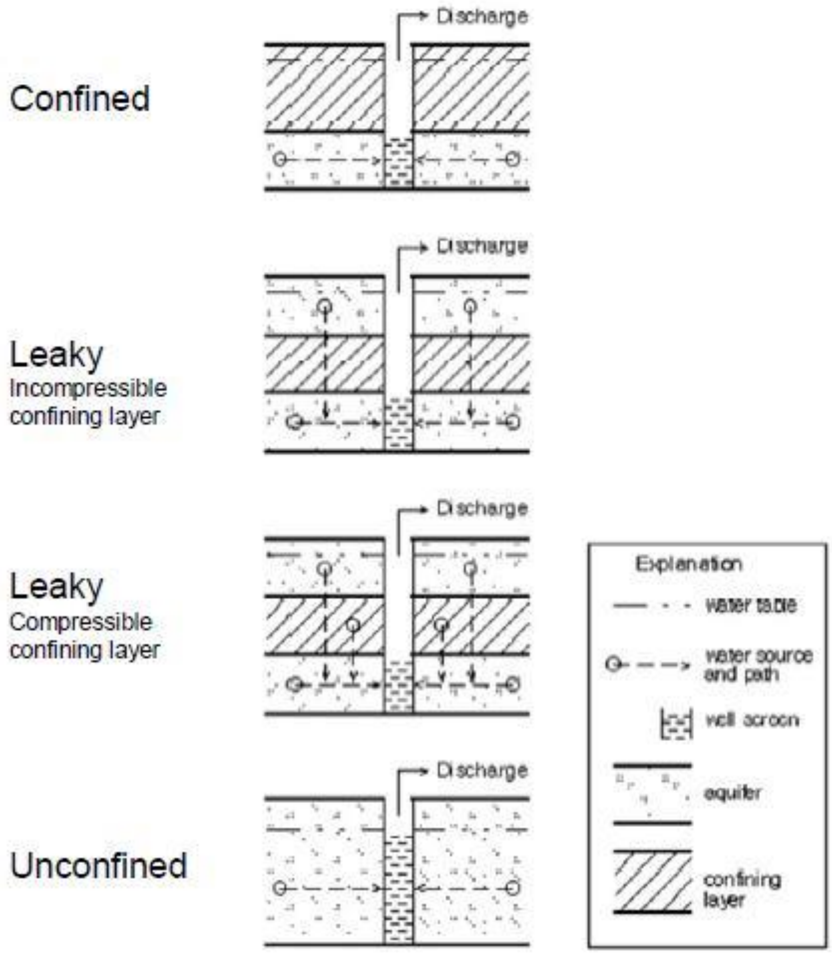

Fig 3.types of aquifer

2.5 Characteristics of Unconfined Aquifer

The characteristics of the aquifer can be decided based on the response that the pumping causes a cone of depression trend that creates in the water table while dewatering water from the aquifer.
As pumping continues, the cone expands and deepens the level of water in the well, and the flow towards the well has clear vertical component. Therefore; some basic characteristics of unconfined aquifers whilst subject to pumping operation, unconfined aquifers, and the water levels in piezometers near the well often tend to decline at a slower rate than that described by the Theis equation. The time-drawdown curve on log-log paper commonly shows a typical S shape. At the present time, the widely used explanation of this S-shaped time-drawdown curve is based on the concept of delayed water table response.

2.6 Properties of Hydraulic parameter

2.6.1 Transmissivity

A useful concept in many studies in hydraulic parameter is 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. Or The capacity of an aquifer to transmit water of the prevailing kinematic viscosity is referred to as its transmissivity. The transmissivity (T) of an aquifer is equal to the hydraulic conductivity of the aquifer multiplied by the saturated thickness of the aquifer. Thus,

$$T = Kb$$

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

2.6.2 Storativity (Storage coefficient)

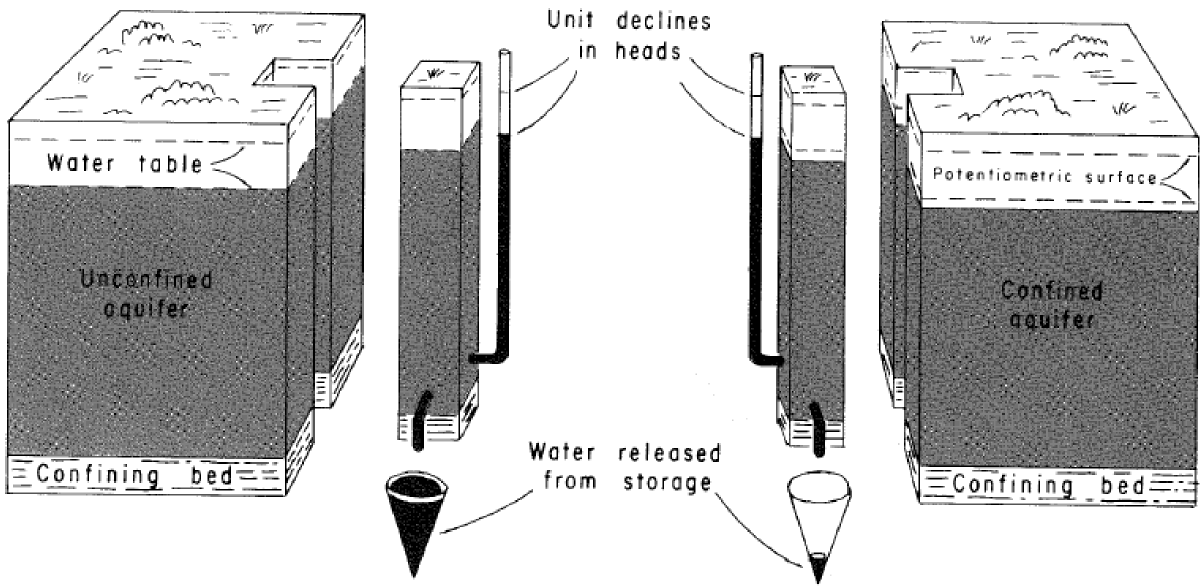

Fig 4.storativity analysis

The abilities (capacities) of water-bearing materials to store and to transmit water are their most important hydraulic properties. Depending on the intended use of the information, these properties are given either in terms of a unit cube of the material or in terms of a unit prism of an aquifer.

The storage coefficient (S) is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is a dimensionless unit, as the following equation shows, in which the units in the numerator and the denominator cancel :

$$S = \frac{\text{volume of water}}{(\text{unit area})(\text{unit head change})} = \frac{(m^3)}{(m^2)(m)} = \frac{m^3}{m^3}$$

The size of the storage coefficient depends on whether the aquifer is confined or unconfined (1) If the aquifer is confined, the water released from storage when the head declines comes from expansion of the water and from compression of the aquifer . Relative to a confined aquifer, the expansion of a given volume of water in response to a decline in pressure is very small. In a confined aquifer having a porosity of 0 .2 and containing water at a temperature of about 15°C, expansion of the water alone releases about 3x10-7 m3 of water per cubic meter of aquifer per meter of decline in head.

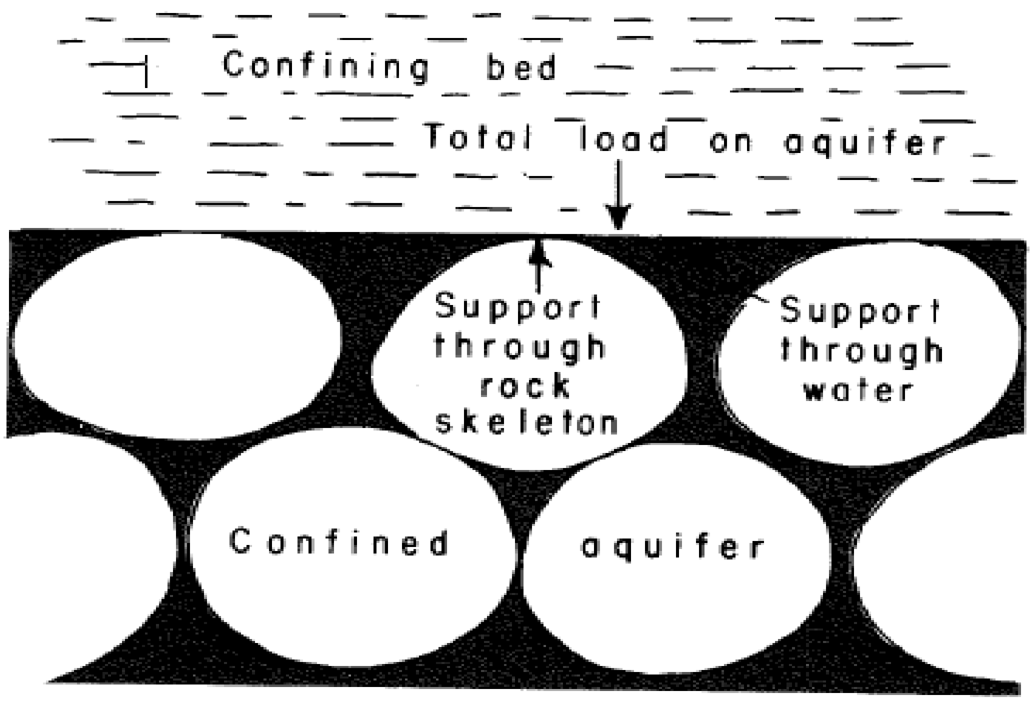

Fig 7. Analysis of storativity depending of material

To determine the storage coefficient of an aquifer due to expansion of the water, it is necessary to multiply the aquifer thickness by 3 x 10 -7. Thus, if only the expansion of water is considered, the storage coefficient of an aquifer 100 m thick would be 3x10-5 . The storage coefficient of most confined aquifers ranges from about 10 -5 to 10 -3 (0.00001 to 0 .001) . The difference between these values and the value due to expansion of the water is attributed to compression of the aquifer. If the aquifer is unconfined, the predominant source of water is from gravity drainage of the sediments through which the decline in the water table occurs . In an unconfined aquifer, the volume of water derived from expansion of the water and compression of the aquifer is negligible. Thus, in such an aquifer, the storage coefficient is virtually equal to the specific yield and ranges from about 0 .1 to about 0.3. Because of the difference in the sources of storage, the storage coefficient of unconfined aquifers is 100 to 10,000 times the storage coefficient of confined aquifer. However, if water levels in an area are reduced to the point where an aquifer changes from a confined condition to an unconfined condition, the storage coefficient of the aquifer immediately increases from that of a confined aquifer to that of an unconfined aquifer . Long-term withdrawals of water from many confined aquifers result in drainage of water both from clay layers within the aquifer and from adjacent confining beds. This drainage increases the load on the solid skeleton and results in compression of the aquifer and subsidence of the land surface. the potential sources of water in a two-unit ground-water system consisting of a confining bed and a confined aquifer. the potentiometric surface is lowered to the top of the aquifer and the second by dewatering the aquifer .

2.7 Pumping tests

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 Parameter of Transmissivity and Storativity.

The five objectives of the purpose of test pumping water wells are:

- To confirm the yield, efficiency and performance of the well.
- To investigate water quality.
- To assess whether the abstraction can be sustained in terms of yield (and quality).
- To identify potential environmental impacts.
- To characterize the hydraulic parameter (such as transmissivity and storativity).

2.8 Duration of a Pumping Test

The question of how long a pumping test should last is difficult to answer because the period of pumping depends on the type of aquifer and the degree of accuracy desired in establishing its physical properties. Economizing on the pumping period is not recommended because the costs of running the pump a few extra hours are low compared with the total costs of the test. Moreover, better and more reliable data are obtained if pumping continues until the cone of depression has stabilized and does not seem to be expanding further as pumping continues. At the beginning of the test, the cone develops quickly 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 may often lead inexperienced observers to conclude that the cone has stabilized, or in other words that steady state has been reached.

2.9 Adjustment of Pumping Test Data

The test data obtained from the observed water levels might have to be corrected for external influences prior of being used in the analysis. The local movement in the hydraulic head or water table has to be analyzed so as to discover out whether the correction is indispensable or not.

The test data that ultimately suitable for these purposes are the water level measurements those had taken in a pumping test itself or in a piezometer. 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.

2.10 Adjustments of Pumping Test Data for Unconfined Aquifers

The observed drawdowns from unconfined aquifers are required correction for unconfined before using for analysis to estimate hydraulic parameters, when the drawdowns in this aquifer are large compared with the aquifer's original saturated thickness. 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. According to the recommendation forwarded by Jacob (1944), the adjusted drawdown for an unconfined aquifer is given by: -

$$s_c = s * \left(1 - \frac{s}{2b}\right)$$

Where:-
b = is the initial saturated thickness;
s = is the measured drawdown and
sc = is the corrected drawdown.
If the drawdown is not corrected, the Jacob and Theis analysis underestimates the true transmissivity under saturated conditions by a factor of sc/s.

2.11 Partially penetrating wells

Corrections may also be required to account for partially penetrating pumping wells. In these circumstances flow in the vicinity of the pumped well will be higher than a fully penetrating well and can result in additional head loss. This effect decreases with increasing distance from the pumping well, and no corrections are required at distances greater than 1.5 to 2 times the saturated thickness of the aquifer.

2.12 Correction for Partial Penetration

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

$$F = \frac{L}{b}\left[1 + 7\cos\left(\pi L/2b\right)\sqrt{r/2L}\,\right]$$

Where
b = is the total aquifer thickness (m)
r = is the well radius (m); and
L = is screen length (m).

2.13 SINGLE-WELL TESTS

It is also possible to obtain useful data from production wells, even where observation wells are not available . Such tests are referred to as single-well tests and may consist of pumping a well at a single constant rate, or at two or more different but constant rates. In order to analyze the data, it is necessary to understand the nature of the drawdown in a pumping well. The total drawdown (s t) in most, if not all, pumping wells consists of two components. One is the drawdown (s) in the aquifer, and the other is the drawdown (s,) that occurs as water moves from the aquifer into the well and up the well bore to the pump intake . Thus, the drawdown in most pumping wells is greater than the drawdown in the aquifer at the radius of the pumping well.

Single well tests are more common than aquifer tests using monitoring wells due to the obvious advantage that only one well is needed. However, in practice, only transmissivity can be estimated, due to the high sensitivity of the (effective) well radius. A single-well test is a test when there are no piezometers existing. The test in a single well involves pumping, displacing, or adding water and measuring changes in water levels in the well. Such type of test allows a rapid and economical calculation of K and T of the zone of interest at a single location. It can also determine response criteria for observation wells in multiple well pumping tests. So using the data that measured from changes in water-level during pumping or recovery which is conducted in the well itself, the hydraulic parameters of the aquifer can be determined in many conditions.

Some of the disadvantages of single well tests are:

1. Well construction (e.g. partial penetration) can lead to an underestimation of hydraulic parameter of transmissivity.

2. Storativity cannot be reliably determined; and

3. Single well test analyses typically make no allowance for leakage, or other recharge/no flow boundaries.

2.14 Multiple Well Pumping Tests

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

2.15 Estimate Hydraulic Parameters and Pumping test Analysis

Estimating the physical properties of water-bearing layers is an essential part of groundwater studies. One of the most effective ways of determining these properties is to conduct and analyses hydraulic parameter tests. Proper management of ground-water resources requires an accurate evaluation of the hydraulic parameters that control the movement and storage of water. Therefore, determination of this parameters and their interpretation must be give a valuable attentions. There are different methods used in the determination of these hydraulic parameters by analyzing aquifers test data. One of the extensive methods used is fitting the measured drawdown with standard simulated type - curve using Analytic Solution or Curve Fitting Technique. The analytical solution methods use conventional mathematical approaches to resolve differential equations into exact solutions. These solution techniques require assumptions of homogeneity and are limited to one dimensional and two dimensional problems. Whereas the curve fitting approach uses log-log plots or semi-log plots and tries to match the simulated curve with the observed data curve and try's to determine the hydraulic parameters from the reading of these plots. In recent years, the computer technology has been widely used to determine the hydraulic parameters. The computer curve-matching method can overcome the inaccuracy caused by the subjectivity completely, and improve the efficiency greatly. The computer software has rapid computing speed, and it also can choose or delete abnormal data points on the screen, as well as to recalculate. A great number of computer software have been presented in other countries to derive the hydraulic parameters, such as Aquifer Test Pro, AQTESOLV, Aquifer Test Pro 3.5, Aquifer Win32, PEST.

In this project Aquifer Test Pro has be used to check how to Transmissivity and storativity results determined deviate from the Theis curve-matching method, Cooper-Jacob straight line method and residual/recovery drawdown vs time method. Aquifer Test Pro, designed for graphical analysis and reporting of pumping test and slug test data, offers the tools necessary to calculate hydraulic parameter such as Transmissivity and Storativity. Aquifer Test Pro is versatile enough to consider confined aquifers, unconfined aquifers, leaky aquifers, and fractured rock aquifers conditions. Analysis results are displayed in report format, or may be exported into graphical formats for use in presentations. Aquifer Test Pro also provides the tools for trends corrections, and graphical contouring water table drawdown around the pumping well.

Aquifer Test provides a flexible, user-friendly environment that will allow you to become more efficient in your aquifer testing projects. Data can be directly entered in Aquifer Test via the keyboard, imported from a Microsoft Excel workbook file, or imported from any data logger file (in ASCII format). Determination of these two hydraulic parameter of constants(Transmissivity and Storativity) is almost always involved in quantitative studies of groundwater problems. In fact, no matter what methods are adopted, the hydraulic parameters should be unique. In this project, we adopt traditional methods Theis curve-matching method, Cooper-Jacob straight line method and residual/recovery drawdown vs time method and together with the Aquifer Test Pro software to determine this two hydraulic parameters.

2.16. Theis Method - Curve Fitting Method

Charles Vernon Theis (1900-1987) was the first hydrologist to develop a rigorous mathematical model of transient flow of water to a pumping well by recognizing the physical analogy between heat flow in solids and groundwater flow in porous media. In his paper publish in 1935 Theis stated that when a well is pumped, water levels in its neighbourhood are lowered. Unless this lowering occurs instantaneity it represents a loss of storage either by the unwatering of a portion of the previously saturated sediments if the aquifer is non-artesian or by release of stored water by the compaction of the aquifer due to lowered pressure if the aquifer is artesian. The mathematical theory of groundwater hydraulics has been based, apparently entirely, on a postulate that equilibrium has been attained and therefore that water-levels are no longer-falling. In a great number of hydrologic problems involving a well or pumping district near or in which water-levels are falling the current theory is therefore not strictly applicable. Thus in his paper, Theis investigates in part, the nature and consequences of a mathematical theory that considers the motion of ground-water before equilibrium is reached and, as a consequence involves time as a variable. Theis used the analogy between heat flow in solids and groundwater flow and stated to the extent that Darcy’s law governs the motion of groundwater under natural conditions and under the artificial conditions set up by pumping, an analogy exists between the hydrologic conditions in an aquifer and the thermal conditions in a similar thermal system. Darcy's law is analogous to the law of the flow of heat by conduction, hydraulic pressure being analogous to temperature, pressure-gradient to thermal gradient, permeability to thermal conductivity, and specific yield to specific heat. Therefore, the mathematical theory of heat-conduction developed by Fourier and subsequent writers is largely applicable to hydraulic theory. This analogy has been recognized, at least since the work of Sichter, but apparently no attempt has been made to introduce the function of time into the mathematics of ground-water hydrology. Among the many problems in heat-conduction analogous to those in ground-water hydraulics are those concerning sources and sinks, sources being analogous to recharging wells and sinks to ordinary discharging wells.

$$s = \frac{Q}{4\pi T} \int_{r2s/4Tt}^{\infty} \frac{e^\wedge - u}{u} du$$

With u= $\frac{r2s}{4Tt}$

Where s = the drawdown, at any point the vicinity of a well discharged at a uniform rate; Q = the discharge of the well; T = the coefficient of transmissibility of the aquifer; r = the distance from pumped well to point of observation, S = is the storativity, as a decimal fraction; and t = the time the well has been pumped. The Equation gives the drawdown at any point around well being discharged uniformly (and continuously) from a homogeneous aquifer of constant thickness and infinite areal extent at any time. The introduction of the function, time is the unique and valuable feature of the equation.

Theis also stated that theoretically, the equation applies rigidly only to water-bodies

I. which are contained in entirely homogeneous sediments,

II. which have infinite areal extent,

III. in which the well penetrates the entire thickness of the water-body,

IV. in which the coefficient of transmissibility is constant at all times and in all places,

V. in which the pumped well has an infinitesimal diameter and

VI. in which the water in the volume of sediments through which the water-table has fallen is discharged instantaneously with the fall of the water-table.

These theoretical restrictions have varying degrees of importance in practice. The effect of heterogeneity in the aquifer can hardly be foretold. The effect of boundaries can be considered by more elaborate analyses, once they are located. The effect of the well failing to penetrate the entire aquifer is apparently negligible in many cases. The equation implies that any two observations of drawdown, whether at different places or at the same place at different times are sufficient to allow the computation of Storativity and Transmissibility. However, more observations are always necessary in order to guard against the possibility that the computations will be vitiated by the heterogeneity of the aquifer. Moreover, it appears that the time-lag in the drainage of the un-watered sediments makes it impossible at present to compute transmissibility and storativity from observations on water-levels in only one observation well during short periods of pumping.

The equation stated above can be simplified by introduction of well function *W(u).* This well function *W(u)* and its argument u are also specified as ‘dimensionless drawdown’ and ‘dimensionless time’, respectively.

$$\boldsymbol{S = \frac{Q}{4kt} W(u)}$$

Where W(U)= $\int_{U}^{\infty} \frac{e\wedge -u}{u} du$ **and u=**$\frac{r2s}{4Tt}$

Theis well function W(u) vs 1/u for fully penetrating confined aquifer.

The Theis equation (analytic solutions for the radial) well flow do not allow direct calculation of the hydraulic parameters (i.e. T and S) for the constraints measured in the test due to the appearance of the two unknowns and the nature of the exponential integral in the equation. Theis suggested that an approximate solution can be found for S and T based on the graphic method of superposition. A plot on the logarithmic paper of *W (u*) versus u, known as a Type curve, is prepared and values of drawdowns are plotted against values of r2/t on logarithmic paper of the same size and scale as of the type curve, keeping the coordinate axes of the two curves parallel, and adjusted until a position is found by trial whereby most of the plotted pointes of the observed data fall on a segment of the type curve. Any convenient point is then selected and the coordinates of this match point are recorded. With values of *W (u)*, u, s and r2/t thus determined, S and T can be determined for the equations;

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

S=$\frac{4Ttu}{r2}$

2.17. Cooper and Jacob Method – Straight Line Method.

The equation given by Theis (1935) involves a transcendental function known as the exponential integral (well function) and two unknown coefficients, one of which occurs both in the argument and as a divisor of the function, thus the coefficients cannot be determined directly. However, they may be determined by a graphical method devised by Theis and describe bed by Jacob (1940) which requires the use of a type curve on which the observed data are superimposed to determine the coefficients. In 1944, Wenzel and Greenlee published a paper that gave a generalization of Theis graphical method by which the coefficient may be determined from tests of one or more discharging wells operated at changing rates. This method requires the computation of a special type curve for each observation of drawdown used. This published paper was worth-while contribution to the quantitative techniques of groundwater hydraulics but in tests that involve more than a very few discharging wells or a very few changes in the rates of discharge the computation of the special type curve is necessarily laborious as to make the method difficult to apply.

H.H. Cooper, Jr. and C. E. Jacob published a paper in 1946 that gives a simple straight- line graphical method for accomplishing the same purposes as the methods developed by Theis and Wenzel and Greenlee. Here the use of type curves are not required. This method, where applicable, has decided advantages in ease of application and interpretation over the other graphical methods. This method is designed especially for artesian conditions, but it may be applied successfully to test of non- artesian aquifers under favorable circumstances. The Cooper and Jacob solution is an approximation of the Theis non-equilibrium method which is given by the following infinite series expression.

$$W(u)=0.5772+\ln(u)+u-\frac{u2}{2*2!}+\frac{u3}{3*3!}-\frac{u4}{4*4!}+\cdots$$

To apply the Cooper and Jacob equation, which is an equation for a line, plot ***s*** as a function of log (*t*) on semi-logarithmic axes and draw a straight line through the data. To determine the transmissivity (T) and storativity (S) uses following equation:

$$T=\frac{2.3.3Q}{4\pi\Delta S}$$

$$S=\frac{2.225Tto}{r2}$$

Where Δs is the slope of the fitted line and to is the intercept of the line on the x axis.
The uses of this straight line method comes with restrictions thus assumption are made to the derivation of this equations. As the equation are based on the Theis equations the assumption made by Theis also apply for Cooper and Jacob solution. The assumptions given by Cooper and Jacob are:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- control well is fully penetrating
- flow to control well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the control well can be neglected

2.18 R- Squared (R2)

Uses of the Cooper-Jacob method is the simples from of determination of transmissivity and storativity of a given aquifer by using a semi-logarithmic graph of drawdown verses logarithms of time data and fitting a best straight line through the scattered point in the graph. Drawing of this straight line by hand on as semi-log graph with no leanings toward a single data point on the graph is tedious job. Different software's have been developed that can draw this straight line using regression analysis with a blink of an eye and can give as the degree of accuracy. This software use a statistical variable known as R-squared to determine the best fit line on a graph is representing the data points on a graph.
R-squared is a statistical relationship between two series of events. It is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression. The definition of R-squared is fairly straight-forward; it is the percentage of the response variable variation that is explained by a linear model. Or

R--- Squared= $\frac{explained\ variation}{total\ variation}$

R-squared is always between 0 and 1. Zero indicates that the model explains none of the variability of the response data around its mean. And 1 indicates that the model explains all the variability of the response data around its mean. Therefore, the uses of R-squared value in Cooper-Jacob semi-log graph gives as the degree of accuracy of the straight line and has been used in this project not only for Cooper Jacobs's analysis but also in different topics that involves best fit lines.

2.19 The Recovery Method for Determining the Coefficient of Transmissibility

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.
The recovery method developed by Theis (1935) has proved useful for determining the coefficient of Transmissibility of an aquifer if the coefficient of storage remains virtually constant throughout both the period of pumping and the subsequent period of recovery. However, if the coefficient of storage does not remain constant, the water-level drawdown data, when plotted on a graph, do not fall along a straight line that passes through the origin. Instead, most of the data fall along a smooth curve that does not pass through the origin, and the coefficient of transmissibility can be determined from the slope of this curve regardless of any variation in the coefficient of storage. 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.

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

$$S=\frac{Q}{4\pi \mathrm{Tt}}\left[\log(\frac{4Tt}{r2ws} - \log(\frac{4Tt\prime}{r2ws\prime})\right.$$

Where *rw* is the effective radius of the pumped well in which the water-level recovery is measured. If *S* (the coefficient of storage during the period of pumping) and *S'* (the coefficient of storage during the period of recovery) are constant and equal. Thus, equation can be simplified to:

$$s' = \frac{Q}{4\pi T} log\left(\frac{t}{t'}\right)$$

The graph of above equation is where **s'** is plotted against **log (t/t')** *is* a straight line. If the value of ***Q*** is known, ***T*** can be determined from the slope of the line. The slope of the line equals 2.3Q/4πT so that Δs′, the change in residual drawdown over one log cycle of t/t′, enables a value of transmissivity to be found from:

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

Where $\Delta s'$is the residual drawdown difference per log cycle of t/t'.
Here we keep in mind that the assumption made by Theis is also applied in the recovery method. The general procedure in the determination of transmissivity recovery method is brief below

- For each observed value of **s'**, calculate the corresponding value of t/t.
- For one of the piezometers, plot **s'** versus t/t' on semi-log paper (t/t' on the logarithmic scale).
- Fit a straight line through the plotted points;
- Determine the slope of the straight line, i.e. the residual drawdown difference $\Delta s'$ per log cycle of t/t'.
- Substitute the known values of Q and $\Delta s'$ into Equation 2.25 and calculate T.

It is always good practice to measure the residual drawdowns during the recovery period. Recovery-test measurements allow the Transmissivity of the hydraulic parameter 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. Unlike the Theis and Cooper–Jacob methods, it is not possible for a value of storativity (S), to be determined by this recovery test method.

2.20 Estimation of Hydraulic parameter (Transmissivity and Storativity) by Aquifer Test Software

There are so many different software that are available for the determination of hydraulic parameters in the hydro geologist society to mention a few we have *AQTESOLV* and Aquifer Test. Aquifer Test is designed by hydro geologists for hydro geologists giving you all the tools you need to efficiently manage hydraulic testing results and provide a selection of the most commonly used solution methods for data analysis - all in the familiar and easy-to-use Microsoft Windows environment Aquifer Test Pro, designed for graphical analysis and reporting of pumping test and slug test data, offers the tools necessary to calculate hydraulic parameter such as Transmissivity and Storativity. Aquifer Test Pro is versatile enough to consider confined aquifers, unconfined aquifers, leaky aquifers, and fractured rock aquifers conditions. Analysis results are displayed in report format, or may be exported into graphical formats for use in presentations. It allows you to calculate hydraulic parameters in all the possible scenarios that were available in previous versions; the difference is that instead of using explicitly defined solution names, the results are obtained by starting with a standard solution, and sequentially applying correction factors in order to get to the most.
Different method of used for analysis of pumping test data in Aquifer Test for example Theis Method (confined), Theis with Jacobs Correction (Unconfined & Isotropic), Theis Recovery Test (confined), Hantush - Jacob –Walton (Leaky), Recovery Analysis- Agarwal Solution (1980). For this Project three methods have be selected for the determination of hydraulic parameter of Transmissivity and Storativity on WF16 and WF17 on the Akaki phase IIIA wells. Those methods are Theis (1935) Cooper-Jacob Time-Drawdown (1946) Theis Recovery (1935).

2.21 Data Correction for Unconfined Aquifer

The water table in an unconfined aquifer is equal to the elevation head (potential). Since Transmissivity in unconfined aquifers is not constant and it will decrease with increasing drawdown, there is no closed solution for this aquifer type. That is why the measured drawdown is corrected, and the pumping test is interpreted as being in a confined aquifer.
For most analysis solutions, the aquifer is assumed to be of constant thickness. This assumption can be accepted if the saturated thickness does not decrease more than 25 percent. If the decrease is greater than 25 percent, then the drawdown data should be corrected prior to analysis (Dawson and Istok, 1991).In an unconfined aquifer, this condition is not met if the drawdown is large compared to the aquifers original saturated thickness. Where this occurs, the Jacob (1944) correction may be applied:

$$Sc = Sa\left(1 - \frac{Sa}{2b}\right)$$

Where , sc=corrected Drawdown

sa=Measured Drawdown

b=is the initial saturated thikness

3. Methodology

3.1 Location of Akaki Well Fields

Akaki groundwater prospective sites are in the upper part of Awash River Basin and distributed in the suburb of Addis Ababa city and adjacent Oromiya Regional State within 10 to 40 km from the center of the city. The south-eastern, central and eastern parts are flat and undulating lands covered with thick quaternary alluvial and lacustrine deposits (AAWSA, 2000). The aquifers at the southern part of the city (Akaki well field) are mainly young volcanic rocks of lava flow and tectonic fractures. In general, the aquifers are complex and highly variable. The thickness of the aquifers is not yet determined. Akaki well phase IIIA on WF02-16, WF02-17 Wells is located between 8°45' 20" to 9°13' 17" N latitude and 38°34' 3" to 39°4'10" E longitude in Oromiya Regional State, Akaki Kality Sub city south of Addis Ababa about20 km from the city center. It is one of the water supply projects implemented to alleviate the prevailing unsatisfactory water supply situation at the capital city, which is an important service for one of the most water deficit areas of the city-western & central Addis Ababa.

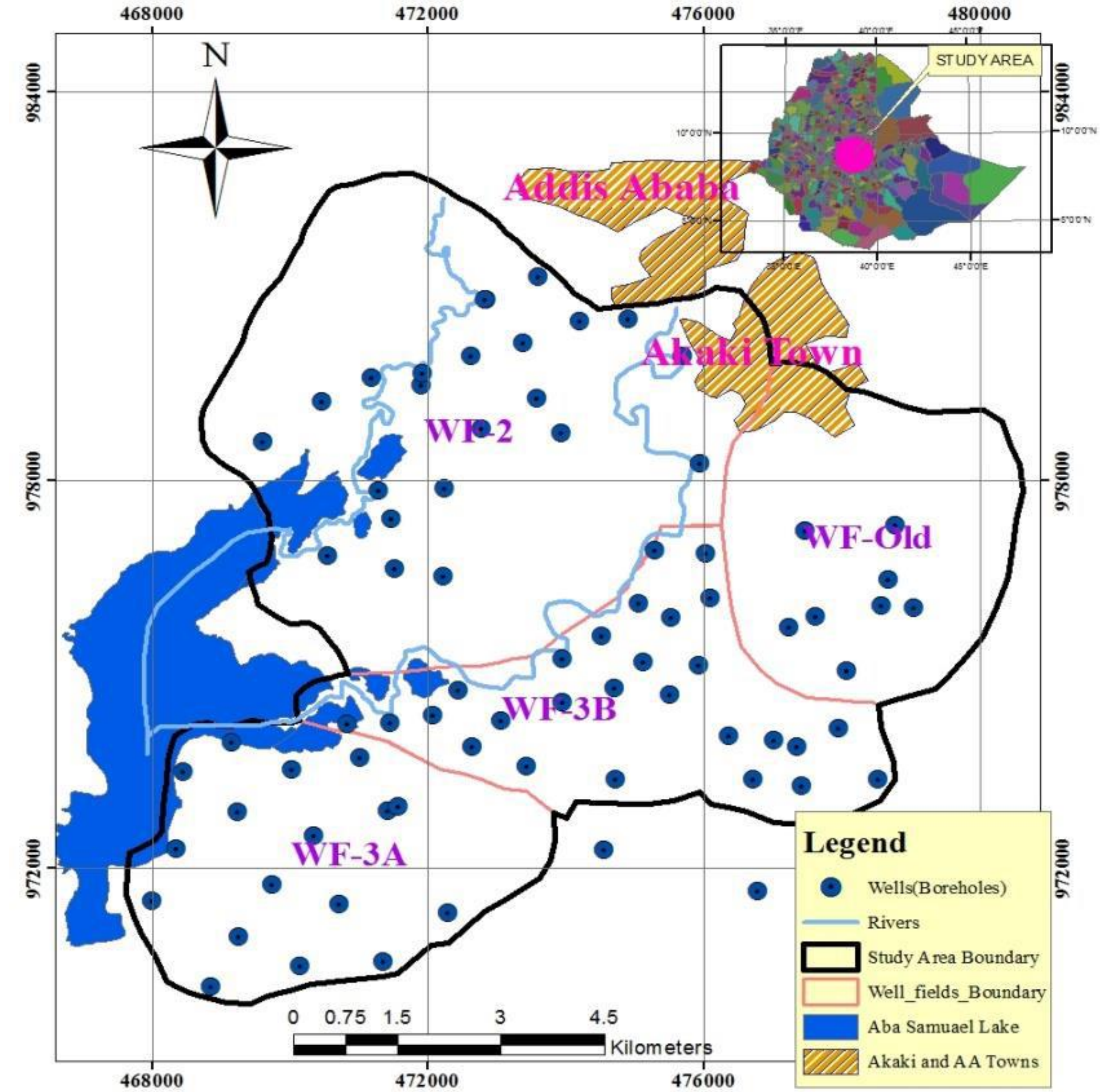

Fig 6 Akaki Groundwater Well Fields Map, 2018

3.2 Data Collection

Data collection is an important aspect of any type of project study. Inaccurate data collection can impact the results of a study and ultimately lead to invalid results. The choice of method for data collection is influenced by the data collection strategy, the type of variable, the accuracy required, the collection point and the skill of the data collector. Basically data is classified as primary and secondary data. The raw pump test data such as the step drawdown test, constant pumping test and recovery test were collected by WWDSE and AAWSA. The secondary data collection for this project includes the activities accomplished at the office work stage. This comprises the gathering of validated and organized data (secondary data) of Borehole information such as:- constant rate test, step drawdown test, recovery test, final drawdown, pumping duration, static water level, dynamic water level, well depth and design discharge.

A successful groundwater investigation depends on field data. However, to minimize additional fieldwork each groundwater study should start with the collection and analysis of the available information and documentation. These project primarily focus on primary data collected from Federal Water Works Design and Supervision, while the pump test was conducted in Akaki phase IIIA On WF02-16, WF02-17 Wells. Hence the primary pump test data like the step drawdown test data, constant pumping test data, recovery test data and the coordinate of each well were collected from Federal Water works Design and Supervision.

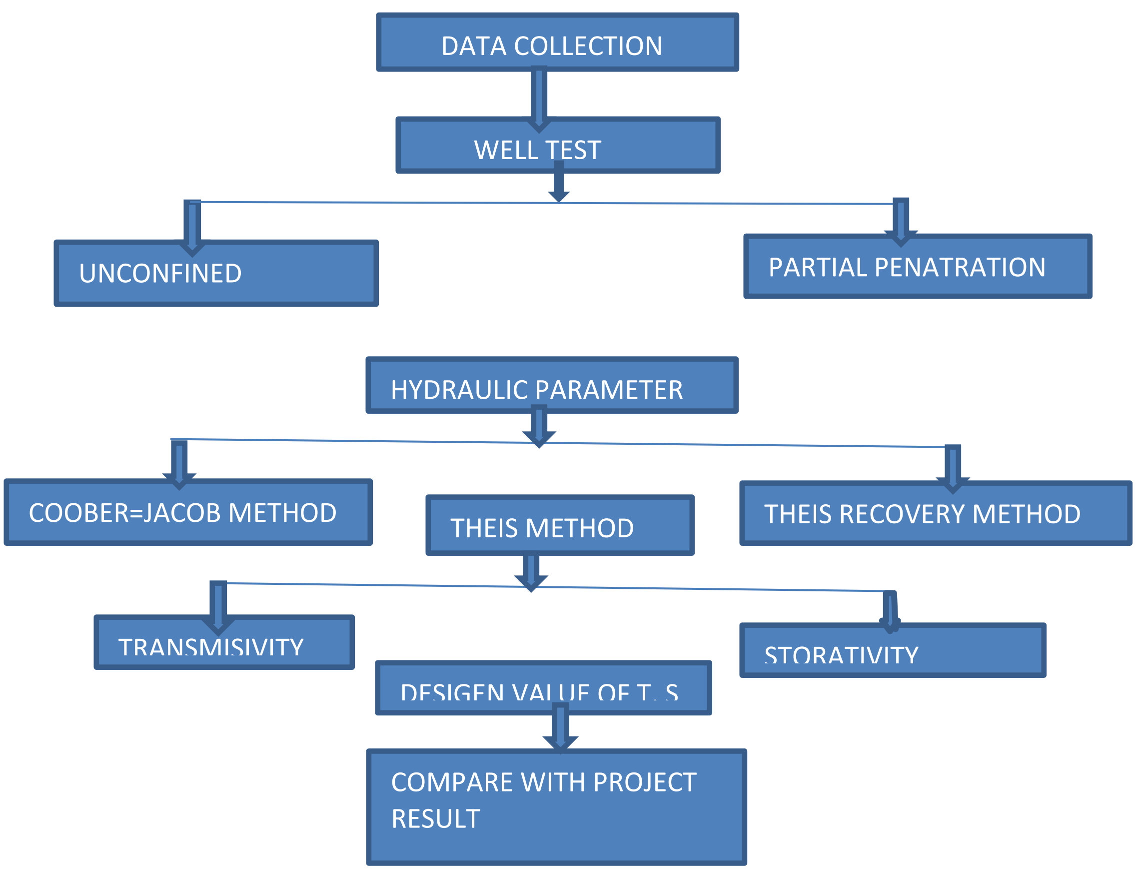

Fig 7 Summary of Project Methodology

3.3 Data analysis

Data correction and analysis on partial penetration effect of the wells:-A well whose length of water entry is less than the aquifer it penetrates is known as partial penetrating wells.

The situation of partially penetrating well in a confined aquifer. The flow pattern to such wells differs from the radial horizontal flow assumed exist around fully penetrating wells.

Analysis pumping test data of the wells analysis by using Theis curve matching method on excel sheet and aquifer test software. Theis method is one of the widely applied methods in groundwater hydrology to Determine S and T, However, this method requires curve matching of a type-curve and time draw down data from a pumping well test. Plotted pumping test data's and type curve.

Detailed calculations: - leading to determinations of hydraulic parameter of Transmissivity and storativity.

Discussion on analysis and evaluation pumping test data of the wells:-to analyses and evaluation of pumping test data and analyze effect of error pumping test data on amount of and amount of yield fluctuation of the well. After collection of secondary data and analyzing of the data estimated from well pumping test data using Theis curve match method, Coober Jacob and Recovery method and aquifer test software results of Transmissivity and storativity result should be compare it each other.

4. Result And Discussion

the main objective of this project is to analysis of the techniques used in the determination of Hydraulic parameter of Transmissivity and Storativity, the result and discussion part mostly contains the comparison between the corrected drawdown and uncorrected drawdown, comparison between manual curve fitting of Theis method and Aquifer Test software, comparison between results obtained by three method (Theis, Cooper-Jacob and a recovery method).

In this project area the two collecting wells are constant-rate single well test. constant-rate test is most common type of pumping test performed, and its concept is very simple the borehole is pumped at a constant rate for an extended period (most of the well pumped 3 day or 72 hour) while the water levels and pumping rates are monitored. If the most value is to be gained from constant-rate tests, water levels should be monitored in an observation borehole as well as in the pumping borehole. Data from constant-rate tests can be analyzed to derive the Transmissivity of hydraulic parameter.

4.1 Well Information

Water well is an excavation or structure created in the ground digging driving boring or drilling to access ground water in underground aquifer. All collected well information of Akaki phase IIIA well fields such as northing, easting, elevation; Depth, Discharge and Average Transmissivity etc… are summarized in Table.

Table 1 summary of well information

Well ID.	X(m)	Y(m)	Z(m)	Depth(m)	Q(l/s)	Tansmivity(m2/d)	static water level(m)	dynamic water level(m
WF02-PW16	468849	970179	2064	493	83	5.2*10^2	55.05	81.41
WF02-PW17	468336	972312	2061	480	81	3.21*10^2	61.62	89.11

4.2 step draw down test

Step-drawdown test is a single-well test in which the well is pumped at a low constant discharge rate until the drawdown within the well stabilizes.

Table 2. Summary of WF02-PW16 and WF02-PW17 wells efficiency

Well Name	DSw	Sw	Q(l/s)	Q(m3/d)	Sw/Q	B	C	R2	E (%)
WF02-PW16	13.25	13.25	58	5011.2	0.00264	0.0024	1.7E-07	0.651	66.2
	2.42	15.67	66	5702.4	0.00275				
	4.72	20.39	74.9	6471.36	0.00315				
	2.2	22.59	83.4	7205.76	0.00313				
WF02-PW17	14.59	14.59	65	5616	0.0026	0.006	1.6E-07	0.814	67.6
	2.43	17.02	70	6048	0.00281				
	3.28	20.3	75	6480	0.00313				
	0.94	21.24	80	6912	0.00307				

From the step draw down test result of calculation from table 2 the R2 and the efficiency of the two wells are fit the requirement of the standard.

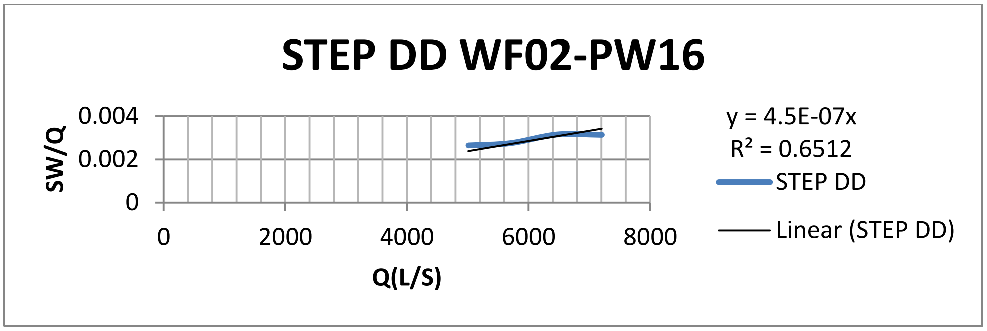

Fig 8 Graphical Representation of WF02-PW16

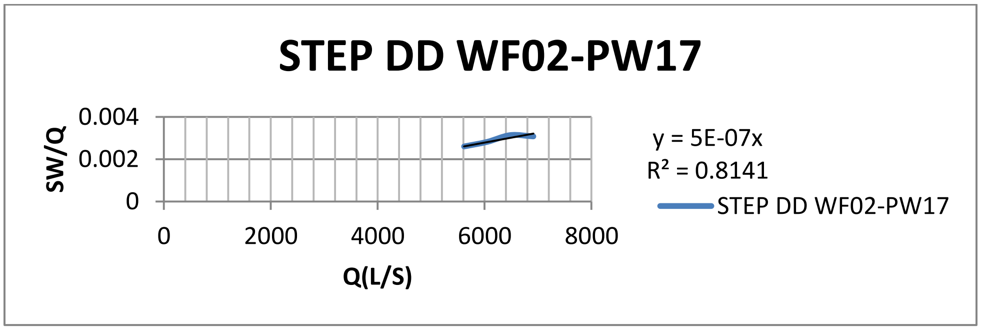

Fig 9 Graphical Representation of WF02-PW17

4.3. Transmissivity and Storativity result for WF02-PW16 and WF02-PW17 wells

The object of this project is to evaluate hydraulic parameter of WF02-PW16 and WF02-PW17 wells. The transmissivity and Storativity values both for observed and corrected drawdown are shown by the three methods using Excel and compare the result of each methods.

4.3.1 Transmissivity and Storativity Results using Cooper-Jacob method

The one of the method to analysis transmissivity and storativity is Cooper- Jacob or in other name refer to as the Cooper-Jacob straight-line method, which is based on a simplification of the Theis method.

When a straight line was fitted to the data points, early time data were ignored because they tend to be affected by the volume of water stored in the borehole itself, and the points would probably not have fallen on the straight line. Because of the above reason used to calculate and analyze hydraulic parameter .The method is apply for two of Akaki phase IIIA WF02-PW16 and WF02-PW17 well in the semi-log plot of the drawdown vs. time.

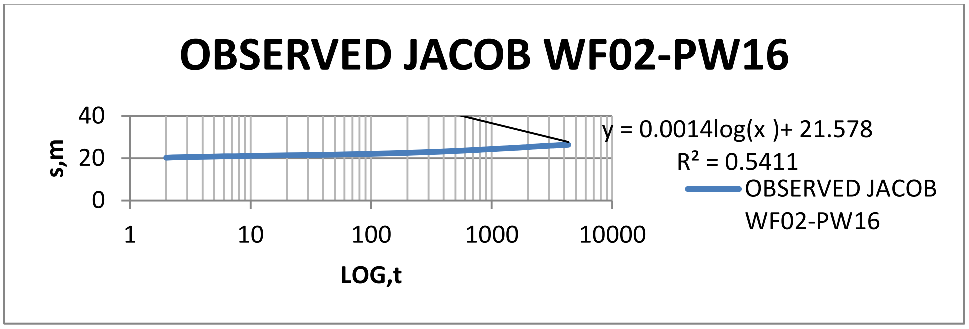

Fig 10 Graphical Representation of Observed Jacob method of WF02-PW16

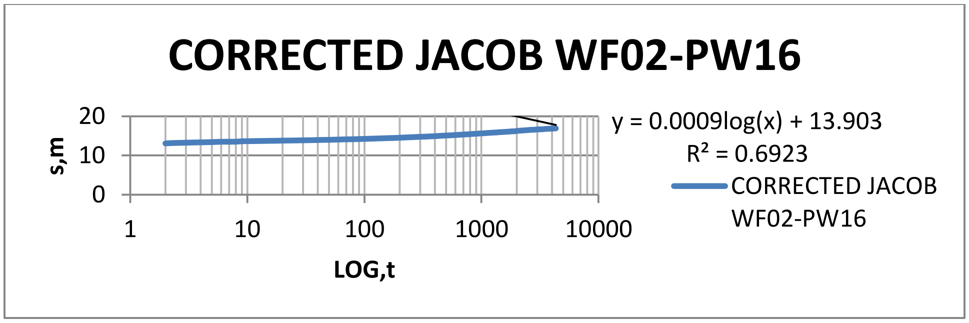

Fig 11 Graphical Representation of Corrected Jacob method of WF02-PW16

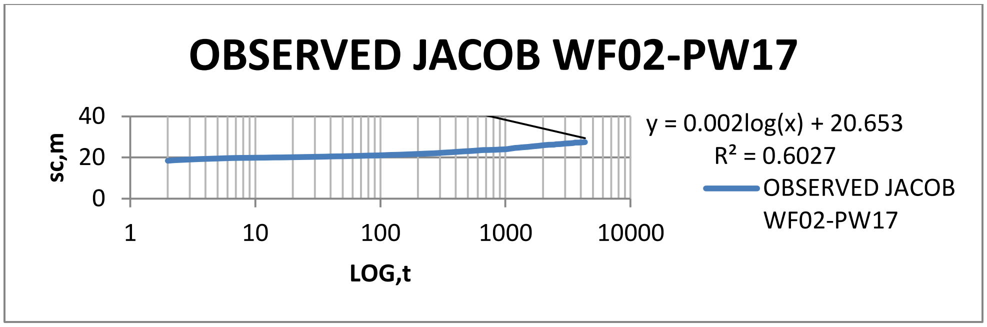

Fig 12 Graphical Representation of Observed Jacob method of WF02-PW17

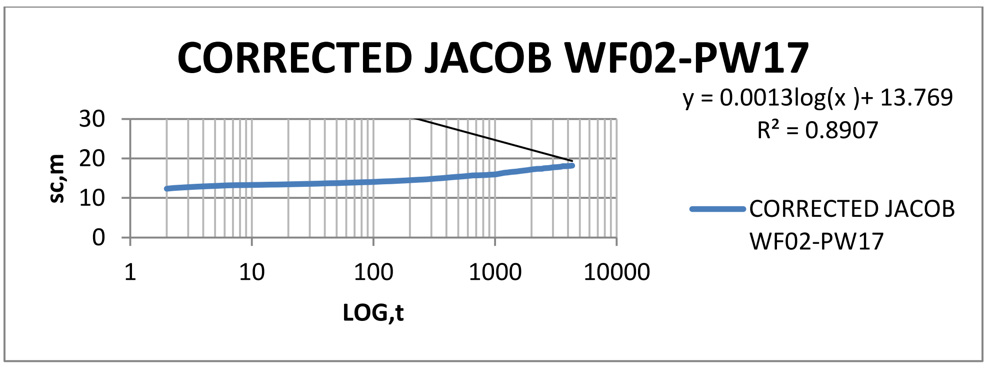

Fig 13 Graphical Representation of Corrected Jacob method of WF02-PW17

The Cooper-Jacob method is applied for all of the two wells in Akaki phase IIIA of WF02-PW16 and WF02-PW17 well fields. This method is simpler than the Theis method in that in the semi-log plot of the drawdown vs time the best fit line is done using Strandline tool which in turn give us the equation of the line and the R-square value to show how the line represents the points in the drawdown vs. time plots. The plots for the two well are show in figure 4 to figure 7 in the semi-log plots of the observed drawdown and corrected drawdowns and The result of the Transmissivity and Storativity values for two wells, using the Cooper-Jacob method, is tabulated in below table 3 for both the Observed and corrected drawdown.

From the Cooper-Jacob method of the excel result the Transmissivity and Storativity value of the corrected drawdown result is much greater than the Observed value.

Transmissivity is widely used in groundwater hydraulics to understand of the hydraulic parameter. It is defined as the rate at which water of prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. The Transmissivity result of WWDSE WF02-PW16 and WF02-PW17 is 520m2/day and 320m^2/day respectively. The comparisons between Cooper-Jacob transmissivity evaluated analysis of the Akaki phase IIIA WF02-PW16 and WF02-PW17 well result overrated with the WWDSE result.

Table 3. Summary of Transmissivity and Storativity Excel result for WF02-PW16 and WF02-PW17 wells By Cooper-Jacob method.

Well Name	Pumping rate	Radius of well in (m)	Best fit line for Observed DD			Best fit line for Corrected DD			Transmisvity(m^2/day)		Storativity	
			Slope	Intercept	R-square	Slope	Intercept	R-square	Observed	Corrected	Observed	Corrected
WF02-PW16	83	0.02032	0.0014	21.57	0.5411	0.0009	13.903	0.6923	1313.197	2487.116	0.002286	0.033882
WF02-PW17	81	0.3556	0.002	20.653	0.6027	0.0013	13.769	0.8907	1154.553	1755.554	0.002853	0.00564

4.3.2 Transmissivity Result Using Recovery Method

Recovery method is one of the transmissivity result obtaining method using the time when pumping was stop (t‘), the semi-log plot of the residual drawdown vs t/ t. the following representation is recovery method of graphical and excel results.

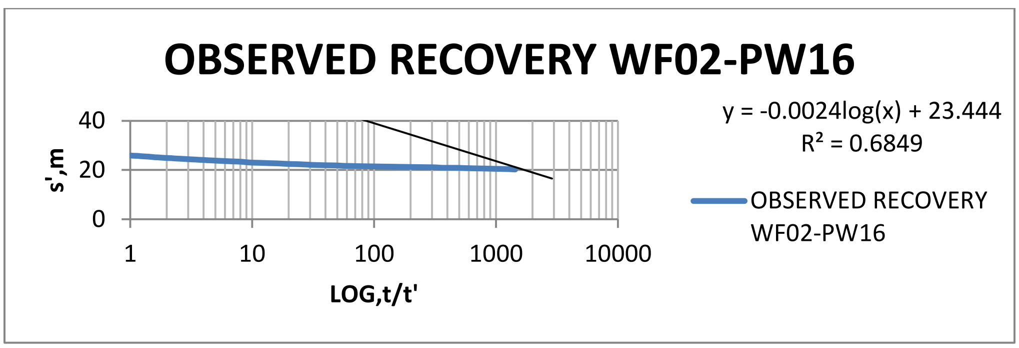

Fig 14 Graphical Representation of Observed Recovery method of WF02-PW16

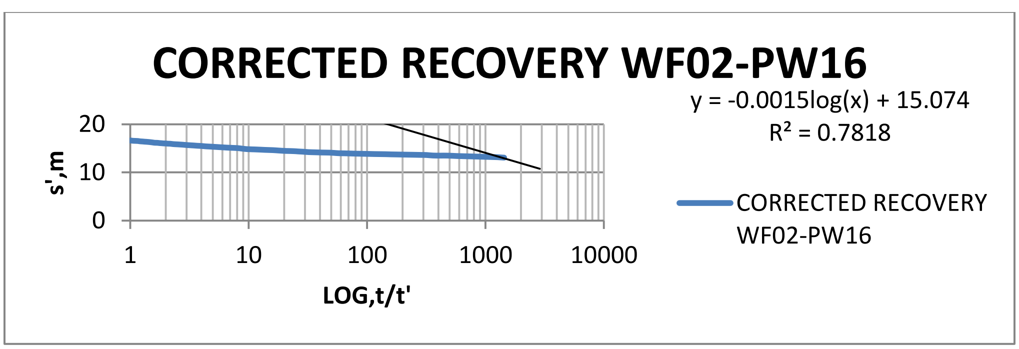

Fig 15 Graphical Representation of Corrected Recovery method of WF02-PW16

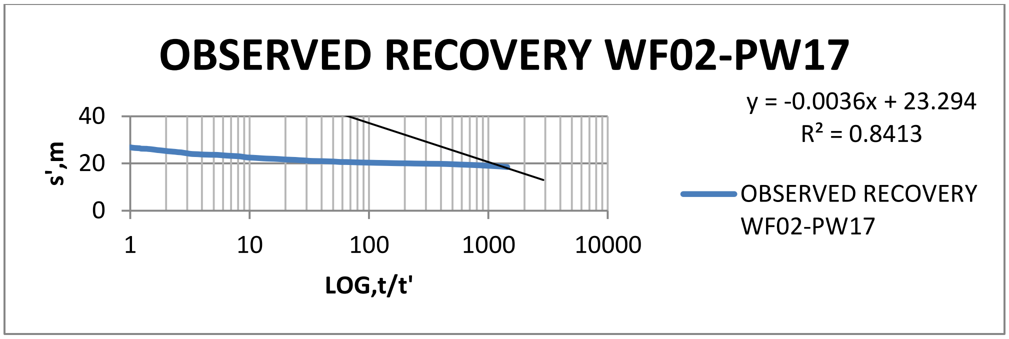

Fig 16 Graphical Representation of Observed Recovery method of WF02-PW17

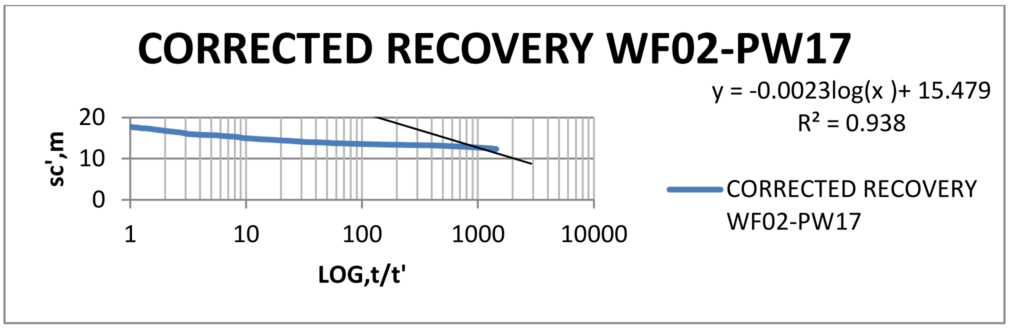

Fig 17 Graphical Representation of Corrected Recovery method of WF02-PW17

The transmissivity values for the two wells have been determined using there recovery drawdown data. The Recovery method is applied for the two wells in Akaki phase IIIA of WF02-PW16 and WF02-PW17 well fields. By using the time when pumping was stop (t'), the semi-log plot of the residual drawdown vs Log t/ t' was plot for each of the well. Here also the use of best fit line was applied for the points in the plot of residual drawdown vs Log t/t'. The plots for the two well are show in figure 8 to figure 11 in the semi-log plots of the observed drawdown and corrected drawdowns and the result of the Transmissivity values for two wells, using the Recovery method, is tabulated in above table 4 for both the Observed and corrected drawdown. From below table 4 the Recovery method of the excel result the Transmissivity value of the corrected drawdown result is much greater than the Observed value.As a final point, transmissivity values described the capacity of an aquifer to transmit water. This means high transmissivity is high ability of aquifer to transmit water and for low transmissivity vies versa. Accordingly, for corrected drawdown, lower transmissivity evaluated values indicate the aquifer is over-estimated and higher transmissivity evaluated values show that the aquifer is under-estimated. The Transmissivity result of WWDSE WF02-PW17 is 321m2/day. The comparisons between Recovery method transmissivity evaluated analysis of the Akaki phase IIIA of WF02-PW17 well result overrated with the WWDSE result.

Table 4.Summary of Transmissivity Excel result for WF02-PW16 and WF02-PW17 wells By Recovery Method.

Well Name	Pumping rate	Radius of well in (m)	Best fit line for observed DD			Best fit line for corrected DD			Transmisvity(m^2/day)	
			Slope	Intercept	R-square	Slope	Intercept	R-square	Observed	Corrected
WF02-PW16	83	0.02032	-0.0024	23.44	0.6849	-0.0015	15.07	0.7818	-383.192	-613.931
WF02-PW17	81	0.3556	-0.0036	23.294	0.8413	-0.0023	15.479	0.938	-279.999	-476.237

4.3.3 Transmissivity and Storativity Results using Theis Method

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

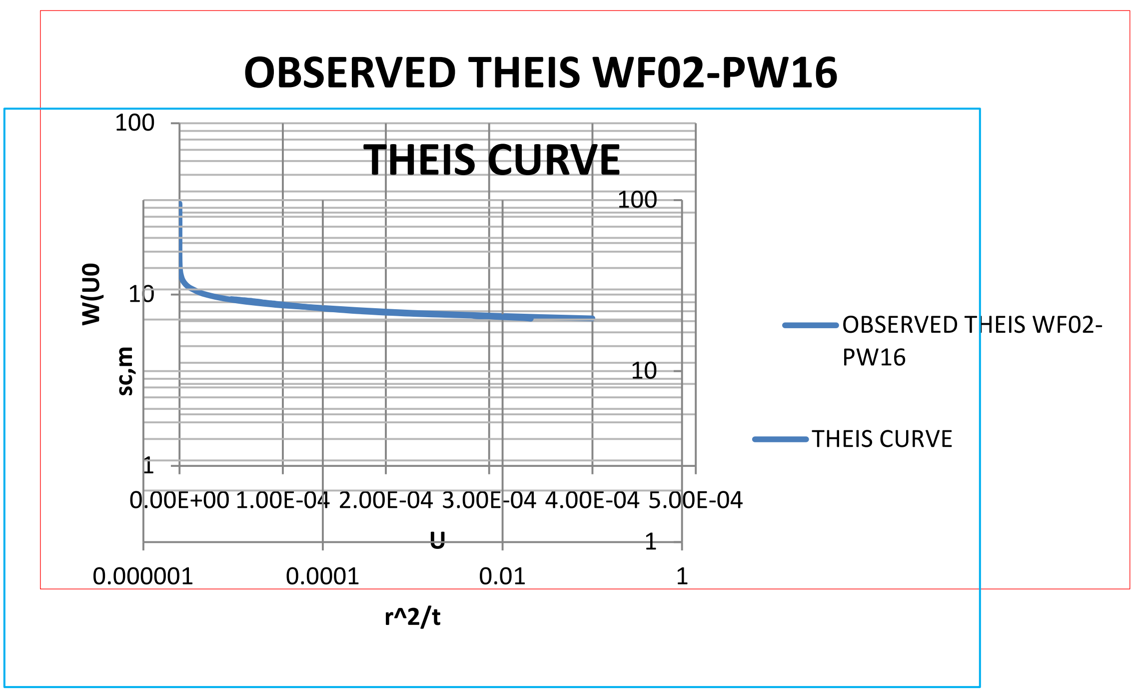

Fig 18 Graphical Representation of Observed Theis method of WF02-PW16

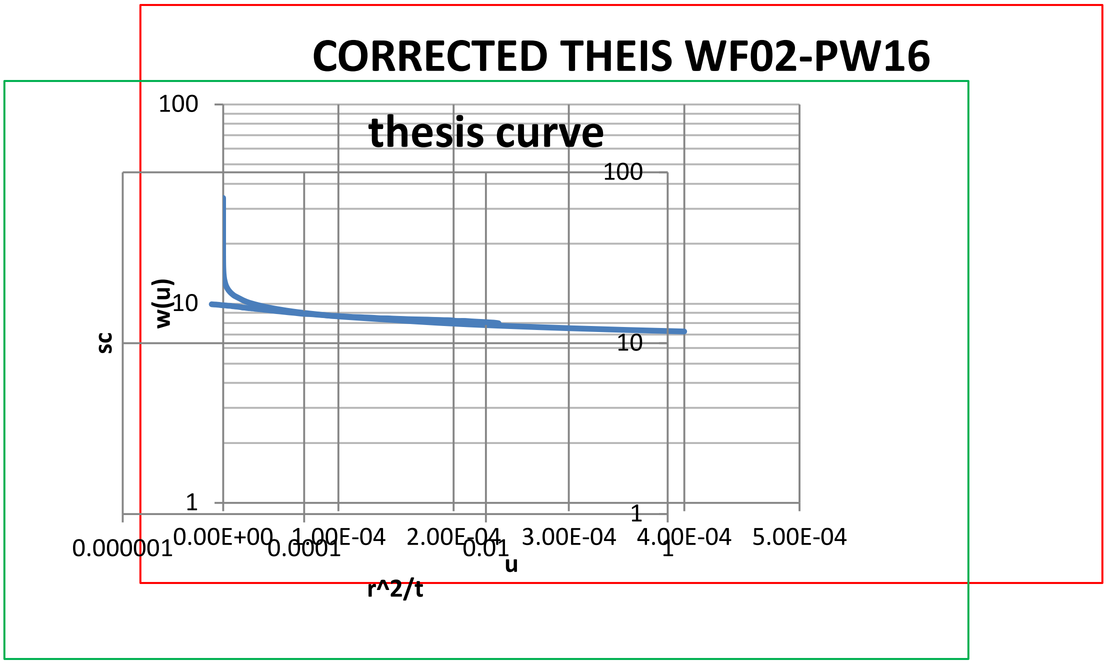

Fig 19 Graphical Representation of Corrected Theis method of WF02-PW16

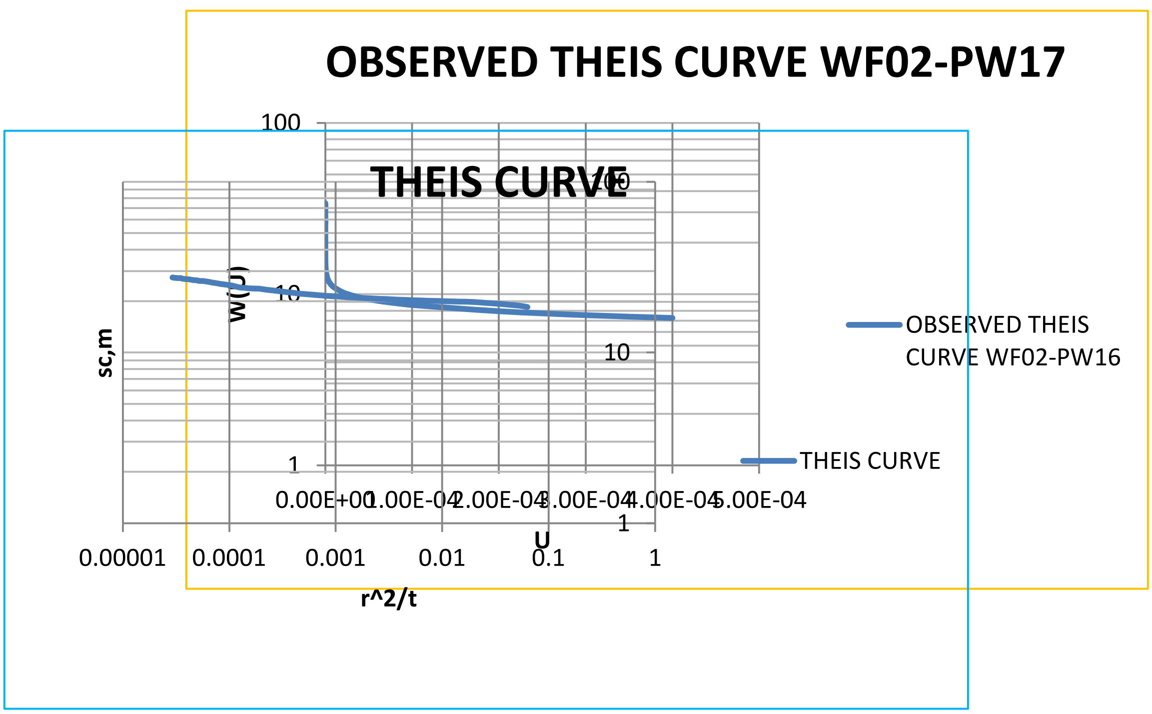

Fig 20 Graphical Representation of Observed Theis method of WF02-PW17

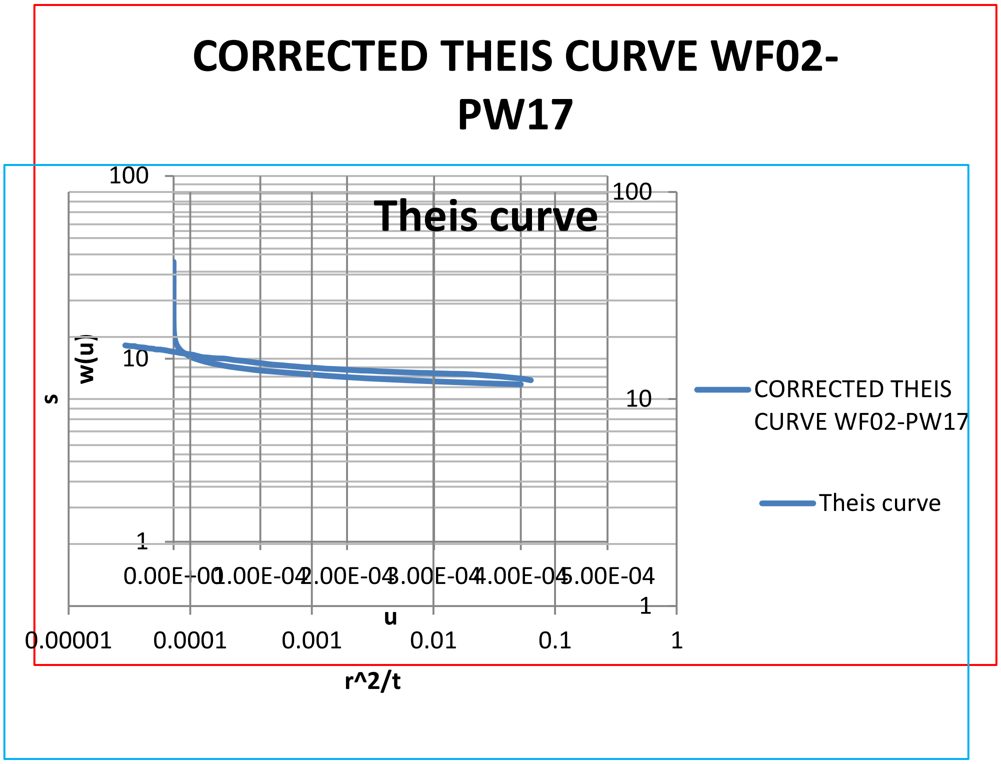

Fig 21 Graphical Representation of Corrected Theis method of WF02-PW17

Table 5.Summary of Transmissivity and Storativity Excel result for WF02-PW16 and WF02-PW17 wells on Theis method

Well name	pumping rate	Radius of well in (m)	Transmisvity(m^2/day)		Storativity	
			Observed	Corrected	Observed	Corrected
WF02-PW16	83	0.02032	534.7922	562.9392	0.12233	0.378714
WF02-PW17	81	0.3556	571.3494	560.3619	0.1883	0.123095616

The Theis method was applied for all of the two wells for Akaki phase IIIA of WF02-PW16 and WF02-PW17 wells. This method when done manually is difficult to comprehend, as it requires the over lapping of the two curves, W (u) vs u plot and s vs r2/t plot. Due to this, some values of both the transmissivity and storativity differ from the Cooper-Jacob method and the recovery method. The plots of the overlap of the type curve and drawdown curve for all of the two well is show from Fig 12 to Fig 15 are plots both the observed drawdown and the corrected drawdown.

The result of the transmissivity and Storativity values using the Theis method is tabulated in table 5 and for both the corrected drawdown and observed drawdowns of each the two well.

4.4 Aquifer Software result of Transmitvity and Storativity

The use of computer software and models in every aspects of human social life has be major part of our life since the turn of the new millennium. It seems that every mathematical problems that can be solved manually by hand can be solved in a blink of an eye with computer software. Aquifer Test is designed to automate the most common tasks that hydro geologists and other water supply professionals typically encounter when planning and analyzing the results of an aquifer test. The program design allows you to efficiently manage all information from your aquifer test and perform more analyses in less time.

4.4.1 Aquifer Software result of Transmitvity and Storativity by Cooper-Jacob method

The application of Cooper-Jacob method in the Aquifer Test software is the same with Theis in how the data is entered with the major difference here is that there is no curve matching here. Instead the software automatically fits straight line in the semi-log plot of the drawdown vs time graph and determines the transmissivity and storativity. The aquifer software result of Coober-Jacob method for WF02-PW16 well of the transmissivity and storativity value is 530m2/day and 5.00E-04 respectively and the aquifer software result of Coober-Jacob method for WF02-PW17 well of the transmissivity and storativity value is 320m2/day and 2.50E-04 respectively. From this result the value of the Excel result transmissivity of cooper-Jacob method greater than with the aquifer software result of Cooper Jacob method for both wells.

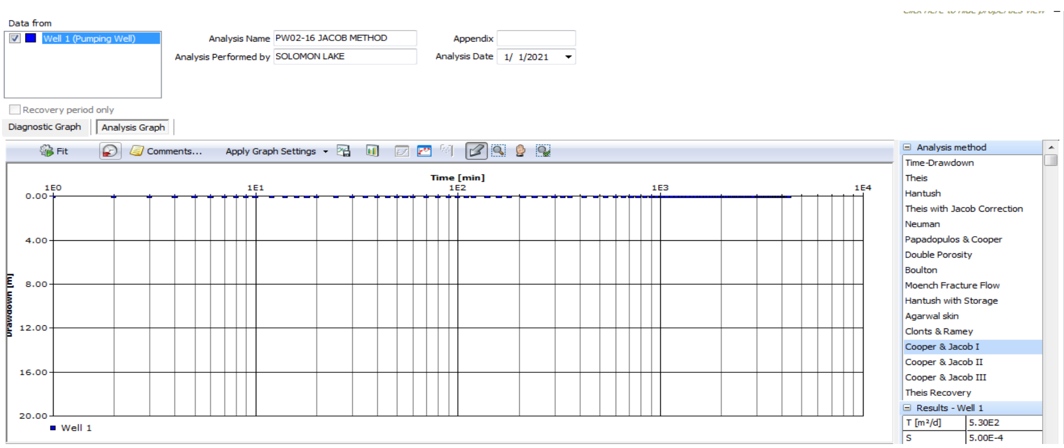

Fig 22 aquifer software result of Cooper-Jacob method of WF02-PW16

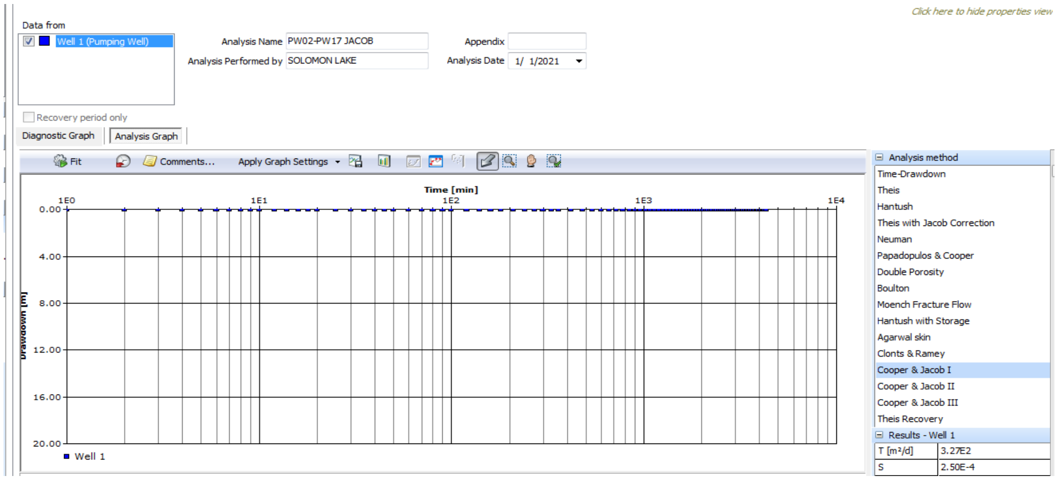

Fig 23 aquifer software result of Cooper-Jacob method of WF02-PW17

4.4.2 Aquifer Software result of Transmitvity by Recovery method

In applying the Theis Recovery method in the Aquifer Test software, the process of the data entry is the same as both the Theis method and the Cooper-Jacob method. The difference here is how the recovery period is determined in the software. This is done by imputing the time where the pumping has be stopped with the correspond discharge the pump was using and the time the drawdown has recovered to its static water level using a discharge equaling zero since there is no pumping in the wells at the time of recovery. By using the data that is entered the software use the semi-log plot residual drawdown vs time and calculates the transmissivity of the wells. The aquifer software result of Recovery method for WF02-PW16 well of the transmissivity value is 540m^2/day and The aquifer software result of Recovery method for WF02-PW17 well of the transmissivity value is 340m^2/day. From this result the value of the Excel result transmissivity of Recovery method greater than with the aquifer software result of Recovery method for both wells.

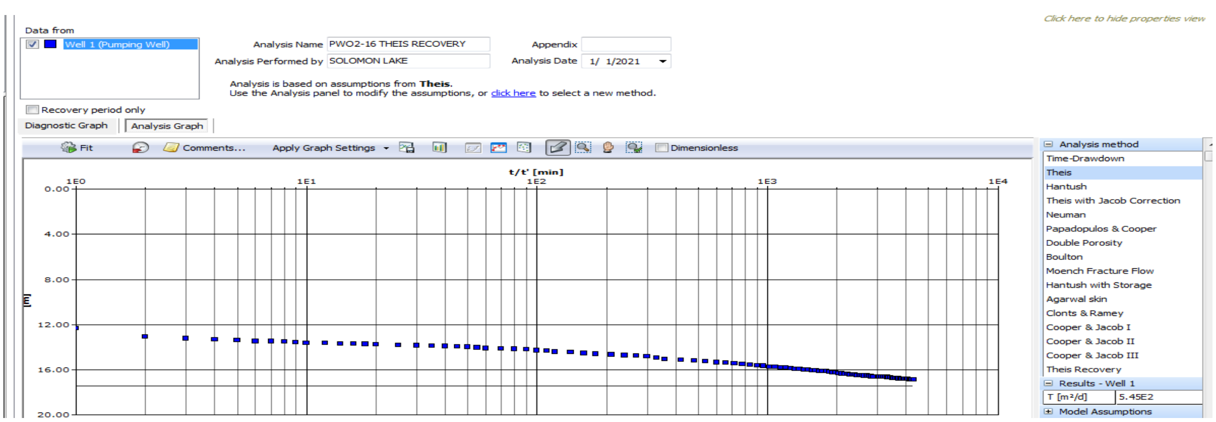

Fig 24 aquifer software result of Recovery method of WF02-PW16

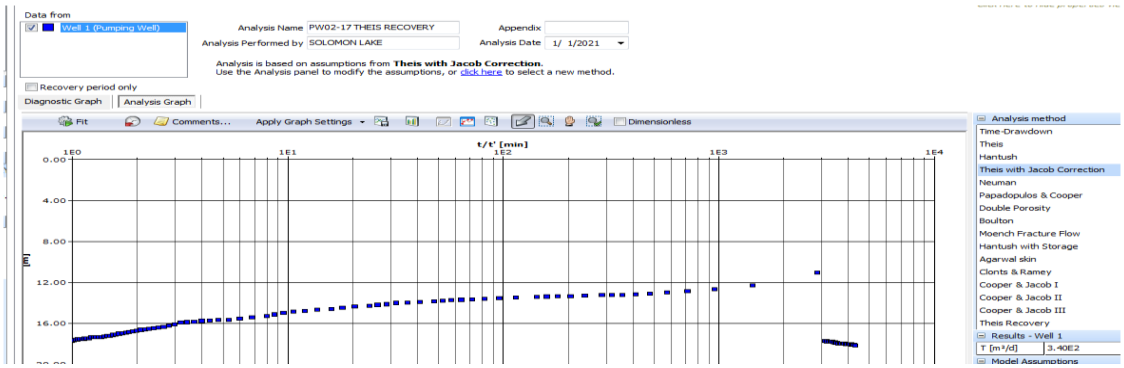

Fig 25 aquifer software result of Recovery method of WF02-PW17

4.4.3 Aquifer Software result of Transmitvity and storativity by Theis method

In this software the application of the Theis method has be simplified and with user friendly environment that allows to be more efficient in automatically fitting the type curve and the drawdown-time curve plots. This method was applied to both uncorrected drawdown and corrected drawdown. Since the data entry can be done by importing the drawdown-time data from excel and also well data such as well screen length, static water levels, well dimension including radius of well and radius of casing, well coordinate, saturated thickness, design discharge and well elevations were produced in spread sheet and saved as tab limited text format and imported to Aquifer Test, the process of determining the hydraulic parameters has been done with so much ease. In the Theis method the data of the recovery period has be omitted as the this values in the drawdown-time plot with create confusion in the software when it tries to much the drawdown- time plot and with the type curve. To avoid this problem the software is provided with a tool that allows as to define the time range of the pumping data in to two as the pumping and recovery period. This time range tool in the software can also help us in avoiding early time and late time data. The Theis method was applied to all of the two wells data that ware constructed and tested on Akaki phase IIIA Well on WF02-PW16 and WF02-PW17 project. Tool in the software can also help us in avoiding early time and late time data. The aquifer software result of Theis method for WF02-PW16 well of the transmissivity storativity value is 456m2/day and 1.00E-04 respectively and the aquifer software result of Theis method for WF02-PW17 well of the transmissivity and storativity value is 324m2/day and 3.00E-04 respectively. From this result the value of the Excel result transmissivity of Theis method greater than with the aquifer software result of Theis method for both wells.

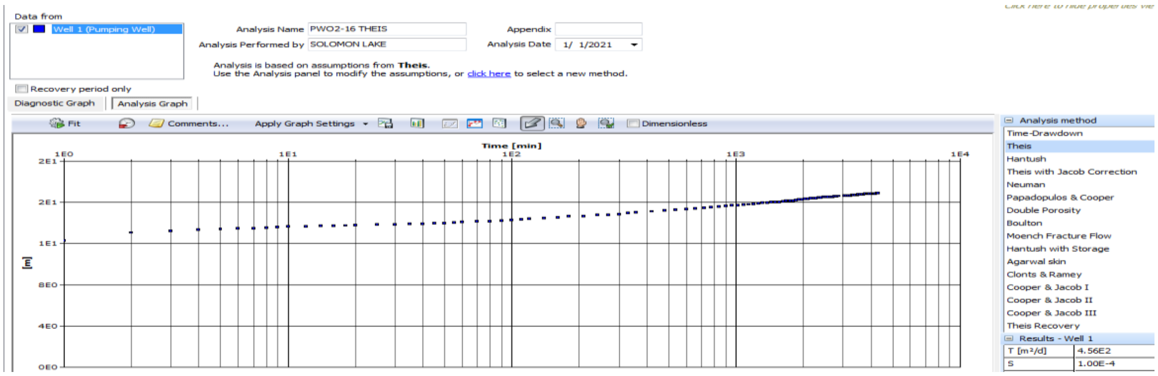

Fig 26 aquifer software result of Theis method of WF02-PW16

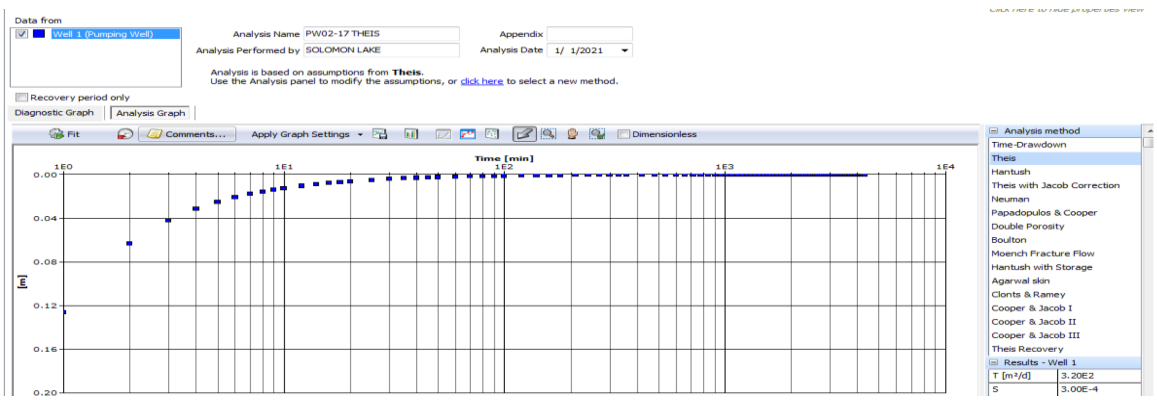

Fig 27 aquifer software result of Theis method of WF02-PW17

Table 6.Summary Aquifer software of Transmissivity and Storativity result for WF02-PW16 and WF02-PW17 wells

Well Name	Pumping Rate	Radius of Well	Coober-Jacob		Recovery	Theis	
			T(m2/day	S	T(m2/day	T(m2/day	S
WF02-PW16	83	0.02032	530	5.00E-04	540	456	1.00E-04
WF02-PW17	81	0.356	320	2.50E-04	340	324	3.00E-04

Generally the Transmissivity result that collect from WWDSE of Akaki phase IIIA in case of WF02-PW16 and WF02-PW17 520m2/day and 321m2/day for both wells respectively. So When we compare the WWDSE result with my result of each ground water scholars the WWDSE value is underestimated with respect to this project result.

5. Conclusion and Recommendations

5.1 Conclusion

Based on the outcomes of the analysis of two of the Akaki phase IIIA in case of WF02-PW16 and WF02-PW17 well the following conclusions are reached.

Single-well aquifer tests provide data in many situations in which aquifer pumping-test data from multiple wells would be a luxury for the ground-water analyst. The primary factor limiting the performance of multi-well aquifer tests is cost, particularly in areas with large depth to water (Belcher et al, 2001).

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

From data quality point of view single well pumping test does not give accurate data and realistic Storativity value during pumping test analysis. Multiple well pumping test give better quality data than single well pumping test data and result in realistic hydraulic parameters estimation for each well.

The transmissivity values obtained in this project has great variation from the study of WWDSE results. From the two wells analyzed specially in the excel result of each method wells have overestimated transmissivity but in the Aquifer software result the gap of the result become close. The overestimated Transmissivity envisions good aquifer with better yield than the capacity of the aquifer.

5.2 Recommendation

Based on the outcomes of the analysis of two of Akaki phase IIIA in case of WF02-16and WF02-PW17 well the following recommendations are cited by this project

Using a single well test system in any given well fields may be economically wise but using this single well test to set the pumping for hydraulic parameter evaluation can lead to unwanted aquifer characterization. Thus, single well tests should be conducted in properly designed and developed wells If development is inadequate, the presence of drilling mud filter or the smearing of fine-grained material along the borehole wall may indicate an artificially observation drawdown.

Determination of well efficiency should be give foremost importance when development of a well in any given well fields. As this will indicates if the well should be abandoned if it has a very low efficiency or it will specify if the well discharge should be decreased in order to prolong the wells life expectancy.

In addition to this, highly efficient wells are less costly to operate because they require less power to operate the pump. Also As most well yield are set for a given well field based on the wells that are within the same well vicinity, mostly without conducting step drawdown test, it will also remove this unscientifically way of setting well yields.

Using the raw observed drawdown data without considering well efficiency or effects of partial penetration for the determination of transmissivity and Storativity is still being applied in the hydrogeological society‘s all over Ethiopia. As this was of interpretative techniques have lead wells most wells to dry up swiftly due to the fact they are being over pumped and also due to this interpretative techniques in some cases the full potential of the well are not being used.

It has become common to use hydrogeological map with transmissivity in many Engineering fields, thus the result of the corrected drawdown transmissivity values determined by this project can be applied for future uses for contouring hydrogeological map for Akaki phase IIIA in case of WF02-PW16 and WF02-PW17 well areas.

Finally During the development of groundwater attention has to be given for the well yield and the hydraulic parameter estimations. Result interpretation and complying with the standard well pumping test approaches shall be strictly followed.

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APPENDIX

Appendix-1:-Summary of Cooper-Jacob Test Result WF02-PW16

Constant Pumping Test Data Sheet					
Employer /Client : AAWSSA		**Discharge Rate** : 83 l/s			
Well ID : WF02-PW16		**Pump Position** : 118 m			
Date of Pumping : 05 -08 /02/2014		SWL : 55.05 m Below ground level			
Time since pumping started	**WF02-PW16 Water Level**	**Observed Draw Down**	**Unconfied DD**	**Corrected DD**	**Discharge in l/s**
0	55.05	0	0	0	83
1	74.08	19.03	18.61654995	12.30553952	83
2	75.28	20.23	19.76276299	13.06318633	83
3	75.57	20.52	20.03927115	13.24595823	83
4	75.71	20.66	20.17268912	13.33414751	83
5	75.82	20.77	20.27748613	13.40341833	83
6	75.95	20.9	20.40130152	13.4852603	83
7	75.95	20.9	20.40130152	13.4852603	83
8	75.98	20.93	20.42986882	13.50414329	83
9	76.14	21.09	20.58219306	13.60482961	83
10	76.18	21.13	20.62026498	13.62999515	83
12	76.24	21.19	20.67736602	13.66773894	83
14	76.28	21.23	20.71542882	13.69289845	83
16	76.33	21.28	20.76300217	13.72434443	83
18	76.36	21.31	20.79154344	13.74321021	83

20	76.41	21.36	20.83910766	13.77465016	83
25	76.47	21.42	20.89617719	13.81237312	83
30	76.54	21.49	20.96274792	13.85637637	83
35	76.59	21.54	21.01029159	13.88780274	83
40	76.65	21.6	21.06733645	13.9255094	83
45	76.71	21.66	21.1243731	13.96321062	83
50	76.74	21.69	21.15288834	13.98205919	83
60	76.85	21.8	21.25742665	14.05115901	83
70	76.93	21.88	21.33343715	14.10140196	83
80	76.98	21.93	21.38093629	14.13279889	83
90	77.05	22	21.44742551	14.17674826	83
100	77.11	22.06	21.50440735	14.21441326	83
120	77.24	22.19	21.62783982	14.29600212	83
140	77.33	22.28	21.71327046	14.35247178	83
160	77.43	22.38	21.80817171	14.4152015	83
180	77.5	22.45	21.87458899	14.45910333	83
210	77.63	22.58	21.9979057	14.54061567	83
240	77.76	22.71	22.12118381	14.6221025	83
270	77.85	22.8	22.20650759	14.67850152	83
300	77.96	22.91	22.3107671	14.74741705	83
330	78.03	22.98	22.37709967	14.79126288	83
360	78.11	23.06	22.45289462	14.84136335	83
420	78.28	23.23	22.6139103	14.9477947	83

			8	6	
480	78.45	23.4	22.77486014	15.05418256	83
540	78.56	23.51	22.87896895	15.12299847	83
600	78.69	23.64	23.001971	15.20430283	83
660	78.81	23.76	23.11547711	15.27933037	83
720	78.92	23.87	23.21949549	15.34808652	83
780	79.01	23.96	23.30458089	15.40432797	83
840	79.14	24.09	23.42744937	15.48554403	83
900	79.21	24.16	23.49359333	15.52926519	83
960	79.31	24.26	23.5880653	15.59171117	83
1020	79.38	24.33	23.6541821	15.63541437	83
1080	79.45	24.4	23.7202877	15.67911017	83
1140	79.54	24.49	23.80526419	15.73527963	83
1200	79.61	24.56	23.87134422	15.77895853	83
1260	79.67	24.62	23.92797534	15.8163917	83
1320	79.72	24.67	23.97516166	15.84758186	83
1380	79.78	24.73	24.03177771	15.88500507	83
1440	79.88	24.83	24.12611953	15.94736501	83
1500	79.9	24.85	24.14498516	15.95983519	83
1560	79.97	24.92	24.21100765	16.00347606	83
1620	79.99	24.94	24.22986916	16.01594352	83
1680	80.05	25	24.28644822	16.05334228	83
1740	80.1	25.05	24.33359116	16.08450376	83

1800	80.17	25.12	24.39958169	16.1281235	83
1860	80.2	25.15	24.42785992	16.1468154	83
1920	80.22	25.17	24.44671093	16.15927592	83
1980	80.31	25.26	24.53152917	16.21534078	83
2040	80.38	25.33	24.59748613	16.25893833	83
2100	80.44	25.39	24.65401176	16.29630177	83
2160	80.49	25.44	24.70111017	16.32743382	83
2220	80.53	25.48	24.73878479	16.35233675	83
2280	80.56	25.51	24.76703836	16.37101236	83
2340	80.6	25.55	24.80470659	16.39591105	83
2400	80.64	25.59	24.84237116	16.42080734	83
2460	80.67	25.62	24.87061719	16.43947797	83
2520	80.71	25.66	24.90827537	16.46437002	83
2580	80.78	25.73	24.9741684	16.50792531	83
2640	80.81	25.76	25.00240484	16.5265896	83
2700	80.83	25.78	25.02122799	16.5390317	83
2760	80.84	25.79	25.03063923	16.54525253	83
2820	80.86	25.81	25.04946101	16.55769373	83
2880	80.89	25.84	25.07769197	16.57635439	83
2940	80.94	25.89	25.12473901	16.60745249	83
3000	80.96	25.91	25.14355623	16.61989067	83
3060	81	25.95	25.18118792	16.64476522	83
3120	81.01	25.96	25.1905952	16.6509834	83

			7	8	
3180	81.02	25.97	25.2000024	16.65720158	83
3240	81.03	25.98	25.20940929	16.66341954	83
3300	81.06	26.01	25.23762861	16.68207251	83
3360	81.08	26.03	25.25644035	16.69450707	83
3420	81.11	26.06	25.28465624	16.71315777	83
3480	81.15	26.1	25.32227423	16.73802327	83
3540	81.18	26.13	25.35048533	16.7566708	83
3600	81.2	26.15	25.36929159	16.76910174	83
3660	81.22	26.17	25.38809693	16.78153207	83
3720	81.24	26.19	25.40690136	16.7939618	83
3780	81.27	26.22	25.43510629	16.81260526	83
3840	81.28	26.23	25.44450748	16.81881944	83
3900	81.29	26.24	25.45390844	16.82503348	83
3960	81.3	26.25	25.46330917	16.83124736	83
4020	81.31	26.26	25.47270967	16.83746109	83
4080	81.33	26.28	25.49150999	16.8498881	83
4140	81.35	26.3	25.5103094	16.86231451	83
4200	81.36	26.31	25.51970876	16.86852749	83
4260	81.39	26.34	25.54790547	16.88716551	83
4320	81.41	26.36	25.56670213	16.89959011	83

Appendix-2:-Summery of Recovery Test Result WF02-PW16

Recovery Test Data Sheet

Employer /Client : AAWSSA					
Well ID : WF02-PW16					
Recovery start Date : 08/2/14					
Time since pumping Stopped	WF02-PW16 Water Level	**Observed Draw Down**	**Unconfied DD**	**Corrected DD**	**t/t'**
0	81.41	0	0	0	0
1	60.83	19.03	18.61654995	12.30553952	2880
2	60.53	20.23	19.76276299	13.06318633	1440
3	60.53	20.52	20.03927115	13.24595823	960
4	60.53	20.66	20.17268912	13.33414751	720
5	60.52	20.77	20.27748613	13.40341833	576
6	60.51	20.9	20.40130152	13.4852603	480
7	60.51	20.9	20.40130152	13.4852603	411.4285714
8	60.51	20.93	20.42986882	13.50414329	360
9	60.5	21.09	20.58219306	13.60482961	320
10	60.49	21.13	20.62026498	13.62999515	288
12	60.46	21.19	20.67736602	13.66773894	240
14	60.42	21.23	20.71542882	13.69289845	205.7142857
16	60.4	21.28	20.76300217	13.72434443	180
18	60.37	21.31	20.79154344	13.74321021	160
20	60.55	21.36	20.83910766	13.77465016	144
25	60.31	21.42	20.89617719	13.81237312	115.2
30	60.28	21.49	20.96274792	13.85637637	96
35	60.25	21.54	21.01029159	13.88780274	82.28571429
40	60.21	21.6	21.06733645	13.9255094	72
45	60.18	21.66	21.1243731	13.96321062	64
50	60.14	21.69	21.15288834	13.98205919	57.6
55	60.11	21.8	21.25742665	14.05115901	52.36363636
60	60.08	21.88	21.33343715	14.10140196	48
70	60.04	21.93	21.38093629	14.13279889	41.14285714
80	59.98	22	21.44742551	14.17674826	36
90	59.91	22.06	21.50440735	14.21441326	32
100	59.85	22.19	21.62783982	14.29600212	28.8
110	59.8	22.28	21.71327046	14.35247178	26.18181818
120	59.76	22.38	21.80817171	14.4152015	24

140	59.69	22.45	21.87458899	14.45910333	20.57142857
160	59.57	22.58	21.9979057	14.54061567	18
180	59.48	22.71	22.12118381	14.6221025	16
210	59.34	22.8	22.20650759	14.67850152	13.71428571
240	59.25	22.91	22.3107671	14.74741705	12
270	59.13	22.98	22.37709967	14.79126288	10.66666667
300	59.04	23.06	22.45289462	14.84136335	9.6
330	58.94	23.23	22.61391038	14.94779476	8.727272727
360	58.85	23.4	22.77486014	15.05418256	8
420	58.72	23.51	22.87896895	15.12299847	6.857142857
480	58.62	23.64	23.001971	15.20430283	6
540	58.5	23.76	23.11547711	15.27933037	5.333333333
600	58.38	23.87	23.21949549	15.34808652	4.8
660	58.27	23.96	23.30458089	15.40432797	4.363636364
720	58.14	24.09	23.42744937	15.48554403	4
780	58.05	24.16	23.49359333	15.52926519	3.692307692
840	57.95	24.26	23.5880653	15.59171117	3.428571429
900	57.84	24.33	23.6541821	15.63541437	3.2
960	57.75	24.4	23.7202877	15.67911017	3
1020	57.66	24.49	23.80526419	15.73527963	2.823529412
1080	57.56	24.56	23.87134422	15.77895853	2.666666667
1140	57.51	24.62	23.92797534	15.8163917	2.526315789
1200	57.56	24.67	23.97516166	15.84758186	2.4
1260	57.4	24.73	24.03177771	15.88500507	2.285714286
1320	57.32	24.83	24.12611953	15.94736501	2.181818182
1380	57.27	24.85	24.14498516	15.95983519	2.086956522
1440	57.22	24.92	24.21100765	16.00347606	2
1500	57.2	24.94	24.22986916	16.01594352	1.92
1560	57.17	25	24.28644822	16.05334228	1.846153846
1620	57.15	25.05	24.33359116	16.08450376	1.777777778
1680	57.09	25.12	24.39958169	16.1281235	1.714285714
1740	57.02	25.15	24.42785992	16.1468154	1.655172414
1800	56.96	25.17	24.44671093	16.15927592	1.6
1860	56.94	25.26	24.53152917	16.21534078	1.548387097
1920	56.92	25.33	24.59748613	16.25893833	1.5
1980	56.9	25.39	24.65401176	16.29630177	1.454545455
2040	56.86	25.44	24.70111017	16.32743382	1.411764706
2100	56.82	25.48	24.73878479	16.35233675	1.371428571

2160	56.78	25.51	24.76703836	16.37101236	1.333333333
2220	56.75	25.55	24.80470659	16.39591105	1.297297297
2280	56.69	25.59	24.84237116	16.42080734	1.263157895
2340	56.63	25.62	24.87061719	16.43947797	1.230769231
2400	56.58	25.66	24.90827537	16.46437002	1.2
2460	56.54	25.73	24.9741684	16.50792531	1.170731707
2520	56.5	25.76	25.00240484	16.5265896	1.142857143
2580	56.46	25.78	25.02122799	16.5390317	1.11627907
2640	56.42	25.79	25.03063923	16.54525253	1.090909091
2700	56.38	25.81	25.04946101	16.55769373	1.066666667
2760	56.34	25.84	25.07769197	16.57635439	1.043478261
2820	56.3	25.89	25.12473901	16.60745249	1.021276596
2880	56.3	25.91	25.14355623	16.61989067	1
2940	80.94	25.95	25.18118792	16.64476522	
3000	80.96	25.96	25.19059527	16.65098348	
3060	81	25.97	25.2000024	16.65720158	
3120	81.01	25.98	25.20940929	16.66341954	
3180	81.02	26.01	25.23762861	16.68207251	
3240	81.03	26.03	25.25644035	16.69450707	
3300	81.06	26.06	25.28465624	16.71315777	
3360	81.08	26.1	25.32227423	16.73802327	
3420	81.11	26.13	25.35048533	16.7566708	
3480	81.15	26.15	25.36929159	16.76910174	
3540	81.18	26.17	25.38809693	16.78153207	
3600	81.2	26.19	25.40690136	16.7939618	
3660	81.22	26.22	25.43510629	16.81260526	
3720	81.24	26.23	25.44450748	16.81881944	
3780	81.27	26.24	25.45390844	16.82503348	
3840	81.28	26.25	25.46330917	16.83124736	
3900	81.29	26.26	25.47270967	16.83746109	
3960	81.3	26.28	25.49150999	16.8498881	
4020	81.31	26.3	25.5103094	16.86231451	
4080	81.33	26.31	25.51970876	16.86852749	
4140	81.35	26.34	25.54790547	16.88716551	
4200	81.36	26.36	25.56670213	16.89959011	

Appendix-3:-Summery of Theis Test Result WF02-PW16

Constant Pumping Test Data Sheet

Employer /Client : AAWSSA		**Discharge Rate** : 83 l/s					
Well ID : WF02-PW16		**Pump Position** : 118 m					
Date of Pumping : 05 -08 /02/2014		SWL : 55.05 m Below ground level					
Time since pumping started	**WF02-PW16 Water Level**	**Observed Draw Down**	**Unconfined DD**	**Corrected DD**	**r^2/t**	**U**	**W(u)**
0	55.05	0	0	0	0	1.00E-15	33.96
1	74.08	19.03	18.6165499	12.30553952	0.04129024	2.00E-15	32.27
2	75.28	20.23	19.762763	13.06318633	0.02064512	3.00E-15	32.86
3	75.57	20.52	20.0392711	13.24595823	0.013763413	4.00E-15	32.58
4	75.71	20.66	20.1726891	13.33414751	0.01032256	5.00E-15	32.35
5	75.82	20.77	20.2774861	13.40341833	0.008258048	6.00E-15	32.17
6	75.95	20.9	20.4013015	13.4852603	0.006881707	7.00E-15	32.02
7	75.95	20.9	20.4013015	13.4852603	0.005898606	8.00E-15	31.88
8	75.98	20.93	20.4298688	13.50414329	0.00516128	9.00E-15	31.76
9	76.14	21.09	20.5821931	13.60482961	0.004587804	1.00E-14	31.66
10	76.18	21.13	20.620265	13.62999515	0.004129024	2.00E-14	30.97
12	76.24	21.19	20.677366	13.66773894	0.003440853	3.00E-14	30.56
14	76.28	21.23	20.7154288	13.69289845	0.002949303	4.00E-14	30.27
16	76.33	21.28	20.7630022	13.72434443	0.00258064	5.00E-14	30.05
18	76.36	21.31	20.7915434	13.74321021	0.002293902	6.00E-14	29.87
20	76.41	21.36	20.8391077	13.77465016	0.002064512	7.00E-14	29.71
25	76.47	21.42	20.8961772	13.81237312	0.00165161	8.00E-14	29.58
30	76.54	21.49	20.96274	13.856376	0.0013763	9.00E-	29.46

			79	37	41	14	
35	76.59	21.54	21.0102916	13.88780274	0.001179721	1.00E-13	29.36
40	76.65	21.6	21.0673365	13.9255094	0.001032256	2.00E-13	28.66
45	76.71	21.66	21.1243731	13.96321062	0.000917561	3.00E-13	28.26
50	76.74	21.69	21.1528883	13.98205919	0.000825805	4.00E-13	27.97
60	76.85	21.8	21.2574266	14.05115901	0.000688171	5.00E-13	27.75
70	76.93	21.88	21.3334372	14.10140196	0.000589861	6.00E-13	27.56
80	76.98	21.93	21.3809363	14.13279889	0.000516128	7.00E-13	27.41
90	77.05	22	21.4474255	14.17674826	0.00045878	8.00E-13	27.28
100	77.11	22.06	21.5044074	14.21441326	0.000412902	9.00E-13	27.16
120	77.24	22.19	21.6278398	14.29600212	0.000344085	1.00E-12	27.05
140	77.33	22.28	21.7132705	14.35247178	0.00029493	2.00E-12	26.36
160	77.43	22.38	21.8081717	14.4152015	0.000258064	3.00E-12	25.96
180	77.5	22.45	21.874589	14.45910333	0.00022939	4.00E-12	26.67
210	77.63	22.58	21.9979057	14.54061567	0.00019662	5.00E-12	25.44
240	77.76	22.71	22.1211838	14.6221025	0.000172043	6.00E-12	25.26
270	77.85	22.8	22.2065076	14.67850152	0.000152927	7.00E-12	25.11
300	77.96	22.91	22.3107671	14.74741705	0.000137634	8.00E-12	24.97
330	78.03	22.98	22.3770997	14.79126288	0.000125122	9.00E-12	24.86
360	78.11	23.06	22.4528946	14.84136335	0.000114695	1.00E-11	24.75
420	78.28	23.23	22.6139104	14.94779476	9.83101E-05	2.00E-11	24.06
480	78.45	23.4	22.7748601	15.05418256	8.60213E-05	3.00E-11	23.65
540	78.56	23.51	22.8789689	15.12299847	7.64634E-05	4.00E-11	23.36

600	78.69	23.64	23.001971	15.20430283	6.88171E-05	5.00E-11	23.14
660	78.81	23.76	23.1154771	15.27933037	6.2561E-05	6.00E-11	22.96
720	78.92	23.87	23.2194955	15.34808652	5.73476E-05	7.00E-11	22.81
780	79.01	23.96	23.3045809	15.40432797	5.29362E-05	8.00E-11	22.67
840	79.14	24.09	23.4274494	15.48554403	4.9155E-05	9.00E-11	22.55
900	79.21	24.16	23.4935933	15.52926519	4.5878E-05	1.00E-10	22.45
960	79.31	24.26	23.5880653	15.59171117	4.30107E-05	2.00E-10	21.76
1020	79.38	24.33	23.6541821	15.63541437	4.04806E-05	3.00E-10	21.35
1080	79.45	24.4	23.7202877	15.67911017	3.82317E-05	4.00E-10	21.06
1140	79.54	24.49	23.8052642	15.73527963	3.62195E-05	5.00E-10	20.84
1200	79.61	24.56	23.8713442	15.77895853	3.44085E-05	6.00E-10	20.66
1260	79.67	24.62	23.9279753	15.8163917	3.277E-05	7.00E-10	20.5
1320	79.72	24.67	23.9751617	15.84758186	3.12805E-05	8.00E-10	20.37
1380	79.78	24.73	24.0317777	15.88500507	2.99205E-05	9.00E-10	20.25
1440	79.88	24.83	24.1261195	15.94736501	2.86738E-05	1.00E-09	20.15
1500	79.9	24.85	24.1449852	15.95983519	2.75268E-05	2.00E-09	19.45
1560	79.97	24.92	24.2110076	16.00347606	2.64681E-05	3.00E-09	19.05
1620	79.99	24.94	24.2298692	16.01594352	2.54878E-05	4.00E-09	18.76
1680	80.05	25	24.2864482	16.05334228	2.45775E-05	5.00E-09	18.54
1740	80.1	25.05	24.3335912	16.08450376	2.373E-05	6.00E-09	18.35
1800	80.17	25.12	24.3995817	16.1281235	2.2939E-05	7.00E-09	18.2
1860	80.2	25.15	24.4278599	16.1468154	2.21991E-05	8.00E-09	18.07
1920	80.22	25.17	24.44671	16.159275	2.15053E-	9.00E-	17.95

			09	92	05	09	
1980	80.31	25.26	24.5315292	16.21534078	2.08537E-05	1.00E-08	17.48
2040	80.38	25.33	24.5974861	16.25893833	2.02403E-05	2.00E-08	17.15
2100	80.44	25.39	24.6540118	16.29630177	1.9662E-05	3.00E-08	16.74
2160	80.49	25.44	24.7011102	16.32743382	1.91159E-05	4.00E-08	16.46
2220	80.53	25.48	24.7387848	16.35233675	1.85992E-05	5.00E-08	16.23
2280	80.56	25.51	24.7670384	16.37101236	1.81098E-05	6.00E-08	16.05
2340	80.6	25.55	24.8047066	16.39591105	1.76454E-05	7.00E-08	15.9
2400	80.64	25.59	24.8423712	16.42080734	1.72043E-05	8.00E-08	15.76
2460	80.67	25.62	24.8706172	16.43947797	1.67847E-05	9.00E-08	15.65
2520	80.71	25.66	24.9082754	16.46437002	1.6385E-05	1.00E-07	15.54
2580	80.78	25.73	24.9741684	16.50792531	1.6004E-05	2.00E-07	14.85
2640	80.81	25.76	25.0024048	16.5265896	1.56402E-05	3.00E-07	14.44
2700	80.83	25.78	25.021228	16.5390317	1.52927E-05	4.00E-07	14.15
2760	80.84	25.79	25.0306392	16.54525253	1.49602E-05	5.00E-07	13.93
2820	80.86	25.81	25.049461	16.55769373	1.46419E-05	6.00E-07	13.75
2880	80.89	25.84	25.077692	16.57635439	1.43369E-05	7.00E-07	13.6
2940	80.94	25.89	25.124739	16.60745249	1.40443E-05	8.00E-07	13.46
3000	80.96	25.91	25.1435562	16.61989067	1.37634E-05	9.00E-07	13.34
3060	81	25.95	25.1811879	16.64476522	1.34935E-05	1.00E-06	13.24
3120	81.01	25.96	25.1905953	16.65098348	1.32341E-05	2.00E-06	12.55
3180	81.02	25.97	25.2000024	16.65720158	1.29844E-05	3.00E-06	12.14
3240	81.03	25.98	25.2094093	16.66341954	1.27439E-05	4.00E-06	11.85

3300	81.06	26.01	25.2376286	16.68207251	1.25122E-05	5.00E-06	11.63
3360	81.08	26.03	25.2564403	16.69450707	1.22888E-05	6.00E-06	11.45
3420	81.11	26.06	25.2846562	16.71315777	1.20732E-05	7.00E-06	11.29
3480	81.15	26.1	25.3222742	16.73802327	1.1865E-05	8.00E-06	11.16
3540	81.18	26.13	25.3504853	16.7566708	1.16639E-05	9.00E-06	11.04
3600	81.2	26.15	25.3692916	16.76910174	1.14695E-05	1.00E-05	10.94
3660	81.22	26.17	25.3880969	16.78153207	1.12815E-05	2.00E-05	10.24
3720	81.24	26.19	25.4069014	16.7939618	1.10995E-05	3.00E-05	9.84
3780	81.27	26.22	25.4351063	16.81260526	1.09233E-05	4.00E-05	9.55
3840	81.28	26.23	25.4445075	16.81881944	1.07527E-05	5.00E-05	9.33
3900	81.29	26.24	25.4539084	16.82503348	1.05872E-05	6.00E-05	9.14
3960	81.3	26.25	25.4633092	16.83124736	1.04268E-05	7.00E-05	8.99
4020	81.31	26.26	25.4727097	16.83746109	1.02712E-05	8.00E-05	8.86
4080	81.33	26.28	25.49151	16.8498881	1.01202E-05	9.00E-05	8.74
4140	81.35	26.3	25.5103094	16.86231451	9.97349E-06	1.00E-04	8.63
4200	81.36	26.31	25.5197088	16.86852749	9.83101E-06	2.00E-04	7.94
4260	81.39	26.34	25.5479055	16.88716551	9.69254E-06	3.00E-04	7.53
4320	81.41	26.36	25.5667021	16.89959011	9.55793E-06	4.00E-04	7.25
						5.00E-04	7.02
						6.00E-04	6.84
						7.00E-04	6.69

Appendix-4:-Summery of Partial Penetration Correction of WF02-PW16

Depth interval in (m)		Type of cas	Length (m)		Diameter of casing								
From	To		Blind	Screen		r	2l/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F	Artmetic Mean
490	484.2	Blind	5.8		8"								
484.2	466.86	Screen		17.34	8"	0.2032	170.669	0.60167	4.10238	0.07655	1.31402	0.7906	
466.86	455.38	Blind	11.48		8"	0.2032							
455.38	437.98	Screen		17.4	8"	0.2032	171.26	0.50245	4.93261	0.07641	1.37692	0.69184	
437.98	420.75	Blind	17.23		8"	0.2032							
420.75	409.21	Screen		11.54	8"	0.2032	113.583	0.40014	5.66353	0.09383	1.53141	0.61278	
409.21	391.91	Blind	17.3		8"	0.2032							
391.91	380.41	Screen		11.5	8"	0.2032	113.189	0.4	5.66443	0.09399	1.53242	0.61297	0.731
380.41	363.16	Blind	17.25		8"	0.2032							
363.16	351.61	Screen		11.55	8"	0.2032	113.681	0.40014	5.66353	0.09379	1.53118	0.61269	
351.61	334.42	Blind	17.19		8"	0.2032							
334.42	322.92	Screen		11.5	8"	0.2032	113.189	0.66667	3.50322	0.09399	1.32928	0.88619	
322.92	317.17	Blind	5.75		8"	0.2032							
317.17	311.41	Screen		5.76	8"	0.2032	56.6929	0.25087	6.46402	0.13281	1.8585	0.46624	
311.41	294.21	Blind	17.2		8"	0.2032							
294.21	276.98	Screen		17.23	8"	0.2032	169.587	0.74946	2.68816	0.07679	1.20642	0.90416	
276.98	271.22	Blind	5.76		8"	0.2032							
271.22	254.03	Screen		17.19	8"	0.2032	169.193	0.7803	2.37219	0.07688	1.18237	0.9226	
254.03	248.28	Blind	5.75		8"	0.2032							
248.28	231.09	Screen		17.19	8"	0.2032	169.193	0.62741	3.86985	0.07688	1.29751	0.81407	
231.09	225.67	Blind	5.42		8"	0.2032							
225.67	219.75	Blind	5.92		14"	0.2032							
219.75	196.11	Screen		23.64	14"	0.2032	232.677	0.67083	3.46354	0.06556	1.22706	0.82315	
196.11	184.51	Blind	11.6		14"	0.2032							
184.51	166.96	Screen		17.55	14"	0.2032	172.736	0.60226	4.09705	0.07609	1.31173	0.79001	0.666
166.96	155.37	Blind	11.59		14"	0.2032							
155.37	137.83	Screen		17.54	14"	0.2032	172.638	0.74989	2.68373	0.07611	1.20425	0.90306	
137.83	131.98	Blind	5.85		14"	0.2032							
131.98	120.26	Screen		11.72	14"	0.2032	115.354	0.0888	6.93208	0.09311	1.64543	0.14612	
120.26	1	Blind	121.26		14"	0.2032						**F Artmetic**	
Total Blind casing length			282.35									**F Geomtric**	**0.661**
Total Screen casing Length				208.65									
Total length Blind Screen Casing			491										

Appendix-5:- Summary of Cooper-Jacob Test Result WF02-PW17

Employer /Client : AAWSSA	**Discharge Rate** : 81 l/s
Well ID : WF02-PW17	**Pump Position** : 125 m
Date of Pumping : 24 -27 /01/2014	SWL :61.62 m Below ground level

Time since pumping started	WF02-PW17 Water Level	Observed Draw Down	Unconfied DD	Corrected DD	Discharge in l/s
0	61.62	0	0	0	
1	78.12	16.5	16.17463789	11.06345232	81
2	80.07	18.45	18.0431898	12.34154183	81
3	80.67	19.05	18.61630037	12.73354946	81
4	80.97	19.35	18.90253298	12.92933256	81
5	81.15	19.53	19.0741693	13.0467318	81
6	81.32	19.7	19.23619915	13.15756022	81
7	81.42	19.8	19.33147856	13.22273134	81
8	81.46	19.84	19.36958363	13.2487952	81
9	81.48	19.86	19.38863473	13.26182616	81
10	81.53	19.91	19.43625831	13.29440068	81
12	81.58	19.96	19.4838759	13.32697112	81
14	81.66	20.04	19.56005163	13.37907531	81
16	81.68	20.06	19.57909317	13.39209973	81
18	81.73	20.11	19.62669284	13.4246579	81
20	81.78	20.16	19.67428653	13.45721199	81
25	81.88	20.26	19.769456	13.5223079	81
30	81.97	20.35	19.85508808	13.58088025	81
35	82.04	20.42	19.92167742	13.62642736	81
40	82.14	20.52	20.01678474	13.69148076	81

45	82.21	20.59	20.08334564	13.73700842	81
50	82.23	20.61	20.10236089	13.75001485	81
60	82.37	20.75	20.23544087	13.84104155	81
70	82.46	20.84	20.32096754	13.8995418	81
80	82.57	20.95	20.42547385	13.97102411	81
90	82.63	21.01	20.4824651	14.01000613	81
100	82.7	21.08	20.54894402	14.05547771	81
120	82.89	21.27	20.72932776	14.17886019	81
140	82.99	21.37	20.82423192	14.24377463	81
160	83.13	21.51	20.95705758	14.33462738	81
180	83.25	21.63	21.07087086	14.41247567	81
210	83.43	21.81	21.24152624	14.52920395	81
240	83.58	21.96	21.38367991	14.62643706	81
270	83.69	22.07	21.48789175	14.69771796	81
300	83.87	22.25	21.65835783	14.81431676	81
330	84.04	22.42	21.81928247	14.92438921	81
360	84.15	22.53	21.92337337	14.99558738	81
420	84.44	22.82	22.1976562	15.18319684	81
480	84.67	23.05	22.41504792	15.33189278	81
540	84.84	23.22	22.5756475	15.44174289	81
600	85.05	23.43	22.77393984	15.57737485	81
660	85.25	23.63	22.96269169	15.70648112	81
720	85.28	23.66	22.990996	15.725841	81

			22	42	
780	85.34	23.72	23.047598 83	15.764557 6	81
840	85.4	23.78	23.104192 84	15.803267 9	81
900	85.52	23.9	23.217355 04	15.880670 84	81
960	85.58	23.96	23.273923 23	15.919363 49	81
1020	85.68	24.06	23.368184 43	15.983838 15	81
1080	85.9	24.28	23.575474 93	16.125624 85	81
1140	86.1	24.48	23.763820 45	16.254453 19	81
1200	86.3	24.68	23.952070 37	16.383216 13	81
1260	86.38	24.76	24.027343 56	16.434703	81
1320	86.52	24.9	24.159034 85	16.524779 84	81
1380	86.61	24.99	24.243668 79	16.582669 46	81
1440	86.7	25.08	24.328283 38	16.640545 83	81
1500	86.77	25.15	24.394081 34	16.685551 63	81
1560	86.88	25.26	24.497454 47	16.756258 86	81
1620	86.99	25.37	24.600798 68	16.826946 29	81
1680	87.09	25.47	24.694722 86	16.891190 44	81
1740	87.18	25.56	24.779234 19	16.948996 19	81
1800	87.25	25.63	24.844951 84	16.993947 06	81
1860	87.34	25.72	24.929428 75	17.051729 26	81
1920	87.45	25.83	25.032652 01	17.122333 98	81
1980	87.54	25.92	25.117085 9	17.180086 76	81
2040	87.63	26.01	25.201500 43	17.237826 29	81

2100	87.7	26.08	25.26714279	17.28272567	81
2160	87.75	26.13	25.31402302	17.31479174	81
2220	87.83	26.21	25.38901895	17.36608896	81
2280	87.83	26.21	25.38901895	17.36608896	81
2340	87.85	26.23	25.40776555	17.37891163	81
2400	87.86	26.24	25.41713849	17.38532272	81
2460	87.89	26.27	25.44525587	17.40455501	81
2520	88.05	26.43	25.5951789	17.50710237	81
2580	88.08	26.46	25.62328266	17.52632534	81
2640	88.12	26.5	25.66075099	17.55195368	81
2700	88.14	26.52	25.67948372	17.56476687	81
2760	88.18	26.56	25.71694632	17.59039128	81
2820	88.23	26.61	25.76376918	17.62241812	81
2880	88.29	26.67	25.81994873	17.66084493	81
2940	88.37	26.75	25.89484141	17.71207153	81
3000	88.42	26.8	25.94164157	17.74408283	81
3060	88.45	26.83	25.9697188	17.76328766	81
3120	88.48	26.86	25.99779387	17.78249101	81
3180	88.5	26.88	26.01650939	17.79529243	81
3240	88.53	26.91	26.04458088	17.81449332	81
3300	88.55	26.93	26.06329402	17.82729311	81
3360	88.59	26.97	26.10071741	17.85289071	81
3420	88.63	27.01	26.138136	17.878485	81

			98	69	
3480	88.68	27.06	26.18490607	17.91047575	81
3540	88.75	27.13	26.25037275	17.95525496	81
3600	88.88	27.26	26.37192265	18.0383951	81
3660	88.89	27.27	26.38127097	18.04478935	81
3720	88.88	27.26	26.37192265	18.0383951	81
3780	88.88	27.26	26.37192265	18.0383951	81
3840	88.89	27.27	26.38127097	18.04478935	81
3900	88.9	27.28	26.39061905	18.05118343	81
3960	88.93	27.31	26.41866186	18.07036471	81
4020	88.94	27.32	26.42800899	18.07675815	81
4080	88.98	27.36	26.4653951	18.10233025	81
4140	89	27.38	26.48408672	18.11511531	81
4200	89.04	27.42	26.52146709	18.14068349	81
4260	89.08	27.46	26.55884363	18.16624905	81
4320	89.11	27.49	26.58687354	18.1854215	81

Appendix-6:- Summary of Recovery Test Result WF02-PW17

Recovery Test Data Sheet						
Employer /Client : AAWSSA						**Pump Position** :
Well ID : WF02-PW17						**Discharge Rate** :
Time since pumping Stopped	WF02-PW17 Water Level	**Observed Draw Down**	**Unconfied DD**	**Corrected DD**	**t/t'**	Residual Dr Down
0	89.11	0	0	0	0	27.49

1	66.42	16.5	16.17463789	11.06345232	2880	4.8
2	66.41	18.45	18.0431898	12.34154183	1440	4.79
3	66.41	19.05	18.61630037	12.73354946	960	4.79
4	66.41	19.35	18.90253298	12.92933256	720	4.79
5	66.4	19.53	19.0741693	13.0467318	576	4.78
6	66.4	19.7	19.23619915	13.15756022	480	4.78
7	66.39	19.8	19.33147856	13.22273134	411.4285714	4.77
8	66.38	19.84	19.36958363	13.2487952	360	4.76
9	66.37	19.86	19.38863473	13.26182616	320	4.75
10	66.35	19.91	19.43625831	13.29440068	288	4.73
12	66.33	19.96	19.4838759	13.32697112	240	4.71
14	66.32	20.04	19.56005163	13.37907531	205.7142857	4.7
16	66.3	20.06	19.57909317	13.39209973	180	4.68
18	66.3	20.11	19.62669284	13.4246579	160	4.68
20	66.3	20.16	19.67428653	13.45721199	144	4.68
25	66.28	20.26	19.769456	13.5223079	115.2	4.66
30	66.25	20.35	19.85508808	13.58088025	96	4.63
35	66.23	20.42	19.92167742	13.62642736	82.28571429	4.61
40	66.18	20.52	20.01678474	13.69148076	72	4.56
45	66.15	20.59	20.08334564	13.73700842	64	4.53
50	66.13	20.61	20.10236089	13.75001485	57.6	4.51
55	66.1	20.75	20.23544087	13.84104155	52.36363636	4.48
60	66.08	20.84	20.32096754	13.8995418	48	4.46

70	65.99	20.95	20.42547385	13.97102411	41.14285714	4.37
80	65.97	21.01	20.4824651	14.01000613	36	4.35
90	65.93	21.08	20.54894402	14.05547771	32	4.31
100	65.9	21.27	20.72932776	14.17886019	28.8	4.28
110	65.83	21.37	20.82423192	14.24377463	26.18181818	4.21
120	65.78	21.51	20.95705758	14.33462738	24	4.16
140	65.75	21.63	21.07087086	14.41247567	20.57142857	4.13
160	65.69	21.81	21.24152624	14.52920395	18	4.07
180	65.62	21.96	21.38367991	14.62643706	16	4
210	65.51	22.07	21.48789175	14.69771796	13.71428571	3.89
240	65.44	22.25	21.65835783	14.81431676	12	3.82
270	65.38	22.42	21.81928247	14.92438921	10.66666667	3.76
300	65.33	22.53	21.92337337	14.99558738	9.6	3.71
330	65.25	22.82	22.1976562	15.18319684	8.727272727	3.63
360	65.2	23.05	22.41504792	15.33189278	8	3.58
420	65.05	23.22	22.5756475	15.44174289	6.857142857	3.43
480	64.91	23.43	22.77393984	15.57737485	6	3.29
540	64.8	23.63	22.96269169	15.70648112	5.333333333	3.18
600	64.68	23.66	22.99099622	15.72584142	4.8	3.06
660	64.66	23.72	23.04759883	15.7645576	4.363636364	3.04
720	64.52	23.78	23.10419284	15.8032679	4	2.9
780	64.46	23.9	23.21735504	15.88067084	3.692307692	2.84
840	64.34	23.96	23.2739232	15.9193634	3.42857142	2.72

			3	9	9	
900	64.25	24.06	23.36818443	15.98383815	3.2	2.63
960	64.09	24.28	23.57547493	16.12562485	3	2.47
1020	64.03	24.48	23.76382045	16.25445319	2.823529412	2.41
1080	63.9	24.68	23.95207037	16.38321613	2.666666667	2.28
1140	63.82	24.76	24.02734356	16.434703	2.526315789	2.2
1200	63.78	24.9	24.15903485	16.52477984	2.4	2.16
1260	63.72	24.99	24.24366879	16.58266946	2.285714286	2.1
1320	63.68	25.08	24.32828338	16.64054583	2.181818182	2.06
1380	63.62	25.15	24.39408134	16.68555163	2.086956522	2
1440	63.59	25.26	24.49745447	16.75625886	2	1.97
1500	63.55	25.37	24.60079868	16.82694629	1.92	1.93
1560	63.5	25.47	24.69472286	16.89119044	1.846153846	1.88
1620	63.45	25.56	24.77923419	16.94899619	1.777777778	1.83
1680	63.41	25.63	24.84495184	16.99394706	1.714285714	1.79
1740	63.37	25.72	24.92942875	17.05172926	1.655172414	1.75
1800	63.35	25.83	25.03265201	17.12233398	1.6	1.73
1860	63.32	25.92	25.1170859	17.18008676	1.548387097	1.7
1920	63.3	26.01	25.20150043	17.23782629	1.5	1.68
1980	63.27	26.08	25.26714279	17.28272567	1.454545455	1.65
2040	63.23	26.13	25.31402302	17.31479174	1.411764706	1.61
2100	63.18	26.21	25.38901895	17.36608896	1.371428571	1.56
2160	63.12	26.21	25.38901895	17.36608896	1.333333333	1.5

2220	63.1	26.23	25.40776555	17.37891163	1.297297297	1.48
2280	63.03	26.24	25.41713849	17.38532272	1.263157895	1.41
2340	63.01	26.27	25.44525587	17.40455501	1.230769231	1.39
2400	62.96	26.43	25.5951789	17.50710237	1.2	1.34
2460	62.91	26.46	25.62328266	17.52632534	1.170731707	1.29
2520	62.88	26.5	25.66075099	17.55195368	1.142857143	1.26
2580	62.86	26.52	25.67948372	17.56476687	1.11627907	1.24
2640	62.83	26.56	25.71694632	17.59039128	1.090909091	1.21
2700	62.82	26.61	25.76376918	17.62241812	1.066666667	1.2
2760	62.81	26.67	25.81994873	17.66084493	1.043478261	1.19
2820	62.8	26.75	25.89484141	17.71207153	1.021276596	1.18
2880	62.79	26.8	25.94164157	17.74408283	1	1.17
2940	88.37	26.83	25.9697188	17.76328766		
3000	88.42	26.86	25.99779387	17.78249101		
3060	88.45	26.88	26.01650939	17.79529243		
3120	88.48	26.91	26.04458088	17.81449332		
3180	88.5	26.93	26.06329402	17.82729311		
3240	88.53	26.97	26.10071741	17.85289071		
3300	88.55	27.01	26.13813698	17.87848569		
3360	88.59	27.06	26.18490607	17.91047575		
3420	88.63	27.13	26.25037275	17.95525496		
3480	88.68	27.26	26.37192265	18.0383951		
3540	88.75	27.27	26.3812709	18.0447893		

			7	5
3600	88.88	27.26	26.37192265	18.0383951
3660	88.89	27.26	26.37192265	18.0383951
3720	88.88	27.27	26.38127097	18.04478935
3780	88.88	27.28	26.39061905	18.05118343
3840	88.89	27.31	26.41866186	18.07036471
3900	88.9	27.32	26.42800899	18.07675815
3960	88.93	27.36	26.4653951	18.10233025
4020	88.94	27.38	26.48408672	18.11511531
4080	88.98	27.42	26.52146709	18.14068349
4140	89	27.46	26.55884363	18.16624905
4200	89.04	27.49	26.58687354	18.1854215
4260	89.08			
4320	89.11			

Appendix-7:- Summary of Theis Test Result WF02-PW17

Constant Test Data Sheet								
Employer /Client : AAWSSA		**Discharge Rate** : 81 l/s						
Well ID : WF02-PW17		**Pump Position** : 125 m						
Date of Pumping : 24 -27 /01/2014		SWL :61.62 m Below ground level						
Time since pumping started	**WF02-PW17 Water Level**	**Observed Draw Down**	**Unconfined DD**	**Corrected DD**	**r^2/t**	**U**	**W(u)**	
0	61.62	0	0	0	0	1.00E-15	33.96	
1	78.12	16.5	16.17463789	11.0634523	0.12645136	2.00E-15	32.27	

2	80.07	18.45	18.0431898	12.3415418	0.06322568	3.00E-15	32.86
3	80.67	19.05	18.61630037	12.7335495	0.042150453	4.00E-15	32.58
4	80.97	19.35	18.90253298	12.9293326	0.03161284	5.00E-15	32.35
5	81.15	19.53	19.0741693	13.0467318	0.025290272	6.00E-15	32.17
6	81.32	19.7	19.23619915	13.1575602	0.021075227	7.00E-15	32.02
7	81.42	19.8	19.33147856	13.2227313	0.01806448	8.00E-15	31.88
8	81.46	19.84	19.36958363	13.2487952	0.01580642	9.00E-15	31.76
9	81.48	19.86	19.38863473	13.2618262	0.014050151	1.00E-14	31.66
10	81.53	19.91	19.43625831	13.2944007	0.012645136	2.00E-14	30.97
12	81.58	19.96	19.4838759	13.3269711	0.010537613	3.00E-14	30.56
14	81.66	20.04	19.56005163	13.3790753	0.00903224	4.00E-14	30.27
16	81.68	20.06	19.57909317	13.3920997	0.00790321	5.00E-14	30.05
18	81.73	20.11	19.62669284	13.4246579	0.007025076	6.00E-14	29.87
20	81.78	20.16	19.67428653	13.457212	0.006322568	7.00E-14	29.71
25	81.88	20.26	19.769456	13.5223079	0.005058054	8.00E-14	29.58
30	81.97	20.35	19.85508808	13.5808802	0.004215045	9.00E-14	29.46
35	82.04	20.42	19.92167742	13.6264274	0.003612896	1.00E-13	29.36
40	82.14	20.52	20.01678474	13.6914808	0.003161284	2.00E-13	28.66
45	82.21	20.59	20.08334564	13.7370084	0.00281003	3.00E-13	28.26
50	82.23	20.61	20.10236089	13.7500149	0.002529027	4.00E-13	27.97
60	82.37	20.75	20.23544087	13.8410416	0.002107523	5.00E-13	27.75
70	82.46	20.84	20.32096754	13.8995418	0.001806448	6.00E-13	27.56
80	82.57	20.95	20.425473	13.97102	0.0015806	7.00E-	27.41

			85	41	42	13		
90	82.63	21.01	20.4824651	14.0100061	0.001405015	8.00E-13	27.28
100	82.7	21.08	20.54894402	14.0554777	0.001264514	9.00E-13	27.16
120	82.89	21.27	20.72932776	14.1788602	0.001053761	1.00E-12	27.05
140	82.99	21.37	20.82423192	14.2437746	0.000903224	2.00E-12	26.36
160	83.13	21.51	20.95705758	14.3346274	0.000790321	3.00E-12	25.96
180	83.25	21.63	21.07087086	14.4124757	0.000702508	4.00E-12	26.67
210	83.43	21.81	21.24152624	14.529204	0.000602149	5.00E-12	25.44
240	83.58	21.96	21.38367991	14.6264371	0.000526881	6.00E-12	25.26
270	83.69	22.07	21.48789175	14.697718	0.000468338	7.00E-12	25.11
300	83.87	22.25	21.65835783	14.8143168	0.000421505	8.00E-12	24.97
330	84.04	22.42	21.81928247	14.9243892	0.000383186	9.00E-12	24.86
360	84.15	22.53	21.92337337	14.9955874	0.000351254	1.00E-11	24.75
420	84.44	22.82	22.1976562	15.1831968	0.000301075	2.00E-11	24.06
480	84.67	23.05	22.41504792	15.3318928	0.00026344	3.00E-11	23.65
540	84.84	23.22	22.5756475	15.4417429	0.000234169	4.00E-11	23.36
600	85.05	23.43	22.77393984	15.5773749	0.000210752	5.00E-11	23.14
660	85.25	23.63	22.96269169	15.7064811	0.000191593	6.00E-11	22.96
720	85.28	23.66	22.99099622	15.7258414	0.000175627	7.00E-11	22.81
780	85.34	23.72	23.04759883	15.7645576	0.000162117	8.00E-11	22.67
840	85.4	23.78	23.10419284	15.8032679	0.000150537	9.00E-11	22.55
900	85.52	23.9	23.21735504	15.8806708	0.000140502	1.00E-10	22.45
960	85.58	23.96	23.27392323	15.9193635	0.00013172	2.00E-10	21.76

1020	85.68	24.06	23.36818443	15.9838381	0.000123972	3.00E-10	21.35
1080	85.9	24.28	23.57547493	16.1256249	0.000117085	4.00E-10	21.06
1140	86.1	24.48	23.76382045	16.2544532	0.000110922	5.00E-10	20.84
1200	86.3	24.68	23.95207037	16.3832161	0.000105376	6.00E-10	20.66
1260	86.38	24.76	24.02734356	16.434703	0.000100358	7.00E-10	20.5
1320	86.52	24.9	24.15903485	16.5247798	9.57965E-05	8.00E-10	20.37
1380	86.61	24.99	24.24366879	16.5826695	9.16314E-05	9.00E-10	20.25
1440	86.7	25.08	24.32828338	16.6405458	8.78134E-05	1.00E-09	20.15
1500	86.77	25.15	24.39408134	16.6855516	8.43009E-05	2.00E-09	19.45
1560	86.88	25.26	24.49745447	16.7562589	8.10586E-05	3.00E-09	19.05
1620	86.99	25.37	24.60079868	16.8269463	7.80564E-05	4.00E-09	18.76
1680	87.09	25.47	24.69472286	16.8911904	7.52687E-05	5.00E-09	18.54
1740	87.18	25.56	24.77923419	16.9489962	7.26732E-05	6.00E-09	18.35
1800	87.25	25.63	24.84495184	16.9939471	7.02508E-05	7.00E-09	18.2
1860	87.34	25.72	24.92942875	17.0517293	6.79846E-05	8.00E-09	18.07
1920	87.45	25.83	25.03265201	17.122334	6.58601E-05	9.00E-09	17.95
1980	87.54	25.92	25.1170859	17.1800868	6.38643E-05	1.00E-08	17.48
2040	87.63	26.01	25.20150043	17.2378263	6.1986E-05	2.00E-08	17.15
2100	87.7	26.08	25.26714279	17.2827257	6.02149E-05	3.00E-08	16.74
2160	87.75	26.13	25.31402302	17.3147917	5.85423E-05	4.00E-08	16.46
2220	87.83	26.21	25.38901895	17.366089	5.69601E-05	5.00E-08	16.23
2280	87.83	26.21	25.38901895	17.366089	5.54611E-05	6.00E-08	16.05
2340	87.85	26.23	25.407765	17.37891	5.4039E-	7.00E-	15.9

			55	16	05	08	
2400	87.86	26.24	25.41713849	17.3853227	5.26881E-05	8.00E-08	15.76
2460	87.89	26.27	25.44525587	17.404555	5.1403E-05	9.00E-08	15.65
2520	88.05	26.43	25.5951789	17.5071024	5.01791E-05	1.00E-07	15.54
2580	88.08	26.46	25.62328266	17.5263253	4.90122E-05	2.00E-07	14.85
2640	88.12	26.5	25.66075099	17.5519537	4.78982E-05	3.00E-07	14.44
2700	88.14	26.52	25.67948372	17.5647669	4.68338E-05	4.00E-07	14.15
2760	88.18	26.56	25.71694632	17.5903913	4.58157E-05	5.00E-07	13.93
2820	88.23	26.61	25.76376918	17.6224181	4.48409E-05	6.00E-07	13.75
2880	88.29	26.67	25.81994873	17.6608449	4.39067E-05	7.00E-07	13.6
2940	88.37	26.75	25.89484141	17.7120715	4.30107E-05	8.00E-07	13.46
3000	88.42	26.8	25.94164157	17.7440828	4.21505E-05	9.00E-07	13.34
3060	88.45	26.83	25.9697188	17.7632877	4.1324E-05	1.00E-06	13.24
3120	88.48	26.86	25.99779387	17.782491	4.05293E-05	2.00E-06	12.55
3180	88.5	26.88	26.01650939	17.7952924	3.97646E-05	3.00E-06	12.14
3240	88.53	26.91	26.04458088	17.8144933	3.90282E-05	4.00E-06	11.85
3300	88.55	26.93	26.06329402	17.8272931	3.83186E-05	5.00E-06	11.63
3360	88.59	26.97	26.10071741	17.8528907	3.76343E-05	6.00E-06	11.45
3420	88.63	27.01	26.13813698	17.8784857	3.69741E-05	7.00E-06	11.29
3480	88.68	27.06	26.18490607	17.9104757	3.63366E-05	8.00E-06	11.16
3540	88.75	27.13	26.25037275	17.955255	3.57207E-05	9.00E-06	11.04
3600	88.88	27.26	26.37192265	18.0383951	3.51254E-05	1.00E-05	10.94
3660	88.89	27.27	26.38127097	18.0447893	3.45496E-05	2.00E-05	10.24

3720	88.88	27.26	26.37192265	18.0383951	3.39923E-05	3.00E-05	9.84
3780	88.88	27.26	26.37192265	18.0383951	3.34527E-05	4.00E-05	9.55
3840	88.89	27.27	26.38127097	18.0447893	3.293E-05	5.00E-05	9.33
3900	88.9	27.28	26.39061905	18.0511834	3.24234E-05	6.00E-05	9.14
3960	88.93	27.31	26.41866186	18.0703647	3.19322E-05	7.00E-05	8.99
4020	88.94	27.32	26.42800899	18.0767581	3.14556E-05	8.00E-05	8.86
4080	88.98	27.36	26.4653951	18.1023302	3.0993E-05	9.00E-05	8.74
4140	89	27.38	26.48408672	18.1151153	3.05438E-05	1.00E-04	8.63
4200	89.04	27.42	26.52146709	18.1406835	3.01075E-05	2.00E-04	7.94
4260	89.08	27.46	26.55884363	18.166249	2.96834E-05	3.00E-04	7.53
4320	89.11	27.49	26.58687354	18.1854215	2.92711E-05	4.00E-04	7.25

Appendix-8:-Summery of Partial Penetration Correction of WF02-PW17

Depth interval in (m)		Type of c	Length (m)		Diameter of casing								
From	To		Blind	Screen		r	2l/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)		F	Artmetic Mean
0.75	127.5	Blind	128.25		14"	0.3556							
127.5	145.1	Screen		17.6	14"	0.3556	98.9876	0.1213	6.87346	0.10051	1.69085	0.20509	
145.1	150.95	Blind	5.85		14"	0.3556							0.661
150.95	168.5	Screen		17.55	14"	0.3556	98.7064	0.75	2.68265	0.10065	1.27002	0.95251	
168.5	186.05	Blind	17.55		14"	0.3556							
186.05	191.9	Screen		5.85	14"	0.3556	32.9021	0.25	6.46769	0.17434	2.12755	0.53189	
191.9	197.75	Blind	5.85		14"	0.3556							
197.5	221.15	Screen		23.65	14"	0.3556	133.015	0.80855	2.07785	0.08671	1.18016	0.95422	
221.15	227	Blind	5.85		14"	0.3556							
227	232.75	Blind	5.75		6"	0.3556							
232.75	244.25	Screen		11.5	6"	0.3556	64.6794	0.49784	4.9685	0.12434	1.61779	0.80539	
244.25	250	Blind	5.75		6"	0.3556							
250	267.25	Screen		17.25	6"	0.3556	97.0191	0.75	2.68265	0.10152	1.27235	0.95427	
267.25	278.25	Blind	11		6"	0.3556							
278.25	284.5	Screen		6.25	6"	0.3556	35.1519	0.36232	5.89768	0.16867	1.99473	0.72273	0.75
284.5	296	Blind	11.5		6"	0.3556							
296	313.25	Screen		17.25	6"	0.3556	97.0191	0.6	4.1172	0.10152	1.418	0.8508	
313.25	336.25	Blind	23		6"	0.3556							
336.25	347.75	Screen		11.5	6"	0.3556	64.6794	0.33333	6.06311	0.12434	1.7539	0.58463	
347.75	359.25	Blind	11.5		6"	0.3556							
359.25	365	Screen		5.75	6"	0.3556	32.3397	0.33333	6.06311	0.17585	2.06617	0.68872	
365	376.5	Blind	11.5		6"	0.3556							
376.5	388	Screen		11.5	6"	0.3556	64.6794	0.5	4.95172	0.12434	1.61571	0.80785	
388	405.25	Blind	17.25		6"	0.3556							
405.25	411	Screen		5.75	6"	0.3556	32.3397	0.25	6.46769	0.17585	2.13732	0.53433	
411	428.5	Blind	17.5		6"	0.3556							
428.5	445.5	Screen		17	6"	0.3556	95.613	0.49275	5.00769	0.10227	1.51213	0.74511	
445.5	457	Blind	11.5		6"	0.3556							
457	468.5	Screen		11.5	6"	0.3556	64.6794	0.5	4.95172	0.12434	1.61571	0.80785	
468.5	480	Blind	11.5		6"	0.3556						F Artmetic	
Total Blind casing length			301.1									F Geomtri	0.684
Total Screen casing Length				179.9									
Total length Blind Screen Casin			481										