Assessment on Interpretive Technique of Transmissivity and Storativity on Aquifers: Case of Legedadi Deep Wells.

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May, 2016

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Assessment on Interpretive Technique of Transmissivity and Storativity on Aquifers: Case of Legedadi Deep Wells.

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

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Certification

The undersigned certify that he has read the thesis entitled: Assessment on Interpretive Technique of Transmissivity and Storativity on Aquifers: Case of Legedadi Deep Wells and hereby recommend for acceptance by the Addis Ababa University in partial fulfilment of the requirements for the degree of Master of Science.

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Declaration

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

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Abstract

Urban part of our country has seen a very dramatic expansions and population growth in the past two decades. Addis Ababa is one of the major city that's affected by this expansion and population growth. Due to this the water supply demand for the city has also increased dramatically. To meet this ever growing demand Addis Ababa Water Supply and Sewerage Authority has been developing groundwater around Addis Ababa area. One of these groundwater developments is in Legedadi well fields. The Legedadi well field's yield capacity is estimated to be around 45,000m^3/d. This potential will be harvested by development of 40 deep wells in the area of which 10 deep wells have been constructed and tested around Legedadi Legetafo Ayat areas. This ten wells have been drilled with average depth of 300m and are sparsely located over the Legedadi well filed. The currently drilled and developed ten well in the well fields do not have an observation well thus, they are considered as a single well tests. The drawdowns for each of the well is measured in the drilled well itself and the analysis is based on this drawdowns. The fact that effects of partial pentation and well head loss have not be counted in the analysis of the wells caused the transmissivity and storativity to vary greatly form the true aquifer nature in the Legedadi well fields.The two major emphasise that was given in this research when trying to determine the transmissivity and storativity using the Copper-Jacob method, Theis method and recovery method is the well efficiency and the effects of partial penetration of the wells. When the well efficiency was determined for the wells, for two wells there efficiency fail drastically below the accepted range of well efficiency and grater partial penetration effect was observed in two other wells. When this three methods are applied to this for the observed and drawdown data the result of the transmissivity and storativity greatly differ from the values that's is determined when the head loss in the well is considered using the well efficiency or effect of partial penetration. Thus this indicates the well to be over pumped or underestimate in some case in this ten wells.

Key words: - **Addis Ababa Water Supply, Legedadi Well Fields, Partial Penetration, Storativity, Transmissivity and Well Efficiency**

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List of Acronyms and Abbreviations

AAWSSA	Addis Ababa Water Supply & Sewerage Authority
ASCII	American Standard Code for Information Interchange
CSA	Central Statistical Agency
DD	Drawdown.
ERA	Ethiopian Road Authority
GPS	*Global Positioning System*
LLA- 1	Legedadi-Legetafo-Ayat Well Number 1
LLA-2	Legedadi-Legetafo-Ayat Well Number 2
LLA-3	Legedadi-Legetafo-Ayat Well Number 3
LLA-5	Legedadi-Legetafo-Ayat Well Number 5
LLA-6	Legedadi-Legetafo-Ayat Well Number 6
LLA-PW1	Legedadi-Legetafo-Ayat Production Well Number 1
LLA-PW3	Legedadi-Legetafo-Ayat Production Well Number 3
LLA-PW4	Legedadi-Legetafo-Ayat Production Well Number 4
LLA-PW5	Legedadi-Legetafo-Ayat Production Well Number 5
LLA-PW7	Legedadi-Legetafo-Ayat Production Well Number 7
MoWE	Ministry of Water and Energy
UNDESA	United Nations Department of Economic and Social Affairs
UNESCO	United Nations Educational, Scientific and Cultural Organization
WWDSE	Water Works Design and Supervision Enterprises

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1.Introduction

The distribution and availability of freshwater resources, through precipitation and runoff, can be erratic, with different areas of the globe receiving different quantities of water over any given year. There can be considerable variability between arid and humid climates and over wet and dry seasons. However, compounded yearly averages show significant variations in per capita water availability between countries. The management and protection of regional, national, and international freshwater resources have reached a crucial period. In the last several decades, it has become obvious to many that traditional water policies are not up to the task of meeting the challenges of the 21st century. New threats to the world's freshwater resources face water managers and policymakers. These threats include rapid population and urbanization, increasing surface and groundwater contamination from pollutants, global climatic changes that are already beginning to affect water supply and demand, resurgent water-related diseases, and the destruction and degradation of freshwater ecosystems

Prior to the 20th century, human demand for water was relatively small compared to availability in most parts of the world. Water demand dramatically increased as a consequence of population and income growth, and the expansion of industry and irrigated agriculture, so that demand now exceeds supply in many developed and developing countries.

Global water demand is largely influenced by rapid urbanization .Cities have become the place where development challenges and opportunities increasingly come face to face. In 2014, 3.9 billion people, or 54% of the global population, lived in cities, and by 2050, two-thirds of the global population will be living in cities (UNDESA, 2014). Furthermore, most of this growth is happening in developing countries, which have limited capacity to deal with this rapid change. Thus to meet this ever growing demand for fresh water the use for the groundwater has increased dramatically in the past five decades. Groundwater contains by far the largest volume of unfrozen fresh water on Earth .The total volume of fresh groundwater stored on earth is believed to be in the region of 8 million km^3 to 10 million km^3 (Margat, 2008), which is more than two thousand times the current annual withdrawal of surface water and groundwater combined.

As one of the rapidly growing country in the developing world, Ethiopia has seen its fair shear of urbanization in most of its major cities. It has one of the fastest growing urban populations in the world, with the number of people living in cities expected to nearly triple in the next two decades. To sustain this ever growing demand the utilization of ground water development plays a major role in supply fresh water in rural as well as urban areas of the country.

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, Bushoftu, and Harar) 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 374,000 m^3 per day.

Compared to other parts of the country, the groundwater potential in Addis Ababa region is relatively well investigated. All of four categories of aquifers occur in Addis Ababa: the very shallow aquifer, the shallow aquifer, the deep aquifer and the very deep aquifers. The most intensively used aquifers are the shallow and deep aquifers. These serve as the source of water for AAWSA, but at the same time they are also increasingly used by private parties such as industries and horticultural farms. For the moment the shallow aquifer contributes importantly to the water supply of Addis Ababa – through the Akaki well fields and wells drilled in different parts of the city. In recent years investigation of the deep and very deep aquifers has revealed possibility of finding large discharge wells and significant numbers of wells have been drilled for Addis Ababa water supply. The shallow and deep aquifers underlay both Addis Ababa and Oromia Region. One of these deep well developments is that of Legedadi Deep Well Developments. This groundwater development is located at the suburb of Addis Ababa city in Oromia Regional State, at a distance of approximately 30 km from the city centre and 8 km south west of Sendfa town, the district centre. According to the latest hydro geological study result, the well field's yield capacity is estimated to be around 45,000m^3/d. This potential will be harvested by development of 40 deep wells in the area of which 10 deep wells have been constructed and tested.

The main beneficiary of the Legedadi Deep Well Development project, from the currently completed wells, are the three condominium sites, which are Yeka Abado, Yeka Hayat and Bole Arebsa, are located Yeka and Bole Sub City. Yeka Abado condominium site is to be occupied by 14,000 households/houses, Yeka Hayat condominium site by 6,000 households and Bole Arebsa condominium site by 40,000 households. As such, the household number in the 3 condominium sites is about 60,000 with 240,000 population considering 4 persons average household number size as per Central Statistical Agency (CSA) document. The beneficiary number may increase since nearby surrounding of the condominium sites and areas along the pipe line are considered as conditional beneficiary.

This thesis paper is assembled in to five main chapters. The first chapter is introduction part. As it was discussed above, it gave a brief description how the use of groundwater as source of the fresh water has evolved over the past half century and also gave a brief description of the of potential of Ledadadi well fields and beneficiary's form the Legedadi groundwater supply project. It also contains the objectives and statement of the problem for this thesis paper. The second section of this paper contains the literature reviews and it deals with relevant citation of literatures that are related to the topic of this research paper. Here large portion is covered by citations from the original papers of Theis and Cooper-Jacob. The third chapter of this thesis paper integrates the methods used to carry on the investigations. In this section the methods and the procedures thoroughly followed has been described in details. Here it is also discussed about the kind of data collected and the kind of adjustment done to data before it can be used for analysis. This adjustment includes correction for drawdown for well loss using well efficiency, correction for partial penetration using Kozeny correction factor and correction for unconfined aquifer. Analysis is done using two ways, manually using Excel and by using Aquifer Test pro software. In both cases the aquifer parameters were determined using Cooper-Jacobs method, Theis method and Recovery method. The fourth chapter consists of the result and discussion of the findings made by the analysis part. Here major emphasis is given to transmissivity vales Legedadi Deep well and classification is done here, based on their result of each wells. The fifth and the final chapter is the conclusion part. On this part some conclusion are reached and stated. Summary of contributions and recommendation are also covered in this chapter.

1.2. Description of the study area

The project is located in two bordering regions: In Addis Ababa City Government/ Addis Ababa City Administration and in Oromia Region. The 3 condominium sites, the main beneficiary of the project, and the 4 reservoirs are located in the North East suburbs of Addis Ababa City Administration. The Pipeline including the collector pipes passes through Dabe Muda Gudo, Lege Beri Lege Bolo, Grar Berek, Dire Sokoru, Welgewo and Yeka sadden Kebeles in Bereh Woreda and Yeka and Bole Sub City in Addis Ababa City Government. The collector tanker is found in Dire Sokoru Kebele. The project possess four reservoirs of which the two (reservoir 2 &3) are found in Yeka Sub City Yeka Abado Woreda while the remaining two reservoirs (reservoir 1 &4) are located in Bole Sub city.

The well field is located 8 km south west of Sendfa town, the district center, and 30 km North East of Addis Ababa. It includes deep well up to 500 meter depth. Six wells are located in Lege Beri Lege Belo kebele and two well in Dabe Muda Gudo kebele to the east of the well field and the collector tanker in Dire Sekoru Kebele North West of the well field adjacently. Figure 1 below tries to show the location of each of the wells in Legedadi Legetafo Ayat areas.

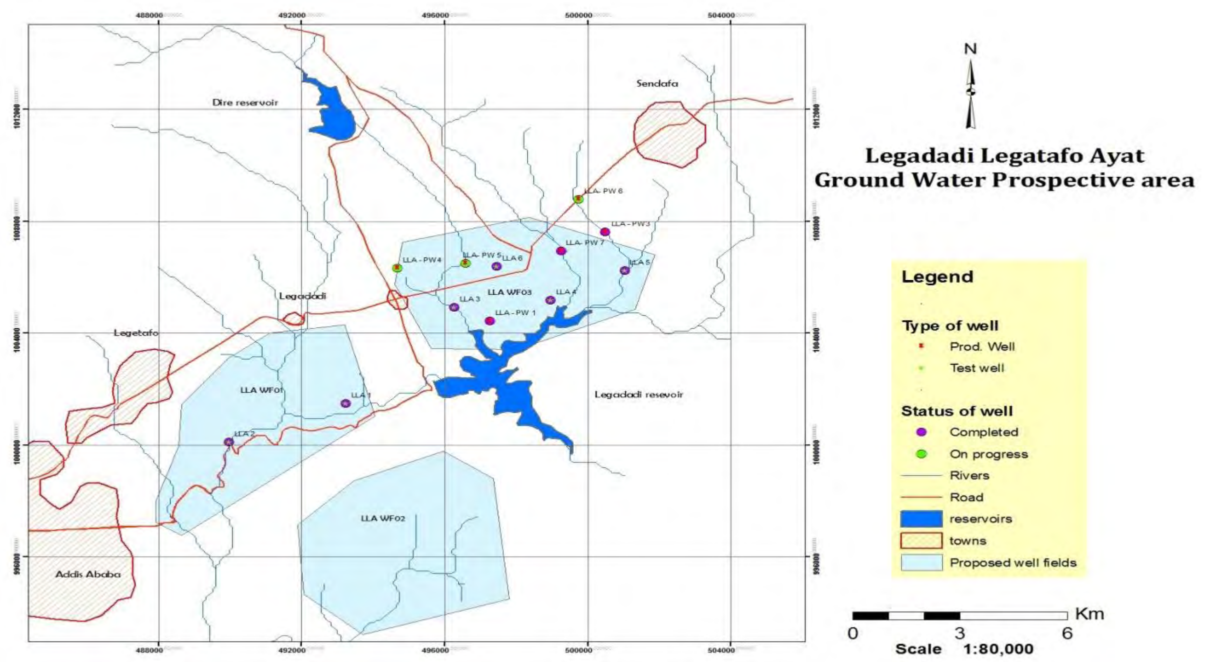


Figure 1. Ledadadi Legtafo Ayat Ground Water Prospective Area.

1.3. Statement of the Problem

Addis Ababa is not only the biggest city and capital for Ethiopia but also a capital city of Africa, a sit for international diplomats, big companies, Universities, Ministries, etc. Hence, improving the infrastructure services of Addis Ababa has not only local and national socio-economic development benefits but it also helps for the city to get continental and international acceptance to continue as a center for continental and international social, economic and political arena. Thus, Addis Ababa City Administration has been dismantling old house in many part of the city and resettling the population of the city in newly built condominiums on the outer part of the city. In addition to this, the inflow of population from the other city of the country and mostly from the rural areas has increased the population of the city.

Due to the above sited reasons, Addis Ababa is expanding and urbanizing at a high rate. Thus, the demand for safe and clean water supply has increased exponentially. Most of the newly built condominiums are being constructed on the outer part of the city, they are not connected to the main water supply pipelines. The three condominiums that are not contacted to the main water supply pipelines are, Yeka Abado condominium site to be occupied by 14,000 households/houses, Yeka Hayat condominium site by 6,000 households and Bole Arebsa condominium site by 40,000 households with an average population in the three condominiums expected to be around 240,000. To meet this demand for safe and clean water supply the Addis Ababa City Administration with cooperation of Addis Ababa Water Supply and Sewerage Authority (AAWSSA) has embarked on groundwater development around Addis Ababa area. One of these groundwater developments is that of 40 deep well developments in Legedadi area. Out of the 40 deep wells developments 10 deep well have been completed.

The primary factor limiting the performance of multi-well aquifer tests is cost, particularly in areas with large depth of water. Limiting analysis to existing wells predominately occurs on Legedadi well developments. During well pump tastings, prior to the commencements of step drawdown test, provisional test were also conducted at least for hour to develop the well and constant rate pumping testes were also conducted at all the completed wells to know the aquifer hydraulic parameters. But the fact that effects of partial pentation that arises from the casing arrangement of the well (blind and screen section) and well head loss have not be counted in the analysis of the wells caused the transmissivity and storativity to vary greatly form the true aquifer nature in the Legedadi well fields. For example well efficiency as low as 25% has been used in some well in Legedadi well fields and also transmissivity values have been underestimated. Error and bias as a function of interpretive technique on well efficiency, transmissivity and storativity have laid to the inadequate uses of wells. Hence it is vital to assess the interpretive technique on transmissivity and storativity of aquifers.

1.4. Objective of the study

1.4.1. General objective

The general objective of this research determining the transmissivity and storativity estimates from single-well tests in Legedadi well developments using pump test data and recovery test data for observed drawdown and for the drawdown considering the effects of partial penetration and well head loss by applying Theis and Copper Jacob methods on EXCLE 2013 and Aquifer Test Pro and comparing and analysing the out comes with the results given in the WWDSE report on Addis Ababa groundwater development, design and construction supervision project (40 Deep Wells) final report volume IV C.

1.4.2. Specific objectives

The specific objective of this thesis will:

- How well yields is set on a given well,
- Giving major emphasis on the efficiency of the wells and determining the efficiency and outlining how the well efficiency can be improved for wells that will be constructed within the vicinity of the well field on Legedadi area.
- Determining the aquifers properties from the pumping test data by adjusting for necessary Theis and Cooper-Jacob assumption to engage in the analysis. Then to see how interpretive technique will affect the transmissivity and storativity estimates from single-well tests in aquifers.

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 m^3 with an annual groundwater recharge of 28 Billion m^3 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.

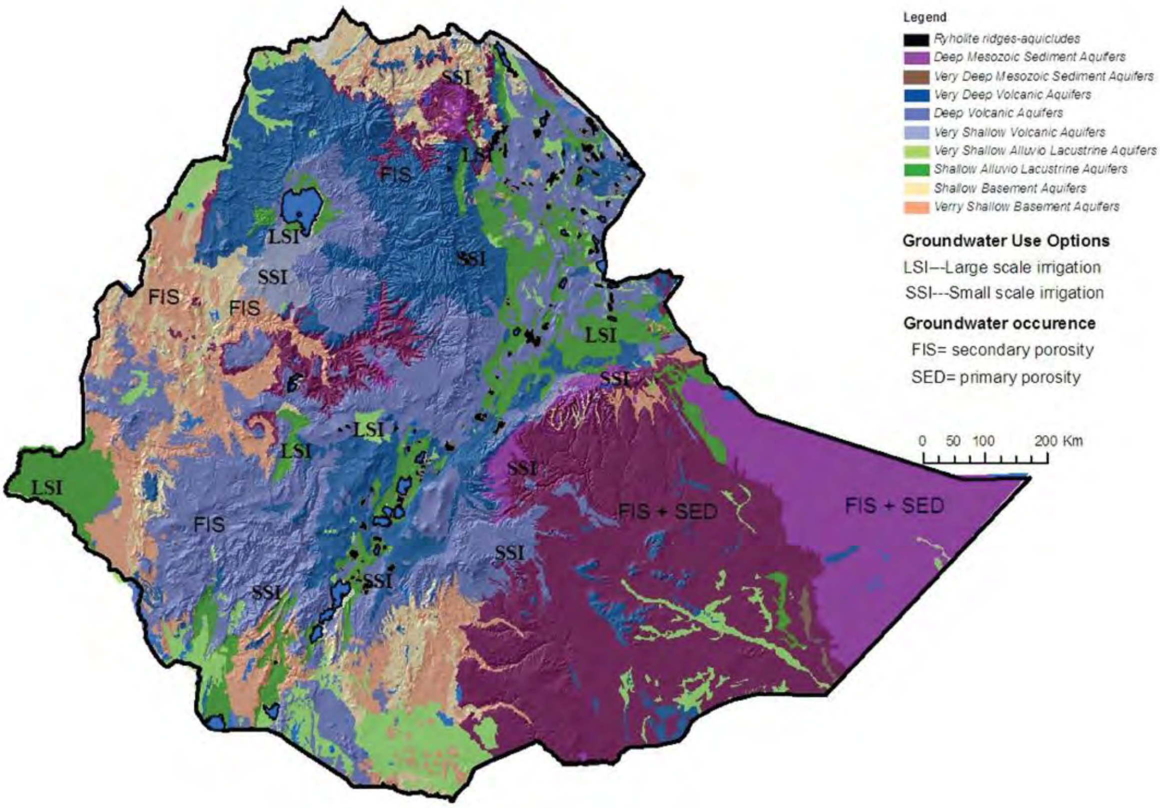


Figure 2.Groundwater occurrence in Ethiopia

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.

2.1.1. 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 research purposes, though out Addis Ababa as show in figure 3. Comparatively, better hydrogeological figures is assembled in the central and southern part of the city where most of the borehole are concentrated. From this boreholes studies researchers 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 studies 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.

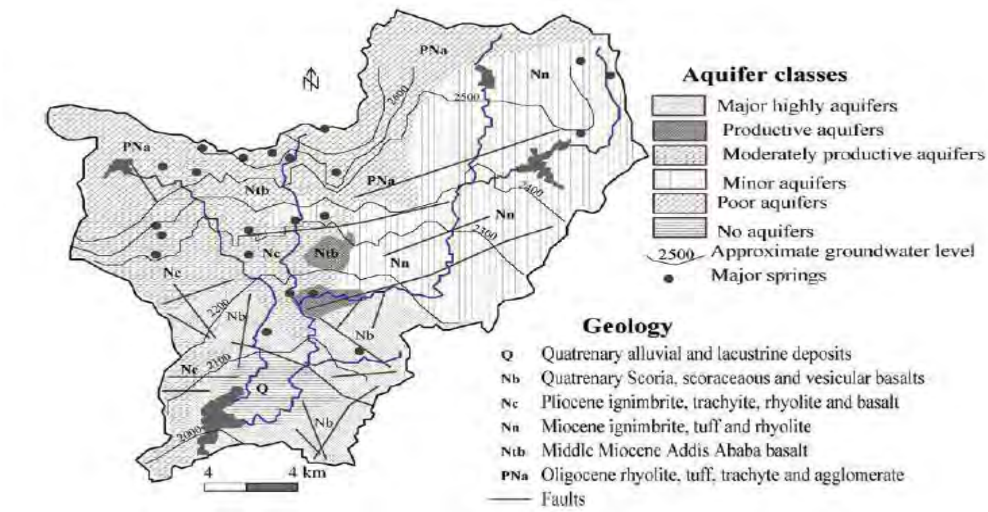


Figure 3.Simplified hydrogeological map of Addis Ababa.

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.

2.1.2 Water Wells Inventory in Addis Ababa

The influence of human population on surface and groundwater is increasing with the development of industry and population size in the city of Addis Ababa. Accordingly, Addis Ababa had a population of 65,000 in 1912, which grew to 100,000 in 1935. In a little over three years it had increased from 100,000 to 143,000 (Techeste, 1987). According to Central Statistic Authority (CSA, 1999), the population of Addis Ababa has grown from 1961-1967 443,728 to 683,530 and from 1978-1984 1,167,315 to 1,423, 111 and the population reached 2,112,737 in 1994 and according to CSA the current population censes conducted on 2007 indicates the population has reach 2,739,551. Due to this population growth the city has seen a vast expansion in the last four decades as shown in figure 4. This population upsurge and expansions has an intense consequence on the shortage of the water supply on the city.

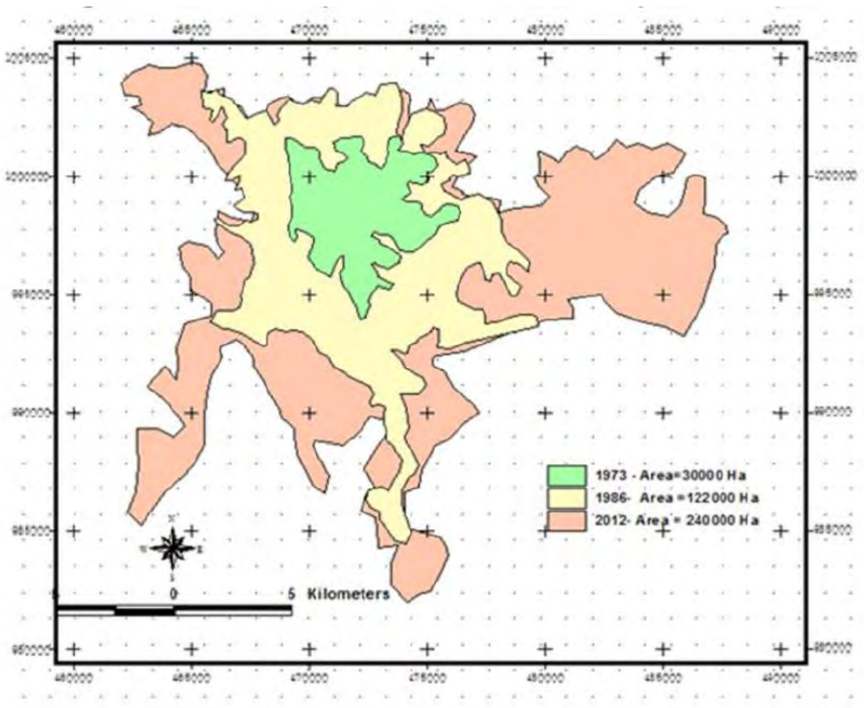


Figure 4.Expansion of Addis Ababa (1973-2012).

Currently the available water resource for the city is from surface water reservoirs (Gefersa, Legedadi and Dire), shallow and deep bore wells, hand-dug wells and springs. However, there is shortage of municipal water supply in different parts of the city particularly during the dry season. Consequently most of the industries, some residential houses, and governmental and non-governmental organizations have water wells in their premises to ease the problem. Moreover, in the bordering parts of the city, where there is a serious shortage of municipal water supply, the problem is being overcome by using water from the nearby well fields.

In spite of the significant role groundwater sources are playing in meeting the demands of the city, the exact number of wells is not known. A number of inventories carried previously have attempted to compile well data. It appears that these inventories were carried out, more for the purpose of documentation rather than for groundwater resource management purposes.

An inventory in the 1970s records a total of 175 deep wells, some in use and some abandoned, with the oldest one on record, drilled near the old airport in 1937. The inventory indicated that, of the 146 wells located within Addis Ababa the average yield for 87 of them was 2.6 litters per second. On the other hand of the 29 wells located in the Akaki-Kaliti area, 24 of them had an average yield of 3.5 litters per second. A 2004 inventory by AG Consult records at least 1200 boreholes, within 200km of the environs of the city. Inventories are still ongoing and a 2005 inventory has revealed that there were at least, 1037 water points in and around Addis Ababa. Of these 925 were boreholes with variable depth, 34 of shallow depth and 78 springs. Of the total number of only 22% have borehole log information. 84% percent of these water points were used for domestic water supply while 14% were used for industrial purposes, (WWDSE, 2007). Figure 2.4 below shows the distribution of wells and springs over the areas of the city.

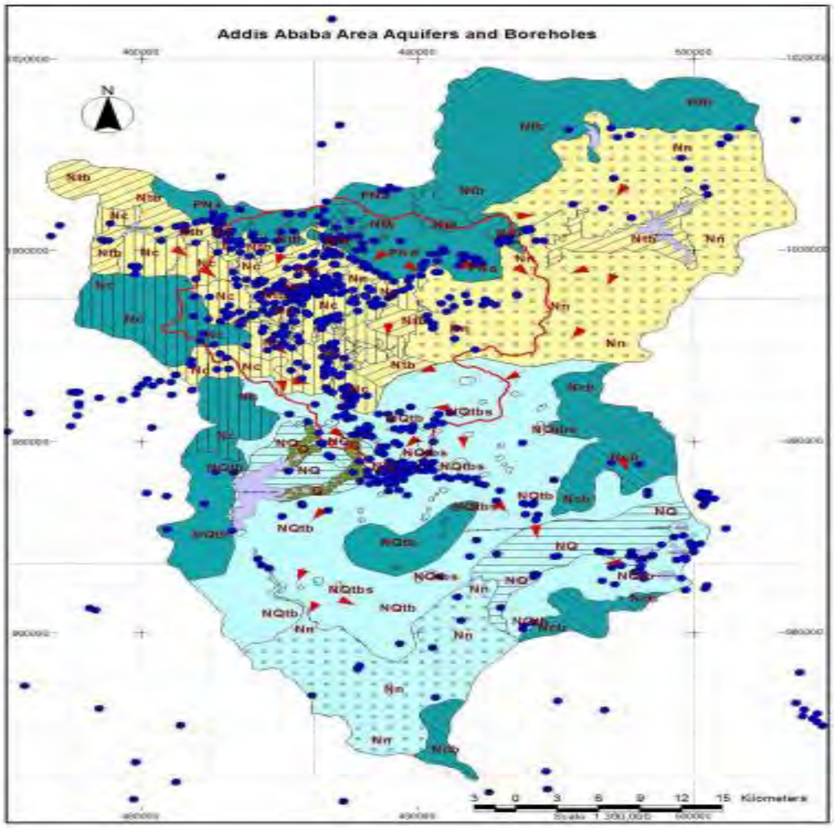


Figure 5.Borehole location in different part of the city. (Adapted from AG Consult)

2.2. Types of Aquifer

Groundwater groupings have been developed at several scales. Most often groundwater systems have been categorised by describing overall properties of geologic materials or lumping earth materials in units with similar hydrogeological properties. Tolman’s (1937) classified the occurrence and distribution of subsurface water into saturated and unsaturated zones. In the saturated zone, groundwater was classified as free water, confined water, and fixed groundwater, or connate water. Tolman identified perched groundwater as water that is part of the unsaturated zone. Todd (1959 and 1980) grouped water bearing units into aquifers and non-aquifers (aquitards, aquifuges and aquicludes) and groundwater basins comprised of one large aquifer or several connected and interrelated aquifers.

An aquifer is a water-bearing layer in which the vertical flow component is so small with respect to the horizontal flow component that it can be neglected. The groundwater flow in an aquifer is assumed to be predominantly horizontal.
The three types of aquifer distinguished are: confined, unconfined and leaky. A confined aquifer is a completely saturated aquifer bounded above and below by impermeable layer. The pressure of the water in confined aquifers is usually higher than atmospheric pressure, which is why when a well is bored into the aquifer the water rises up the well tube, to a level higher than the aquifer. An unconfined aquifer is a partly saturated aquifer bounded below by an impermeable layer and above by the free water table or phreatic surface. At the free water table, the groundwater is at atmospheric pressure. In general, the water level in a well penetrating an unconfined aquifer does not rise above the water table, except when there is vertical flow. A leaky aquifer, also known as a semi-confined aquifer, is a completely saturated aquifer that is bounded below by an impermeable layer and above by an aquitard. If the overlying aquitard extends to the land surface, it may be partly saturated, but if it is overlain by an unconfined aquifer that is bounded above by the water table, it will be fully saturated.

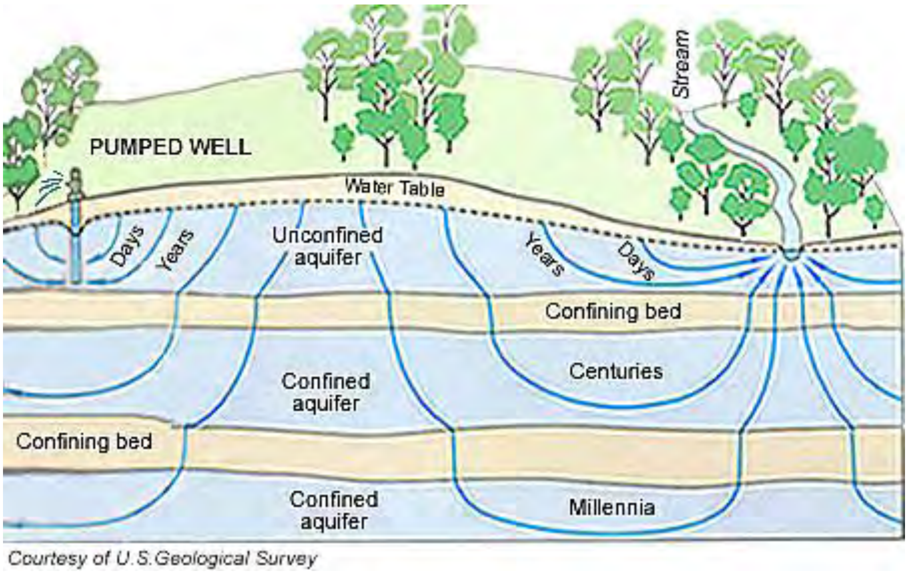


Figure 6.Confined and unconfined aquifers.

2.4. Aquifer Parameters

As groundwater becomes more important as a source of uncontaminated water, improved hydrogeological knowledge, new groundwater exploration technologies and data processing methods must be efficient to facilitate investigations and evaluation of groundwater resources. Many investigation techniques are commonly employed with the aim of estimating the spatial distribution of aquifer parameters such as hydraulic conductivity, transmissivity, and storativity and aquifer depth. Unfortunately, the conventional methods for the determination of hydraulic parameters such as pumping tests, and grain size analysis are invasive, relatively expensive and either integrate over a largest volume of data or provide information only to a small section of the aquifer in the surrounding area of the borehole . Accordingly, interpolating aquifer properties between boreholes is often difficult with little or no data in which to base these extrapolations. Therefore, in areas with few pumping test information, the spatial distribution of aquifer properties cannot be confidently calculated.

2.4.1. Transmissivity

Transmissivity is an essential hydraulic property of aquifers and water bearing materials. In common with permeability, transmissivity provides a representation about the water bearing features of hydrogeological bodies. Transmissivity values enable us to assess possibilities of groundwater abstraction, in the first approximation. Therefore, knowledge of transmissivity distribution helps us to draw important conclusion from hydrogeological studies, and for this reason, prevailing transmissivity values are often represented in hydrogeological maps. They provide a basis for future groundwater exploration, development, abstraction and protection.

By definition, Transmissivity (T) is a measure of the amount of water that can be transmitted horizontally through a unit width by the fully saturated thickness of an aquifer under a hydraulic gradient equal to 1. Transmissivity is equal to the hydraulic conductivity multiplied by the saturated thickness of the aquifer and is given by:

$$T = Kb \qquad (2.1)$$

Where;

K = hydraulic conductivity [LT-1]

b = saturated thickness of the aquifer [L]

The statistical distribution and prevailing values of permeability and transmissivity strongly depend on the relation of the magnitude of the elements of the rocks heterogeneity to the extent of the studied area (Rats, 1967). Since transmissivity depends on hydraulic conductivity and saturated thickness, its value will differ at different locations within aquifers comprised of heterogeneous material, bounded by sloping confining beds, or under unconfined conditions where the saturated thickness will vary with the water table.

In spite of the quantitative nature of transmissivity and its importance for quantitative appraisals, no objective classification of transmissivity has been introduce until Jiri Krasny published it on 1993 (Vol. 31 No. 2- GROUNDWATER- March- April 1993) . Before this, quantitative or semi-quantitative terms describing transmissivity are often used, denominating different grades or classes as large, small etc., but without strictly stating limits between them. This is the current case with hydrogeological maps where the inexactly defined term ''productivity'' is sometimes used (cf.eg, IAH et al., 1983). Even if transmissivity is expressed numerically the verbal designation of the numerical classes might involuntary reflect the relation between hydrogeological condition and water demand. In areas where yields of the water well are sufficient to cover limited water consumptions transmissivity may be designated as high. On the other hand where well yields do not suffice for the large requirements transmissivity might be designated as low. Such a subjective approach prevents the objective comparison of the transmissivity at both local and regional scales, including vales represented on the hydrogeological maps.

As sated above pumping test are the most frequent procedures used to determine transmissivity values that are often available as extensive data populations that may be used to characterize a hydrogeological environments. Thus, the classification of transmissivity magnitudes and variation was proposed with the intention of expressing, representing and comparing available transmissivity data in a more objective manner.

2.4.1.1. Classification of Transmissivity Magnitudes

This classification of transmissivity magnitude was published by Krasny 1970 and has been modified several times afterwards (Krasny 1986c) to reach the present form. Based on transmissivity studies the ranges of values generally are divided into six classes from very high transmissivity (*I class:* coefficient of transmissivity more than 1000 m^2/d) to imperceptible transmissivity *(VI class:* transmissivity is less than 0.1 m^2/d) as shown in Table 1.

Table 1.Confined and unconfined aquifers.

Coefficient of transmissivity m^2/d	*Class of transmissivity magnitude*	*Designation of transmissivity magnitude*	*Groundwater supply potential*	*Approximated expected discharge in l/s of a single well at 5 m drawdown*
>1000	*I*	*Very High*	*Withdrawals of great reginal importance*	*>50*
1000-100	*II*	*High*	*Withdrawals of lesser reginal importance*	*5-50*
100-10	*III*	*Intermediate*	*Withdrawals for local water supply (small communities)*	*0.5-5*
10-1	*V*	*Low*	*Smaller Withdrawals for local water supply (private consumption)*	*0.05-05*
1-0.1	*VI*	*Very low*	*Withdrawals for local water supply with limited consumption*	*0.005-0.05*
<0.1	*VII*	**Imperceptible**	*Sources for local water supply are difficult to ensure*	*<0.005*

2.4.1.2. Variations in Transmissivity

It is nearly impossible to find a homogeneous environments under natural conditions. Thus all environmental conditions are heterogeneous under natural conditions to different extent often depending on the extent of the studied area and the method used for hydraulic parameters assessment. Due to this, variations are expected in transmissivity in a given vicinity of well fields. Variation in transmissivity can be expressed by using the standard deviation of the sample population of transmissivity value. Six classes denominated *a to f* distinguished as shown in Table 2. This classes are based on the results of the studies in different hydrogeological sites.

Table 2.Classification of Transmissivity variations.

Standard deviation of transmissivity	Class of transmissivity variation	Designation of transmissivity variation	Hydrogeological Environments from the point of view of its hydraulic heterogeneity
<0.2	a	Insignificant	Nearly Homogeneous
0.2-0.4	b	Small	Slightly heterogeneous
0.4-0.6	c	Moderate	Fairly heterogeneous
0.6-0.8	d	Large	Considerably heterogeneous
0.8-1	f	Extremely large	Extremely heterogeneous

The classification of transmissivity magnitudes combined with the classification of transmissivity variation can be used for a quick and very simple quantitative characterization of different hydrogeological environments and for their comparisons. Knowledge of transmissivity variation enables us to predict future well yields and to indicate the hydraulic character of the hydrogeological environment.

2.4.2. Storativity

Storage is an important characteristic of an aquifer because it allows water to be stored throughout the year. At the water table, water is released from storage by gravity drainage. Below the water table, water is released from storage due to the release of hydrostatic pressure within the pore spaces which accompanies the withdrawal of water from the aquifer. The total load above an aquifer is supported by a combination of the solids skeleton of the aquifer and by the hydraulic pressure exerted by the water in the aquifer. Withdrawal of water from the aquifer results in a decline in the pore water pressure and subsequently more of the load must be supported by the solids skeleton. As a result, the rock particles are distorted and the skeleton is compressed, leading to a reduction in effective porosity. Additionally, the decreased water pressure causes the pore water to expand. Compression of the skeleton and expansion of the pore water both cause water to be expelled from the aquifer.

In plain words, the storativity of an aquifer of thickness b is the volume of water released from the storage per unit surface area of the aquifer per unit decline in hydraulic head or potentiometric surface as shown in Figure 7.
The storativity, *S*, of a confined aquifer is defined as:

$$S = S_s * b \qquad (2.2)$$

Where S_s is the specific storage term, and represents the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface .
Storativity values are dimensionless and range in value from 0.005 to 0.00005, such that large head changes over extensive areas are required to produce significant yields from confined aquifers.

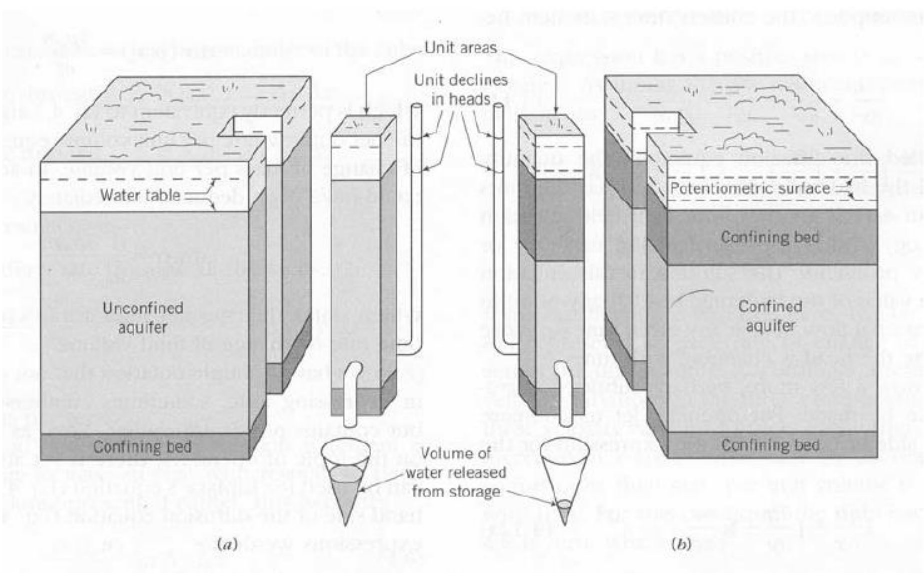


Figure 7.Concept of Storativity (a) unconfined aquifer (b) confined aquifer.

Theoretical, Storage coefficient (storativity) can be used to calculate the volume of water contained within an aquifer or that will be released when it is pumped. However, not all of the groundwater stored in an aquifer can be accessed. Most is needed to provide the gradient for groundwater to flow or to maintain spring flow, and keep the seawater interface in a safe position. Some water will also be so tightly held by natural capillary, friction or suction forces, that no pump will be able to extract all of it.

2.4. Types of Pump Test

In any given well filed, the aquifer system has to be, as much as possible, accurately known so that hydraulic parameters can be determined without any confusion. One way of knowing the aquifer system weather it is bounded or unbounded or if the system is being recharged from a nearby river or stream is to conduct pumping testes. The principle of a pumping test involves applying a stress to an aquifer by extracting groundwater from a pumping well and measuring the aquifer response to that stress by monitoring drawdown as function of time. These measurements are then incorporated into an appropriate well flow equation to calculate the hydraulic parameters of the aquifer. In well filed pumping test principles can be applied on Single Well or Multi-Well systems.

In Multi-Well aquifer test observation of the drawdown are recorded at some distance from the pumping well. In this case, drawdown are measured against time in the observation wells. Hear the recorded data are more reliable since the drawdown measured in the observation well is more or less has laminar flow in the observation well. Although no fixed rule can be given on where to put the observation well or the piezometers, placing them at distances of between 10 and 100 m from the well will usually give reliable data. For thick or stratified confined aquifers, these distances must be greater, say between 100 and 250 m or more.

With single-well tests, basically the same procedures can be applied as with multi-well tests, with the exception that drawdown measurements are conducted in the pumping well. Thus, the distance value now represents the effective radius of the single well. This is difficult to determine under field conditions as a “best” estimate, the outer radius of the well screen is often used. A complicating factor is the phenomenon that due to nonlinear well losses the water levels inside the well can be considerably lower than those directly outside the well screen. This implies that drawdown data from the pumped well can, in general, only be used for the analysis when corrected for these nonlinear well losses using the results of so-called step-drawdown tests.

Ideally, an aquifer test should be performed under the natural conditions of a stable water table. This is, however, not always possible. Water tables rise and fall due to natural recharge and discharge of the groundwater reservoir (precipitation and evaporation), manmade recharge and discharge of the groundwater reservoir (irrigation losses and pumping from wells), changes in barometric pressure, and tidal movements in coastal aquifers. Such short-term variations of the water table have an adverse effect on the drawdown and recovery of the water table during testing.

2.4.1. Duration of a Pumping Test

The question of how long a pumping test should last is difficult to answer as 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 as 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 as 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 as, 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. Inaccurate measurements of the drawdowns in the piezometers, drawdowns that are becoming smaller and smaller as pumping continue, can also lead to this wrong conclusion. In reality, the depression cone will continue to expand until the recharge of the aquifer, if any, equals the discharge. Kruseman and de Ridder (1994) suggest that, under average conditions, steady-state flow is generally reached in leaky aquifers after 15 to 20 hours of pumping, and in a confined aquifer, after 24 hours. In an unconfined aquifer, the cone of depression expands more slowly, so a longer period of pumping is required, say, three days.

To establish whether unsteady or steady-state conditions prevail, the changes in head during the pumping test should be plotted. Preliminary plotting of drawdown data during the test will often show what is happening and may indicate whether or not a test should be continued.

2.4.2. Preliminary Pump Test

Before implementing a constant-rate or step-drawdown pumping test, the well should be developed adequately to reduce the influence of well construction on aquifer response. Preliminary pumping test are the usually the first tests that are performed during well pumping tests. They are implanted so that the well can settle. This provisional pumping test are commonly conducted for 2 hours prior to step drawdown test;

- to check the possible discharge of the well,
- to check the maximum anticipated drawdown,
- to decide the pump position for the step drawdown test.

2.4.3. Step-Drawdown Pumping Test

Step drawdown tests are normally conducted to assess well/aquifer-loss performance and for guidance in selecting an optimum pumping rate for a subsequent, longer-duration, constant-rate pumping test. The test is conducted as a series of sequential, short-duration constant-rate pumping tests, with each step conducted of uniform duration and at progressively higher pumping rates. Step-drawdown tests are nowadays quite popular, they are the most frequently performed tests in the case of single well (Kawecki 1995). There are various reasons why they are performed: in the case of exploration wells, they allow to determine the proper discharge rate for the subsequent aquifer test, to understand the behaviour of the well during the pumping, to determine the optimum production capacity and to analyse the well performance over time (Boonstra and Kselik 2001). This test are also used in determining efficiency of the well.

2.4.4. Constant-Rate Pumping Test

The constant-rate test is the 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 (from several hours to several days or even weeks) while the water levels and pumping rates are monitored. During constant-rate pumping tests, groundwater is extracted from the aquifer and regulated to maintain a constant, uniform rate. The pressure response within the pumped well is monitored during the active withdrawal (drawdown) phase. Ideally, a constant-rate test should be long enough for the water level to reach or at least approach equilibrium. How long it takes to do this depends on the hydraulic properties of the aquifer. Usually, the drawdown against time is recorded a period of 72 hour by keeping the discharge at a uniform rate.

Maintaining a steady pumping rate during a constant rate test is sometimes a problem, especially if the chosen pumping rate results in a large drawdown. This is because for centrifugal pumps (the most commonly used type of pump) there is a relationship between pumping rate and pumping head. Incidentally, the pump must be set at a depth that is several metres below the deepest water level expected during the test. During a constant-rate test, it is worth roughly plotting the data in the field as the test proceeds, in case these deviations are observed. Decisions can then be made about extending or shortening the planned test length, or trying a different pumping rate.

2.4.5. Recovery Test

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**.** It is expressed as the difference between the original water level before the start of pumping and the water level measured at a time after the cessation of pumping. The recovery test is not strictly a pumping test, because it involves monitoring the recovery of the water level after the pump has been switched off. Recovery tests are valuable for several reasons:

- They provide a useful check on the aquifer characteristics derived from pumping tests, for very little extra effort – just extending the monitoring period after the pump has been switched off.
- The start of the test is relatively ‘clean.’ In practice, the start of a constant-rate test, for example, rarely achieves a clean jump from no pumping to the chosen

pumping rate. Switching a pump off is usually much easier than starting a pump, and the jump from a constant pumping rate to no pumping can be achieved fairly cleanly.

- Similarly, recovery smoothes out small changes in the pumping rate that occurred during the pumping phase, and there is no problem with well losses from turbulent flow. This results in more reliable estimates of aquifer properties when the recovery data are analysed.

Ideally, the duration of the recovery test should be as long as is necessary for the water to return to its original level, which, theoretically, would be as long as the duration of the pumping phase of the test programme. In practice, however, the recovery test is often shorter, partly for reasons of cost (keeping equipment and personnel on the site). In theory, the recovery curve should be a mirror image of the drawdown curve, as long as it is measured from the extension to the drawdown curve. However In practice, the water level may not actually recover to the original rest level for a variety of reasons, such as

- The aquifer might be of limited extent with no recharge having taken place, in which case the recovered rest water level may be lower than the original one (conversely, if recharge occurs during the test, recovery may occur sooner than expected).
- Some confined aquifers are not perfectly elastic, so they behave differently on recovery (they have a different storage coefficient).
- In unconfined aquifers, air may be trapped in pore spaces on rewetting of the dewatered portion of the aquifer.

2.4.6. Correction of Pump Test Data

Pumping tests are used to determine in-situ properties of water-bearing formations and define the overall hydrogeological regime. Such tests can determine transmissivity (T), hydraulic conductivity (K), storativity (S), connection between saturated zones, identification of boundary conditions, and the cone of influence of a pumping well in a ground water extraction system .The water-level data collected before, during, and after the test must converted to drawdowns by subtracting the static water from the measured water level and should be expressed in appropriate units.

Before being used in the analysis, the observed water levels may have to be corrected for external influences (i.e. those not related to the pumping). To find out whether this is necessary, one has to analyse the local trend in the hydraulic head or water table. The most suitable data for this purpose are the water level measurements taken in. If, after the recovery period, the same constant water level is observed as during the pre-testing period, it can safely be assumed that no external events influenced the hydraulic head during the test. If, however, the water level is subject to unidirectional or rhythmic changes, it will have to be corrected. Unidirectional variation is when the aquifer is be influenced by natural recharge or discharge, which will result in a rise or a fall in the hydraulic head. By interpolation from the hydrographs of the well and the piezometers, this natural rise or fall can be determined for the pumping and recovery periods. This information is then used to correct the observed water levels. Rhythmic fluctuations of the hydraulic head may be atmospheric pressure. Hydrographs of the well and the piezometers, covering sufficiently long pre-test and post-recovery periods, will yield the information required to correct the water levels observed during the test.

2.4.6.1. 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:

$$S_{cor} = s(1 - \frac{S}{2D}) \qquad (2.3)$$

Where;

- S_{cor} is the corrected drawdown,
- s is observed drawdown and

- D is the original saturated aquifer thickness.

However, this correction is based on the Dupuit-Forchheimer assumption (ground water flows horizontally and hydraulic gradient is equal to the slope of the water table). Neuman (1975) showed that this assumption is not valid for an unconfined aquifer until the later portion of the test when the drawdown matches the Theis type curve. Therefore, the correction is not recommended with early and intermediate data (Dawson and Istok, 1991).

2.4.6.2. Well Efficiency and Correction for Well Loss

The drawdown in a pumped well consists of two components: the aquifer losses and the well losses. Aquifer losses are the head losses that occur in the aquifer where the flow is laminar. They are time dependent and vary linearly with the well discharge. Well loss are associated with turbulent flows caused by flow through the well screen and flow inside of the well to the pump intake.

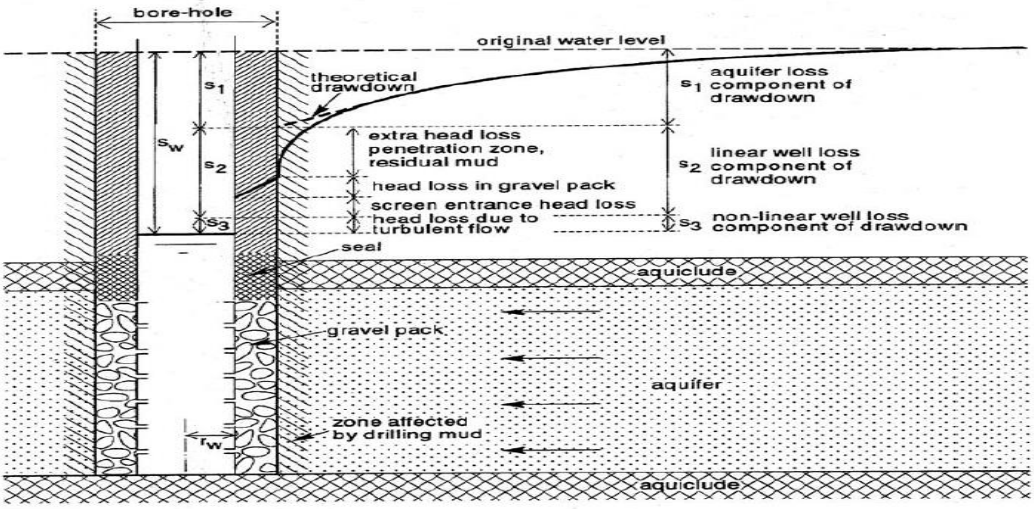


Figure 8.Various components of head losses in a pumped well.

The general equation describing the drawdown in a pumped well as function of aquifer/well losses and discharge rate can be written as

$$S= (B_1+B_2)\ Q + CQ^p \qquad \textbf{(2.4)}$$

Or

$$S=BQ+CQ^P \qquad \textbf{(2.5)}$$

Where;

- S is the total drawdown
- Q is the discharge

- B is the liner well loss coefficient
- C is the non- liner well loss coefficient
- P is exponent

Values of the three parameters *B*, *C*, and *P* in the above equation can be found from the analysis of so-called step-drawdown tests. Jacob (1947) used a constant value of 2 for the exponent *P*. According to Lennox (1966), the value of P can vary between 1.5 and 3.5, its value may be even higher in fractured rock aquifers. The value of P = 2 as proposed by Jacob is, however, still widely accepted.

It is apparent that well loss can be a substantial fraction of the total drawdown when pumping rates are large. With proper design and development of new well, well losses can be minimized. Clogging or deterioration of well screens can also increase well losses in old wells. Based on field experiences, Welton suggested criteria for the non-liner well loss coefficient C as shown in Table 3.

Table 3.Relation of well loss coefficient to well condition (after Walton).

Well loss coefficient (C)min^2/m^5	***Well conditions***
< 0.5	***Properly designed and developed***
0.5 to 1.0	***Mild deterioration or clogging***
1.0 to 4.0	***Severe deterioration or clogging***
>4.0	***Difficult to restore well to original capacity***

Knowing B and C, we can predict the drawdown inside the well for any realistic discharge Q at a certain time t (B is time-dependent). We can then use the relationship between drawdown and discharge to choose, empirically, an optimum yield for the well, or to obtain information on the condition or efficiency of the well. We can use to express the relationship between drawdown and discharge as the specific capacity of a well (Q/s) which describes the productivity of both the aquifer and the well. The specific capacity is not a constant but decreases as pumping continues (discharge is constant), and also decreases with increasing discharge. The well efficiency (η) is defined as the ratio of the aquifer head loss to the total head losses and it is expressed as a percentage;

$$\eta = \frac{BQ}{BQ+CQ^2} * 100 \qquad \textbf{(2.6)}$$

The above Equation can simply be interpreted as the theoretical drawdown (S_t) divided by actual drawdown (S_a) which is the sum theoretical drawdown and drawdown in the well caused by well loss (S_w). Thus,

$$\eta = \frac{S_t}{S_a}$$

Where: $S_a = S_t + S_w$ **(2.7)**

$$\eta = \frac{S_t}{S_t+S_w}$$

$$\eta(S_t + S_w) = S_t$$

$S_w = \left(\frac{1-\eta}{\eta}\right) S_t$ Or $S_t = \left(\frac{\eta}{1-\eta}\right) S_w$

$$S_a = \left(\frac{\eta}{1-\eta} + 1\right) S_w$$

$S_a = \left(\frac{1}{1-\eta}\right) S_w$ Thus:

$$S_w = (1-\eta)S_a \qquad \textbf{(2.8)}$$

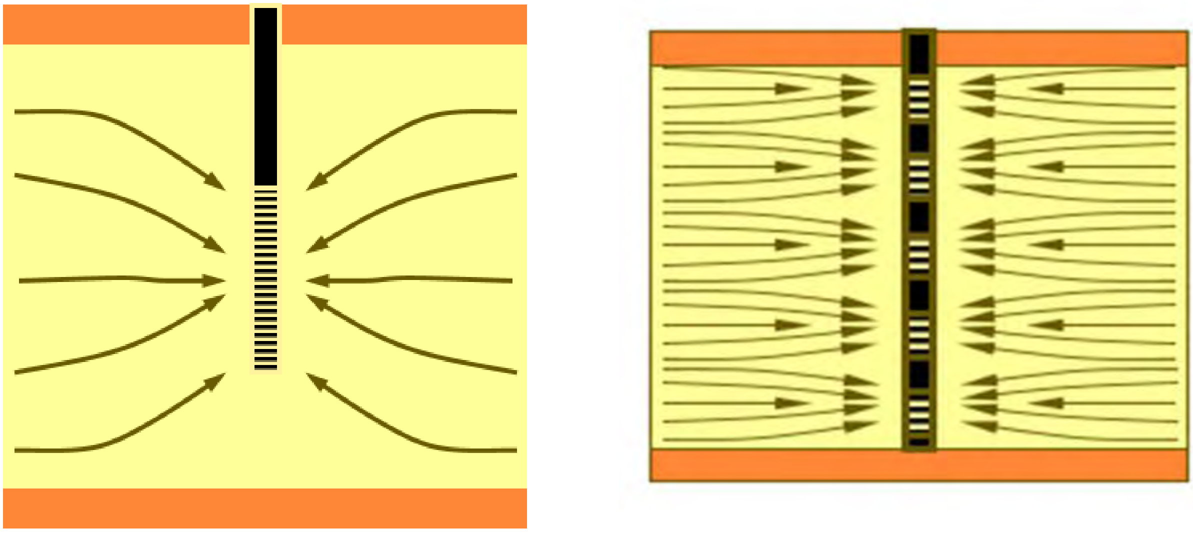
Before the observed drawdown can be used for any analysis the drawdown must be corrected. By using the well efficiency correction to the drawdown can be done to the observed drawdown by subtracting the well loss drawdown (S_w) from the observed well filed drawdown data.

2.4.6.3. Correction for Partial Penetration

It is quite common in developing aquifer drilling, entire aquifer thickness cannot be drilled, and as the thickness is not known .But most analysis for aquifer properties considers/assumes the well to penetrate the aquifer fully and this assumption does not satisfies pumping tests. Therefore, it is necessary to consider the effects of partial penetration.

There are two case where partial penetration may occur. The first case is when the aquifer is not fully penetrated and the second case arises from the casing arrangement of the well. This two case are show blow in figure 9.

Partial penetration of the well into the aquifer causes vertical component flow to happen in the vicinity of the well and which in turn causes a head loss in the pumping well. When the well only partially penetrates the aquifer, the average flow path length is increased so that a greater resistance to flow is encountered.



(a) **(b)**

Figure 9.Partial Penetration (a) when the aquifer is not fully drilled (b) due to Blind and Screen section of the well.

Kozeny (1933) contributes the following approximate reduction factor to correct specific capacity (Q/s) for the effects of partial penetrations.

$$F = \frac{L}{b}\left[1 + 7cos\left(\frac{\pi L}{2b}\right)\sqrt{\frac{r}{2L}}\right] \qquad \textbf{\textit{(2.9)}}$$

Where

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

The equation is valid for L/b < 0.5 and L/r > 30. Accordingly the required correction for the possible effect of partial penetration is conduct by considering the geometric mean of the each correction factors for the combination of blind and screen in casing arrangements of the wells, so that it can be used for the adjustment of the observed drawdown data for the analysis of such conditions.

2.5. Estimate Aquifers 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 analyse aquifer tests. Proper management of ground-water resources requires an accurate evaluation of the aquifer 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 this aquifer parameters by analysing 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 try to match the simulated curve with the observed data curve and try's to determine the aquifer parameters from the reading of this plots

In recent years, the computer technology has been widely used to determine the aquifer's 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 aquifer's parameters, such as Aquifer Test Pro, AQTESOLV, Aquifer Test Pro 3.5, Aquifer Win32, PEST.

In this thesis 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 an aquifer's hydraulic properties such as hydraulic conductivity, 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).

The capacities of an aquifer to transmit water under a hydraulic gradient and to yield water from storage when the water table or artesian pressure declines are generally expressed respectively in terms of a coefficient of transmissibility and coefficient of storage. Determination of these two constants are almost always involved in quantitative studies of groundwater problems. In fact, no matter what methods are adopted, the aquifer’s parameters should be unique. In this thesis, 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 parameters.

2.5.1. 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.

With the help of C.I. Lubin who developed the relation for changes in temperature due to the type of sours or sink that is analogous to a recharging or discharging well used the equation developed by H.S Carslow in 1921 about temperature at any point in an infinite palne derived the equation below

$$v_{(t)} = \frac{\lambda}{4\pi k} \int_{(x^2+y^2)/4kt}^{\infty} \frac{e^{-u}}{u}\, du \qquad \textbf{(2.10)}$$

With $u = \frac{x^2+y^2}{4kt}$

Where: $v_{(t)}$ is change in temperatures at any point x, y

λ is the strength of the source or sink (amount of heat added or taken)

k is Kalvin's coefficient of diffusivity

t is the time

The above equation can be immediately adapted to ground-water hydraulics to express the draw-down at any point at any time due to discharging a well. The coefficient of diffusivity, k, is analogous to the coefficient of transmissibility of the aquifer. The continuous strength of the sink is analogous to the discharge rate. Making these substitutions we have,

$$s = \frac{Q}{4\pi T} \int_{r^s S/4Tt}^{\infty} \frac{e^{-u}}{u}\, du \qquad \textbf{(2.11)}$$

With $u = \frac{r^2 S}{4Tt}$ **(2.12)**

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.

$$s = \frac{Q}{4kt} W(u) \qquad \textbf{(2.13)}$$

Where: $W(u) = \int_{u}^{\infty} \frac{e^{-u}}{u} du$ and $u = \frac{r^2 S}{4Tt}$ **(2.14)**

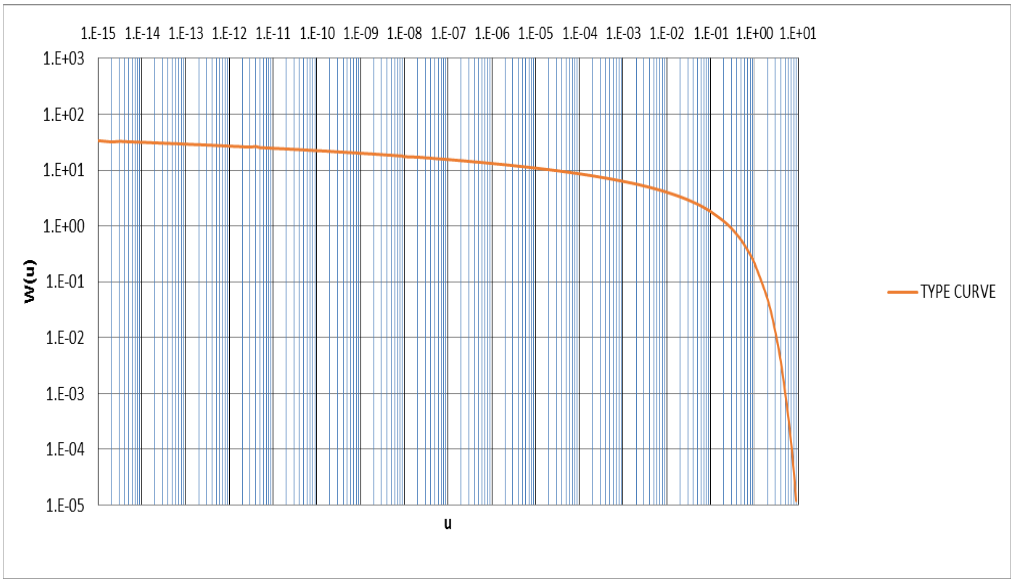


Figure 10.Theis well function W(u) vs 1/u for fully penetrating confined aquifer.

The Theis equation (analytic solutions for the radial) well flow do not allow direct calculation of the 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 r^2/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 r^2/t thus determined, S and T can be determined for the equations;

$$T = \frac{Q}{4\pi s} W(u) \quad \text{And} \qquad \textbf{(2.15)}$$

$$S = \frac{4Ttu}{r^2} \qquad \textbf{(2.16)}$$

2.5.2. 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 favourable circumstances. The Cooper and Jacob solution is an approximation of the Theis non-equilibrium method which is given by equation (2.12). The Theis well function, *W(u)*, in Equation (2.13) may be evaluated using the following infinite series expression

$$W(u) = 0.5772 + \ln(u) + u - \frac{u^2}{2*2!} + \frac{u^3}{3*3!} - \frac{u^4}{4*4!} + \cdots \qquad \textbf{(2.17)}$$

Where ***u*** is given in equation (2.12). For small values of ***u*** (i.e., large values of ***t*** and small values of ***r***), Cooper and Jacob found that the Theis well function may be approximated using only the first two terms in Equation (2.17):

$$W(u) \doteqdot -0.5772 - ln(u) \qquad \textbf{(2.18)}$$

The critical value of *u* for the Cooper and Jacob approximation is alternately given as $u \leq 0.05$ (Driscoll 1986) and $u \leq 0.01$ (Kruseman and de Ridder 1994). A smaller value for the critical value of *u* leads to a more accurate approximation of the Theis well function. Combining equation (2.13) and equation (2.18) Cooper and Jacob approximate drawdown in a non-leaky confined aquifer with the following linear equation:

$$s = \frac{Q}{4\pi T}\left(-0.5572 - ln\frac{r^2 s}{4Tt}\right) \qquad \textbf{(2.19)}$$

Converting to decimal logarithms, the Cooper and Jacob equation is as follows:

$$s = \frac{2.303Q}{4\pi T} log\left(\frac{2.25Tt}{r^2}\right) \qquad \textbf{(2.20)}$$

To apply the Cooper and Jacob equation 2.20, 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:

$$T = \frac{2.303Q}{4\pi\Delta s} \qquad \textbf{\textit{(2.21)}}$$

$$S = \frac{2.25Tt_o}{r^2} \qquad \textbf{\textit{(2.22)}}$$

Where Δs is the slope of the fitted line and t_o 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

2.5.3.1. R- Squared (R^2)

Uses of the Cooper-Jacob mothed 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:

$$R - \ squared = \frac{Explained\ variation}{Total\ variation} \qquad \textbf{(2.23)}$$

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 thesis not only for Cooper Jacobs's analysis but also in different topics that involves best fit lines.

2.5.3. 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

$$s' = \frac{Q}{4\pi T}\left[log\left(\frac{4Tt}{r_w^2 S}\right) - log\left(\frac{4Tt\prime}{r_w^2 S\prime}\right)\right] \qquad \textbf{\textit{(2.24)}}$$

Where r_w 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 2.24 can be simplified to:

$$s' = \frac{Q}{4\pi T} log\left(\frac{t}{t'}\right) \qquad \textbf{\textit{(2.25)}}$$

The graph of equation 2.25, 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:

$$T = \frac{2.3Q}{4\pi\Delta s\prime} \qquad \textbf{\textit{(2.26)}}$$

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 mothed 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 aquifer to be calculated, thereby providing an independent check on the results of the pumping test, although costing very little in comparison with the pumping test. 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

2.5.4. Estimation of Transmissivity and Storativity by AquiferTest Software

There are so many different software that are available for the determination of aquifer parameters in the hydrogeologist society to mention a few we have *AQTESOLV* and AquiferTest.AquiferTest is designed by hydrogeologists for hydrogeologists 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

AquiferTest Pro, designed for graphical analysis and reporting of pumping test and slug test data, offers the tools necessary to calculate an aquifer's hydraulic properties such as hydraulic conductivity, transmissivity, and storativity. AquiferTest 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. AquiferTest Pro also provides the tools for trends corrections, and graphical contouring water table drawdown around the pumping well. It allows you to calculate aquifer 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 AquiferTest for example Theis Method (confined), Theis with Jacobs Correction (Unconfined & Isotropic), Theis Recovery Test (confined), Hantush - Jacob –Walton (Leaky), Recovery Analysis-Agarwal Solution (1980). In addition to this the software performs analysis on Horizontal Well using a methods developed by Clots & Ramey (1986) and also performs analysis Slug Test Solutions using methods developed by Bouwer-Rice Slug Test method, Hvorslev Slug Test methods and Cooper-Bredehoeft-Papadopulos Slug Test methods.

For this paper three methods have be selected for the determination of transmissivity and storativity on the Legedadi Legetafo Ayat wells. This are Theis (1935) Cooper-Jacob Time-Drawdown (1946) Theis Recovery (1935)

3. Methodology

Legedadi deep Well water supply project is located at eastern part of Addis Ababa city which the layout of the water supply lines passes through the north catchments of Legedadi reservoir Catchment areas. It crosses a number of geomorphologic units of the upper catchments of Akaki river basin flood paths, minor and major streams crossing and the water supply lines which requires structures to convey design floods. The water supply lines the cross drainages catchments are found in similar climatic condition. The flood magnitudes at the cross drainage sites are the function of geomorphology, geology, rainfall, and soil and land use/ land cover of the catchments of the rivers and streams crossing the road.

A total of 40 well are to be drilled in Legedadi well fields with ten wells already completed The average target depths intended to drill at each site was 400m to test wells and 500 m to Pilot production wells. However there was possibility of increasing or decreasing the drilling depth by 10 % to test and pilot production It was arranged and managed to drill to the maximum depth up to 598m at some of the sites in the prospective area in order to get more information about the extent of the aquifer, water quality variation and the aquifer thickness. Table 4 below shows the details of the ten well in Legedadi well fields.

Table 4.Ten of Legedadi Deep Wells (from WWDSE).

No	Prospective site	Well Index	Well type	Coordinate UTM Zone 37 Adindan		Elev, m	Contractor	Depth, m	Static water level, m	Dynamic water level, m	Draw down, m	Q, test, (l/S)	Status
				UTM east	UTM north								
1	Legedadi	LLA1	Test well	493247	1001478	2399	CGCOC	432	7.3	132.1	124.8	15	Completed
2	Legedadi	LLA3	Test well	496269	1004908	2444		598	Artesian	14.31	16.12	52.03	Completed
3	Legedadi	LLA5	Test well	497374	1006185	2470		182	27.68	37.25	10.15	50	Completed
4	Legedadi	LLA6	Test well	497470	1006388	2510		440	32.2	111.1	78.9	38	Completed
5	Legedadi	LLA-PW5	Pilot produc.	496594	1006485	2486	ECC	550	14.24	86.72	72.48	45	Completed
6	Legedadi	LLA-PW1	Pilot produc.	497270	1004423	2472		504	12.86	27.82	14.96	78	Completed
7	Legedadi	LLA-PW4	Pilot produc.	494679	1006306	2492		504	19.80	26.38	6.58	88	Completed
8	Legedadi	LLA-PW3	Pilot produc.	500497	1007598	2474		372	29.4	32.79	3.43	97	Completed
9	Legedadi	LLA-PW7	Pilot produc.	499253	1006931	2510		378	33.84	70.65	36.81	80	Completed
10	Legedadi	LLA2	Test well	489977	1000102	2349	ANBG	500	9.7	88.4	78.7	20	Completed

3.1. Data Collection

Data collection is an important aspect of any type of research 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. Even though, for research purposes the collection of primary data is thought to give the research paper a more reliable outcome, but for this paper the collection of the pump test data as a primary data was not possible as the wells for the Legedadi Deep Well was were constructed and tested on November of 2012. Hence the raw pump test data such as the step drawdown test, constant pumping test and recovery test were collected by WWDSE and the three contractors that participated in the drilling and well construction processes (CGC Overseas Construction. Ltd, Al-Nile Business Group Plc and ECC Energy Plc.) More effort was put to collected primary data thus site visit was conducted to collect the coordinate for each well and to see the condition of each well where in.

The secondary data collection for this research 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.

The data collected from field investigation and office work are tuned and made ready for computer code that aids for producing result such as Aquifer Test. The source from which the single wells pumping test data is gathered from WWDSE who has accepted the contract of Legedadi Deep Well Project construction. The data collected from WWDSE contains 10 well data out of which has for five wells (LLA-1, LLA-6, LLA-PW1, LLA-PW5 and LLA-PW7) have the raw Step Drawdown Test data was selected and for the remaining five wells (LLA-2, LLA-3, LLA-5, LLA-PW3 and LLA-PW4) the raw Step Drawdown Test data was not used due to the difficulty in acquiring these data.

3.2. Data Analysis

After the raw pumping and GPS data was collected the process of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions, and supporting decision-making was conducted. The entire analysis made was for the determination of the physical characteristics of the aquifers, such as the aquifer's design discharge, transmissivity and storage coefficient (storativity) are computed. The determination the aquifers parameters for each well is concluded via curve–fitting by EXCEL 2013 tool and Aquifer Test 2016.1. The obtained hydraulic parameters were compared with the parameters obtained in their original (applied) reports.

There are different method used for the determination of the aquifer physical characteristics. Three common methods that are used in this thesis are: -

- Theis's Curve-Fitting Method,
- Cooper and Jacob Drawdown versus Time Graph and
- Residual Drawdown versus Time Graph

For comparison purpose for the uncorrected pumping test data Transmissivity and Storativity was also determined with the three methods by using both the Excel 2013 and Aquifer Test Pro.

3.2.1. Estimate Aquifers Parameters and Pumping test Analysis

Due to the fact that more than three unknown variables in the any drawdown calculation equations exist, the use of sample analytical method for the determination aquifer parameters is a difficult task. Thus, for this study analyzing aquifers test data for the determination of its parameters is done by matching the measured drawdown with standard simulated type - curve in combination with analytical method. But first in order to see what kind of aquifer (confined or unconfined) can be expected, the to use the curve fitting method drawdown verses time graph and a log-log graph of the measured drawdown as a function of time since pumping started was plotted for each well and compered with the standard type curves. Besides, the recovery test data analysis on the basis of time the water took to recover to its static level will give a basic idea the kind of aquifer to expect.

3.2.1.1. Adjustment of Pump Test Data

Adequate and reliable estimates of aquifer parameters are of utmost importance for proper management of vital groundwater resources. The pumping (aquifer) test is the standard technique for estimating various hydraulic properties of aquifer systems, viz., transmissivity (*T*) and storage coefficient (*S*), for which the graphical method is widely used. And also data from recovery phase are available to interpret the well parameters.

In this thesis, before the interpretation of each pumping well was done for the determination of the aquifer parameters, adjustment to the data was conducted in two ways:-

- Correction on drawdown using efficiency of the well,
    - Here correction was conducted for wells LLA-1, LLA-6, LLA-PW1, LLA-PW5 and LLA-PW7 using the step drawdown data collected from WWDSE.
    - From the step drawdown test for each well the efficiency of the wells was calculated and from the well efficiency the drawdown caused by well loss by determined and subtracted from the observed drawdown and the actual drawdown is tabulated and for analysis.
- Correction on drawdown for partial penetration,
    - Here correction was conducted for well LLA-2, LLA-3, LLA-5, LLA-PW3 and LLA-PW4 using the casing arrangement data collected form WWDSE.
    - By using the casing arrangement for each individual well the effect of partial penetration on the drawdown is determined by using a factor developed by Kozeny's correction factor. The Kozeny's correction factor is obtained by calculating the geometric mean of each screen and blind length combination. By multiplying the correction factor to the observed drawdown the actual drawdown is obtained as if the well was a fully penetrating well.

After the correction for the drawdown was done for each well by using appropriate method from the above stated methods correction was also applied unconfined aquifers. Thus, the measured drawdown data, observed in individual single well pumping test data, are corrected for issues that may have risen from the outside forces.

3.2.1.2. Theis Method - Curve Fitting Method

Theis no equilibrium equation allows determining the storage coefficient(*S)* and the transmissivity (*T)* of the aquifer. Thus, the Theis method was applied to each of the ten well for the determination of the transmissivity and storativity of both uncorrected and corrected drawdown. As this method includes the curve fitting of the type curve and drawdown vs time the values calculated can relatively differ from one person to the other as the manual curve fitting is difficult to obtain a perfect match.

For the purpose of attaching the result the manual curve fitting was done on Excel. The procedure was taken from Leelaruban and Padmanabhan (2013), An EXCEL Tool for teaching Theis method of estimating aquifer parameters. The step used to determine the transmissivity and the storativity of each of the ten wells based on this paper is as follows. The first step was plotting the drawdown (s) vs time (t) on a log-log graph then superimposing this plot on the type curve that is the same size and scale as the drawdown- time plot. Here the axes of both plots must be kept parallel. The next step is selecting a match point, which can be any two convenient points on the type curve (W (u) vs u) then determining the values of s and t of which the selected W (u) and u intersect the drawdown- time plot. Then this values are substituted in the transmissivity and storativity values given by Theis and calculated manually.

3.2.1.3. Cooper and Jacob Method.

It was noted by Cooper and Jacob that for small values of radius of observation and large values of time, u is small. Based on this, they suggested their own method for the determination of transmissivity and storativity. This graphical method of determining the two parameters is done by plotting the drawdown vs the logarithm of time which forms a straight line. By calculating the slope of the line and substituting in the equation driven by Cooper and Jacob the values of the transmissivity and storativity is calculated for the ten wells.

The major problem in evaluating the straight line method drawn by hand on a semi log paper of drawdown and time is that of determining the best fit line for the points on the plot. Thus to avoid this problem the MS. Excel was used in drawing this best fit line and to measure the accuracy of this best fit line.

3.2.1.4. The Recovery Method

Observing change water level as function of recovery time with respect to original water level after pumping of the well is complete is one set of data that will improve the accuracy of the determination of transmissivity of the aquifer. One of the method of determining the transmissivity of the aquifer is the Residual drawdown/Recovery method. If the set of data observed during recovery are precise, the result obtained by this method can be the best result of transmissivity.From the ten wells data that were collected in the determination of the aquifer parameters, only on well LLA-5 was not observed (it was not included in the raw pumping test data on WWDSE report.) for the rest nine wells the recovery was recorded.

Based on the data collected the transmissivity was calculated for each of the nine wells and was done as follows Frist the data for each observed value of drawdown, calculate the corresponding value of t/(t-t') was calculate from the time the pumping was stopped, where t' is the time at which the pumping was stopped.
Then for each of the nine wells plot of drawdown versus t/ (t-t') was drown on semi-log paper (t/ (t-t') on the logarithmic scale) using Excel. Finally fit a straight line through the plotted points and determine the slope of the straight line. By substituting the observed slope and the discharge of each well in the transmissivity in equation value for each well is determined.

3.2.1.5. Estimation of Transmissivity and Storativity by AquiferTest Software

The use of computer software and models in every aspects of human social life have 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.

AquiferTest is designed to automate the most common tasks that hydrogeologists 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.

In Aquifer Tests software, the following analysis methods are used for pumping tests analysis:-

- Theis (1935)
- Cooper-Jacob Time-Drawdown (1946)
- Theis Recovery (1935)

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 aquifer 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 ten wells data that ware constructed and tested on Legedadi Deep Well project.

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. Here also by using the time range defining tool in the software the recovery period data has be removed. In addition to this the Cooper –Jacob method was applied to both the corrected and uncorrected pumping test data for the ten wells.

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 was entered the software use the semi-log plot residual drawdown vs time and calculates the transmissivity of the wells. Theis Recovery method was applied to the both the corrected and uncorrected residual drawdown on all of the well except LLA-5 since the recovery data for this well was not collected.

The Aquifer Test software was included in this research paper as one way of comparing the results obtained by manual curve fitting method applied on MS Excel 2013.

4. Results and Discussion

As the main goal of this paper is to see the interpretive techniques used in the determination 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 the three method (Theis, Cooper-Jacob and a recovery method). Also here will discuss the values obtained from the WWDSE and comparing them with the result determined in this paper.

4.1. Basic Description of each of the Wells

As per the contact agreement with AAWSSA, three drilling campiness were given the task of drilling and contraction of wells located at the Ledadadi, Legetafo and Ayat areas. This were CGC Overseas Construction. Ltd which was given the task of drilling and constructing four wells (LLA-1, LLA-3, LLA-5 and LLA-6), Al-Nile Business Group Plc was give one well for drilling and constriction (LLA-2) and ECC Energy Plc was give the contract for drilling and construction of five pumping well (LLA-PW1, LLA-PW3, LLA-PW4, LLA-PW5 and LLA-PW7). The location of this ten wells in Legedadi well fields are sparsely distrusted throughout the Legedadi area. This ten wells are located in two bordering regions: In Addis Ababa City Government/ Addis Ababa City Administration and in Oromia Region. The basic well characteristics of each of the ten wells are shown in table 5.

After drilling of each well is concluded, the wells were slotted with water level observation pipes as all of the ten wells are considered as a single well test. And also permanent casings, and couplings for open wells were installed in all the wells after completion of drilling and logging. Some of the wells were left open and uncased on the lower part when the physical property of the rocks of the well walls are found to be sound and free from collapsing. In some of the wells, such as LLA5 and LLA 6 installation of casings was difficult because of clay swellings. After the completion of casing installation the annular space between the wall of the well and the casing packed with 15m^3 gravel. These gravels are clean, well rounded grains of uniform size which ranges between 9-12mm and they are free from soluble materials.

Table 5.Basic well characteristics of Legedadi deep wells.

Well Index	Well type	Coordinate		Elev, m	Depth, m	SWL	Q, test, (l/S)
		UTM east	UTM north				
LLA1	Test well	493247	1001478	2399	432	7.3	15
LLA3	Test well	496269	1004908	2444	598	Artesian	52.03
LLA5	Test well	497374	1006185	2470	182	27.68	50
LLA6	Test well	497470	1006388	2510	440	32.2	38
LLA-PW5	Pilot Production	496594	1006485	2486	550	14.24	45
LLA-PW1	Pilot Production	497270	1004423	2472	504	12.86	78
LLA-PW4	Pilot Production	494679	1006306	2492	504	19.8	88
LLA-PW3	Pilot Production	500497	1007598	2474	372	29.4	97
LLA-PW7	Pilot Production	499253	1006931	2510	378	33.84	80
LLA2	Pilot Production	489977	1000102	2349	500	9.7	20

4.2. Well efficiency

Step drawdown tests are usually lids us to assess well/aquifer-loss performance and for guidance in decide on optimum pumping rate for a later constant-rate pumping test. Since raw step drawdown data was available for five well in the Legedadi Deep Well project, the well efficiency of these wells have been determined and comparison of was done with the result collected from WWDSE. This values are tabulated on table 6 below.

Table 6.Well efficiency of five well of Legedadi Deep Wells.

Well	Well Efficiency	
	From WWDSE	Calculated
LLA-1	Poor	62.42%
LLA-6	22.10%	22.60%
LLA-PW1	64.70%	69.60%
LLA-PW5	73.75%	52.53%
LLA-PW6	70.00%	25.03%

Well efficiency range in the hydrogeologist's society is defined to be within the range of 65% to 85%. As it can be seen in table 5 well LLA-6 and well LLA-PW7 are well below the defend range.

Step drawdown test was performed on LLA-6 using discharges of 15lit/s, 20lit/s, 25lit/s and 38lit/s. The liner well loss coefficient (B) and the non- liner well loss coefficient (C) was determined from this step drawdown test was calculated to be 0.521 and 0.0446 respectively. Using this values the efficiency was determined for each of the corresponding discharges. A constant pumping rate of 38 lit/s for LLA-6 was used as pumping rate, which resulted in a well efficacy of 23.51%. This low well efficiency could have been avoided with low discharging rate as it can be observed in the table 7 below.

Table 7.Relation between discharge and well efficiency for well LLA-6.

∆	Sum of ∆	Q	Sw/Q	B	C	Efficiency
-	-	10		5.21E-01	4.46E-02	53.88%
14.59	13.9	15	0.9267	5.21E-01	4.46E-02	43.78%
19.04	17.30	20	0.865	5.21E-01	4.46E-02	36.87%
10.41	10.34	25	0.4138	5.21E-01	4.46E-02	31.85%
16.66	35.00	38	0.921	5.21E-01	4.46E-02	23.51%

In the WWDSE report the recovery period using 38 lit/s was only 4 minutes for the well to recover 100% completely. Thus, based on this it was recommended the well constant discharge be set to 40 lit/s.

In case of well LLA-PW7 the calculated and the one reported in the WWDSE document have big difference in well efficiency. The figure 11 below show the step drawdown test with its step drawdown given in WWDSE document. Based on this delta values from the figure reported in WWDSE, the efficiency was calculated and the result of well efficiency was close to on the one calculated for this research using the row step drawdown test for LLA-PW7, i.e. not in 70% range given in the report but close to 25% range. Table 8 shows values for B, C and the efficiency from the WWDSE report calculated based on figure 11 by WWDSE and Table 9 shows values of B, C and the efficiency calculated by this research based on figure

11. The chart plot of figure 12 is used for the determination of B and C values is based on delta values from figure 11.

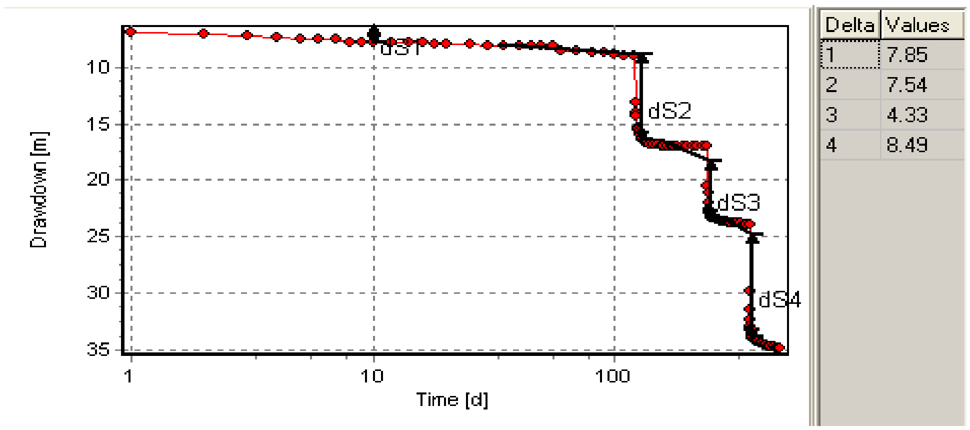


Figure 11.Step drawdown Test and Delta values for well LLA-PW7 given in WWDSE report.

Table 8.Values of B, C and well efficiency from WWDSE for LLA-PW7 based on figure 10.

B	C	Q	CQ	B+CQ	E=B/B+CQ	%
2.45E-03	1.93E-07	4320	8.34E-04	3.28E-03	7.46E-01	74.60%
2.45E-03	1.93E-07	5184	1.00E-03	3.45E-03	7.10E-01	71.00%
2.45E-03	1.93E-07	6048	1.17E-03	3.62E-03	6.77E-01	67.70%
2.45E-03	1.93E-07	6912	1.33E-03	3.78E-03	6.47E-01	64.70%

Table 9.Values of B, C and well efficiency calculated for LLA-PW7 based on figure 10.

∆	Sum of ∆	Q	Sw/Q	B	C	Efficiency
7.85	7.85	4320	0.001817	1.60E-03	8.00E-07	32%
7.54	15.39	5184	0.002969	1.60E-03	8.00E-07	28%
4.33	19.72	6048	0.003261	1.60E-03	8.00E-07	25%
8.49	28.21	6912	0.004081	1.60E-03	8.00E-07	22%

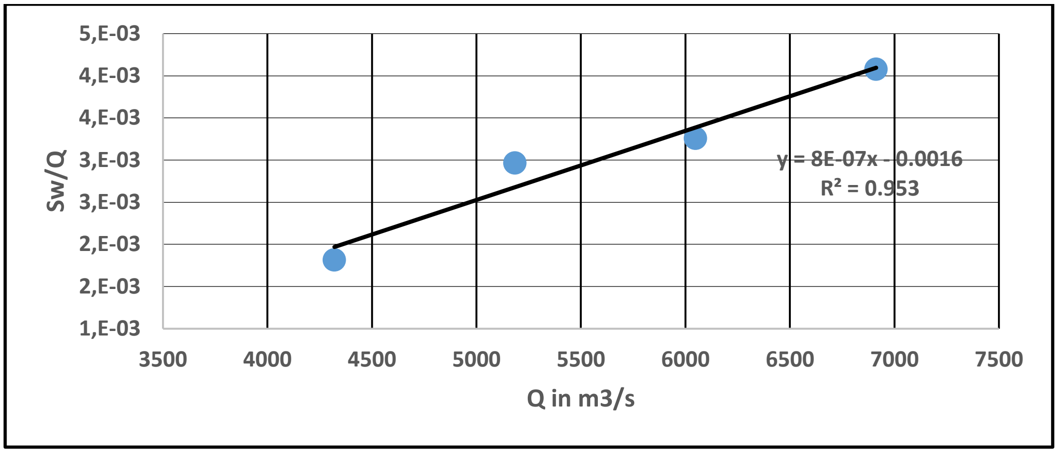


Figure 12.Sw/Q vs Q plot based on delta values from figure 10.

The actual values of the well efficiency determined by step drawdown test for a discharge values of 50 lit/s 60lit/s 70 lit/s and 80 lit/s for LLA-PW7 for a constant pumping rate of 80 lit/s is 25.50%, which is well below the accepted well efficiency range. Values of the well efficiency of LLA-PW7 with the corresponding discharge values is tabulated in table 10 below.

Table 10.Discharge and well efficiency of well LLA-PW7.

Discharge (lit/s)	Well Efficiency
50	34.83%
60	30.81%
70	27.62%
80	25.04%

The drawdown in a pumped well consists of two components: the aquifer losses and the well losses. By using the well efficiency the drawdown was corrected for both LLA-6 and LLA-PW7 which resulted a much reduced value drawdown in both of the wells.

The well efficiency analysis of the remaining three wells is included in the appendix with the raw step drawdown test. Also the raw step drawdown data for all five wells is included.

4.3. 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. During construction of wells the installations of blind and screen with in the drilled well case the well to be a partially penetrated well. Based on the arrangement of the blind and screen the observed drawdown is adjusted for wells in Legedadi Deep Wells. Since the step drawdown test data was not included in the WWDSE report document for LL-2, LLA-3, LLA-5, LLA-PW4and LAA-PW5 correction for the drawdown of this was established using the casing arrangement of each of the five wells based on Kozeny Correction factor. As it can be observed from table 11 below the correction factor of LLA-2 and LLA-5 have low correction values which may have be due to the casing arrangements not having the best blind and screen combinations. This low correction factor values have caused a decrease in the observed drawdown with more than 55% than original assumed to be.

Table 11. Kozeny correction for five of Legedadi Deep *Wells.*

Well	Kozeny Correction factor
LLA-2	0.447
LLA-3	0.794
LLA-5	0.374
LLA-PW3	0.720
LLA-PW4	0.680

The analyses used for the determination of the correction factor used in of all of the five well is attached in the appendix part with their casing arraignments collected form WWDSE.

4.4. Drawdown –Time Plots for Uncorrected and Corrected Drawdown

Based on the well efficiency, partial penetration and correction for unconfined aquifer the observed drawdown for all of the ten well have been adjusted. For wells LLA-1, **LLA**-6, LLA-PW1, LLA-PW5 and LLA-PW7 combination of correction for well loss and unconfined aquifer was used. The plot of drawdown vs time for well LLA-1 is shown in figure 13 with the corrected and uncorrected drawdown. The plots for the reaming four wells is given in the appendix part.

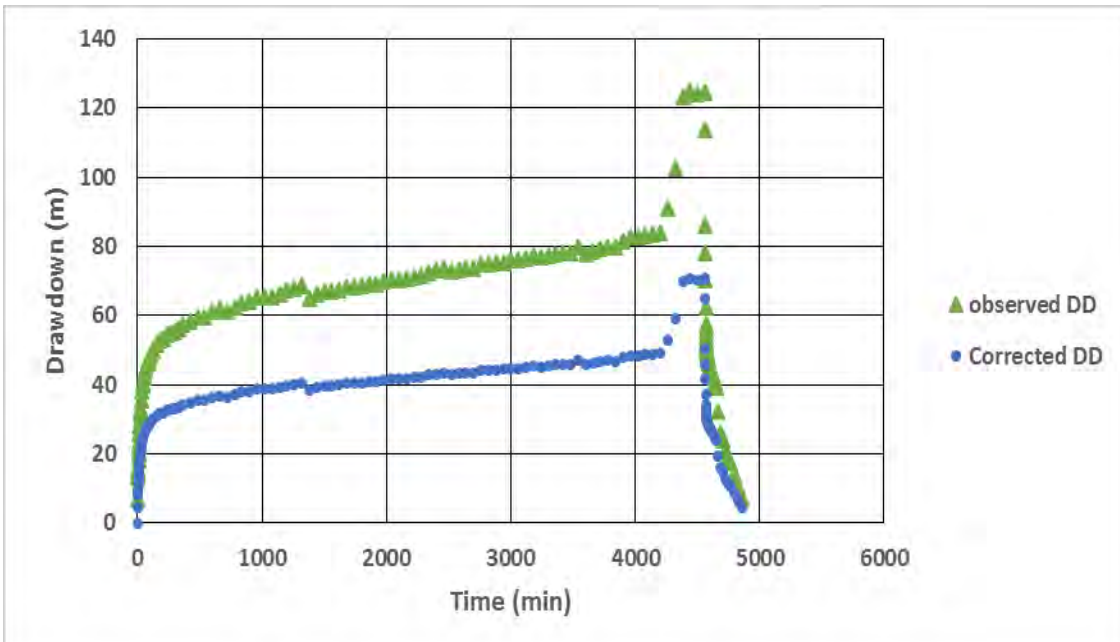


Figure 13.Plot for observed and corrected drawdown for LLA-1.

For wells LLA-2, LLA-3, LLA-5, LLA-PW3 and LLA-PW4 correction is done for both partial penetration and unconfined aquifer. By using this, the drawdown vs time plot for both the uncorrected and corrected drawdown was done for this five wells and figure 14 shows plot for observed and corrected drawdown for LLA-2.

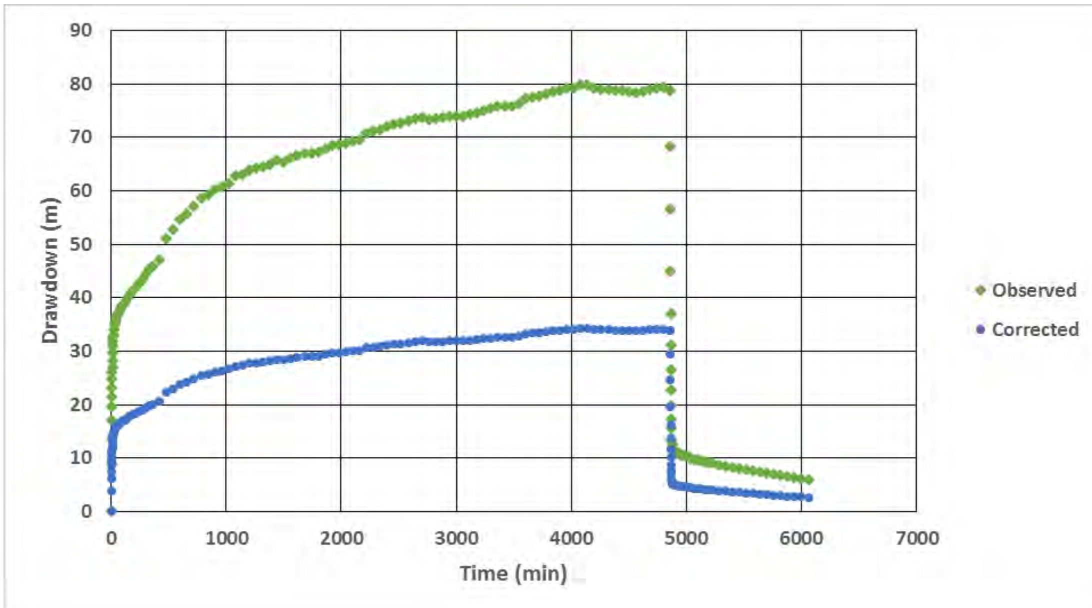


Figure 14. Plot for observed and corrected drawdown for LLA-2.

4.5. Transmissivity and Storativity Values for Legedadi Deep Wells.

As the general objective of this research is determining the transmissivity and discussing on their interpretive techniques, transmissivity values of each ten well have be calculated by using the Theis, Cooper-Jacob and the recovery method with the both the corrected drawdown and uncorrected drawdown using Excel 2013 and Aquifer Test software. This results are also compared with the values collected from WWDSE.

As stated in the introduction part the determination of storativity is another major goal of this research. Consequently, the storativity values of each of the ten wells have be calculated by using the Theis method and Cooper-Jacob method. Since all of the ten wells in the Legedadi Deep Well project do not have observation wells, the determination of storativity using Theis recovery method has not be done.

Due to this observation pipes installed between the wall of the well and steel casing before the gravel pack, the storativity determined using single well test is usually a difficult task and to state that the result calculated can express the true nature aquifer characteristic is cynical. Keeping in mind the previously stated statement the storativity of ten wells has been calculated for Legedadi Deep well and are discussed below.

4.5.1. Transmissivity and Storativity Values Using Cooper-Jacob Method.

The Cooper-Jacob method is applied for all of the ten wells in Legedadi deep 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 Trendline 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 all of the ten well is show in figure A-19 to figure A-28 in the appendix part. Figure A-19 to figure A-23 show the semi-log plots of the observed drawdown and corrected drawdowns where the correction is for well loss drawdown. And figure A-24 to figure A-28 show the semi-log plots of the observed drawdown and the corrected drawdown where the correction is done for the effects of partial penetration. The result of the transmissivity and storativity values for five wells, using the Cooper-Jacob method, is tabulated in table 12 below for both the uncorrected and corrected drawdown. Here well efficiency is used to determine the drawdown loss in the well. Whereas, table 13 shows the transmissivity and storativity values for the remaining five wells with correction done to the drawdown using Kozeny correction factor. In both table the drawdown correction also includes correction for unconfined aquifer.

Table 12.Transmissivity and storativity values for five wells using Cooper-Jacob method using well efficiency.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Well Efficency	Best Fit Line for observed DD			Best Fit Line for corrected DD			Estimated to in minutes		Transmissivity m2/day		Storativity	
				Slope	Intercept	R-square	Slope	Intercept	R-square	For observed DD	For corrected DD	For observed DD	For corrected DD	For observed DD	For corrected DD
LLA-1	1296	0.152	62.42%	8.979	4.018	0.9878	5.1996	3.2057	0.987	0.64	0.54	11.49	18.22	0.452	0.6652
LLA-6	3283.2	0.254	22.60%	0.4782	74.872	0.9553	0.2322	16.341	0.447	1.06E-68	2.61E-31	546.36	1125.18	1.00E-67	9.785E-31
LLA-PW1	6739.2	0.178	69.60%	0.7574	7.6105	0.8925	0.5183	5.2763	0.931	4.33E-05	3.79E-05	708.06	1035.046	1.51E-03	1.93E-03
LLA-PW5	3888	0.178	52.53%	0.7993	65.375	0.8062	0.3836	32.958	0.8062	3.01E-36	4.86E-38	387.09	806.56	5.75E-35	1.93E-36
LLA-PW7	6912	0.178	25.03%	0.916	29.492	0.8058	0.2236	7.2997	0.8045	1.04E-14	6.64E-15	600.48	2459.26	3.12E-13	8.05E-13

Table 13.Transmissivity and storativity values for five wells using Cooper-Jacob method using Kozeny correction factor.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Kozeny correction factor	Best Fit Line for observed DD			Best Fit Line for corrected DD			Estimated to in minutes		Transmissivity m2/day		Storativity	
				Slope	Intercept	R-square	Slope	Intercept	R-square	For observed DD	For corrected DD	For observed DD	For corrected DD	For observed DD	For corrected DD
LLA-2	6739..2	0.1525	0.447	8.5749	4.1633	0.9685	3.6556	2.2055	0.9679	6.15E-01	5.47E-01	16.04	37.616	7.00E-01	1.38E+00
LLA-3	4492.8	0.25	0.794	0.2149	12.219	0.7481	0.1676	9.6233	0.7477	2.03E-25	1.16E-25	1664.64	2134.438	8.00E-24	6.19E-24
LLA-5	4320	0.1525	0.374	0.8224	2.8135	0.9621	0.3023	1.0565	0.9625	3.26E-02	3.03E-02	418.01	1137.197	9.00E-01	2.32E+00
LLA-PW3	8380.8	0.178	0.720	0.2108	1.5366	0.9525	0.1508	1.1047	0.9527	6.83E-04	6.58E-04	3163.77	4422.565	1.07E-01	1.44E-01
LLA-PW4	7603.2	0.178	0.680	0.2007	4.6904	0.9612	0.1354	3.1797	0.9613	7.09E-11	5.90E-11	3014.67	4468.56	1.05E-08	1.30E-08

- **DD-Drawdown**

4.5.2. Transmissivity and Storativity Values Using Theis Method

The Theis method was applied for all of the ten wells for Legedadi deep well. 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 r^2/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 ten well is show in the appendix. From figure A -28 to figure A-38. Figure A-29 to figure A-33 are plots were the drawdown plots contain the correction to for well loss using well efficiency and correction for unconfined aquifer, where are figure from A-43 to figure A-38 contains the drawdown pots were where the effects of partial penetration is considered in addition to unconfined aquifer correction. The result of the transmissivity values using the Thesis method is tabulated in table 14 and table 15 for both the corrected drawdown and uncorrected drawdowns of each the ten well.

Table 14.Transmissivity and Storativity values for five wells using the Theis method with well efficiency.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Well Efficency	Points Slected in Type Curve				Points Slected in S Curve				Transmissivity m2/day		Storativity	
				For observed DD		For corrected DD		For observed DD		For corrected DD		For observed DD	For corrected DD	For observed DD	For corrected DD
				W(u)	u	W(u)	u	s	r^2/t	s	r^2/t				
LLA-1	1296	0.152	62.42%	10	1.00E-02	10	1.00E-02	99	1.85E-03	55	1.70E-04	10.42	18.75	1.56E-01	3.60E+00
LLA-6	3283.2	0.254	22.60%	10	1.00E-13	10	1.00E-12	7.1	1.90E-03	6.2	1.80E-04	367.98	421.40	7.75E-08	6.50E-09
LLA-PW1	6739.2	0.178	69.60%	10	1.00E-10	10	1.00E-13	5.5	1.90E-04	2.9	1.20E-05	975.07	1849.27	1.43E-06	2.49E-08
LLA-PW5	3888	0.178	52.53%	10	1.00E-13	10	1.00E-13	24	1.20E-04	11.0	1.50E-04	128.92	281.27	2.98E-10	5.21E-10
LLA-PW7	6912	0.178	25.03%	10	1.00E-09	10	1.00E-13	10.5	1.52E-03	2.9	1.50E-04	530.39	1920.39	9.68E-07	3.56E-09

Table 15.Transmissivity and Storativity values for five wells using the Theis method with Kozeny correction factor.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Kozeny correction factor	Points Slected in Type Curve				Points Slected in S Curve				Transmissivity m2/day		Storativity	
				For observed DD		For corrected DD		For observed DD		For corrected DD		For observed DD	For corrected DD	For observed DD	For corrected DD
				W(u)	u	W(u)	u	s	r^2/t	s	r^2/t				
LLA-2	6739..2	0.1525	0.447	1	1.00E-03	1	1.00E-04	11	9.00E-05	3.9	1.70E-05	9.38	26.44	2.89E-01	4.32E-01
LLA-3	4492.8	0.25	0.794	100	1.00E-13	10	1.00E-13	45	1.02E-05	3.9	1.72E-07	794.96	917.26	2.16E-08	1.26E-06
LLA-5	4320	0.1525	0.374	100	1.00E-08	10	1.00E-04	38	1.18E-04	2.0	1.00E-02	904.67	1718.87	2.13E-04	4.77E-02
LLA-PW3	8380.8	0.178	0.720	10	1.00E-07	10	1.00E-08	1.9	1.03E-04	1.4	1.85E-05	3510.12	4763.73	9.47E-03	7.15E-03
LLA-PW4	7603.2	0.178	0.680	10	1.00E-13	10	1.00E-11	2.1	1.65E-05	1.5	1.38E-04	2881.16	4033.62	4.85E-08	8.12E-07

- **DD-Drawdown**

4.5.3. Transmissivity Values Using Recovery Method

The transmissivity values for all of the well with the exception of well LLA-3 have been determined using there recovery drawdown data. For LLA-3 this method was not applied because the raw recovery drawdown data was could not be collected. And also for well LLA-6 the recovery period was only four minutes thus the transmissivity result for LLA-6 deviates from the one calculated from the Cooper-Jacob and Theis method for LLA-6. By using the time when pumping was stop (t'), the semi-log plot of the residual drawdown vs t/ (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 t/(t-t'). Table 16 and Table 17 show the result for the transmissivity of both the corrected and the uncorrected drawdown for the wells. Figure A-39 through figure A-47 in the appendix show the residual drawdown vs t/(t-t') for nine of the wells. Figure A-39 to figure A-42 are plots were the residual drawdown plots contain the correction to for well loss using well efficiency and correction for unconfined aquifer, where are figure from A-43 to A-47 contains the drawdown plots were where the effects of partial penetration is considered in addition to unconfined aquifer correction.

Storativity value by this method cannot be determined as in all case of the wells, single well test is conduct

Table 16.Transmissivity and values for five wells using the Recovery method with well efficiency.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Well Efficency	Best Fit Line for observed DD			Best Fit Line for corrected DD			Transmissivity m2/day	
				Slope	Intercept	R-square	Slope	Intercept	R-square	For observed DD	For corrected DD
LLA-1	1296	0.152	62.42%	13.649	-23.732	0.8958	7.88	-12.726	0.901	7.56	13.09
LLA-6	3283.2	0.254	22.60%	17.049	-122.61	0.8711	3.9821	-28.638	0.876	15.32	65.61
LLA-PW1	6739.2	0.178	69.60%	0.9285	0.0825	0.9059	0.6423	0.0646	0.9072	577.59	834.95
LLA-PW5	3888	0.178	52.53%	0.268	0.474	0.9287	0.1405	0.2496	0.2496	1154.47	2202.12
LLA-PW7	6912	0.178	25.03%	0.5057	-2.2684	0.8984	0.1265	-0.567	0.8984	1087.68	4348.14

Table 17.Transmissivity and values for five wells using the Recovery method with Kozeny correction factor.

Well Index	Pumping rate (m3/day)	Radius of well in meters	Kozeny correction factor	Best Fit Line for observed DD			Best Fit Line for corrected DD			Transmissivity m2/day	
				Slope	Intercept	R-square	Slope	Intercept	R-square	For observed DD	For corrected DD
LLA-2	6739..2	0.1525	0.447	5.0732	-6.618	0.5952	2.211	-2.7987	0.6004	27.11	62.19
LLA-3	4492.8	0.25	0.794	-	-	-	-	-	-	-	-
LLA-5	4320	0.1525	0.374	0.1792	-1.0928	0.9898	0.067	-0.4088	0.9898	1918.39	5130.97
LLA-PW3	8380.8	0.178	0.720	0.1564	0.4372	0.9668	0.1123	0.3146	0.9667	4264.21	5938.76
LLA-PW4	7603.2	0.178	0.680	0.1608	0.3778	0.9664	0.1092	0.257	0.9664	3762.71	5540.69

It is a known for a fact that any particular aquifer should have only one transmissivity and storativity values for the same well drilled in its vicinity at any given time that can describe the aquifer. But as it can be observed from the three methods used the values for same well different values of transmissivity and storativity is observed. Table 18 summarizes the transmissivity of the five well with correction done using well efficiency as an adjustment for the drawdown whereas table 19 uses Kozeny correction factors to for the correction of the drawdown. The tables also show values from Aquifer Test pro software and some values transmissivity from WWDSE results.

As shown in table 20 and table 21 summery of the storativity of all of the ten wells is show. In table 20 shows the storativity of five wells with correction done to the drawdown using there corresponding well efficiency and table 21 shows storativity of the five wells with correction done to the observed data considering partial penetration. As it is highlighted in table 21 storativity values for LLA-2 and LLA-5 have storativity values greater than one, which is not acceptable in hydrogeological society. This values may have risen due to that fact observed drawdown data when the constant pumping test is being conducted have not been recorded correctly. In some cases the storativity values are close to zero they may not even be considered as reliable values.

Table 18.Transmissivity of the five wells for Legedadi Deep Wells by using well efficiency as a correction factor on the drawdown.

Transmisivity m^2/day										
Well	Effecincy (η)		Method Used		Excle 2013		AquiferTest 2016.1		Geometric mean	
	From WWDSE result	Calculated		From WWDSE result	With No Drawdown Correction	With Drawdown Correction	With No Drawdown Correction	With Drawdown Correction	GeoMean No Correction	GeoMean Correction
LLA-1	-	62.42%	Cooper - Jacob	1.45E+01	1.149E+01	1.8221E+01	1.11E+01	1.82E+01	9.58	16.28
			Theis		1.042E+01	1.875E+01	1.05E+01	1.81E+01		
			Theis Recovery	1.44E+01	7.556E+00	1.3088E+01	7.55E+00	1.31E+01		
LLA-6	22.10%	22.60%	Cooper - Jacob		5.464E+02	2.3245E+03	2.53E+02	1.17E+03	261.85	1184.91
			Theis	1.95E+02	3.680E+02	4.2140E+02	2.71E+02	1.20E+03		
			Theis Recovery		1.5325E+01	6.5611E+01	1.532E+01	6.5612E+01		
LLA-PW1	64.70%	69.60%	Cooper - Jacob	6.97E+02	7.081E+02	1.0350E+03	7.07E+02	1.03E+03	511.55	861.76
			Theis		9.751E+02	1.8493E+03	4.83E+02	7.45E+02		
			Theis Recovery	6.32E+02	5.776E+02	8.3495E+02	3.92E+02	8.34E+02		
LLA-PW5	73.75%	52.53%	Cooper - Jacob	7.25E+02	3.871E+02	8.0656E+02	1.49E+02	3.06E+02	108.14	217.61
			Theis		1.289E+02	2.8127E+02	1.04E+02	2.13E+02		
			Theis Recovery	7.12E+02	1.154E+03	2.2021E+03	8.16E+01	1.58E+02		
LLA-PW7	70%	25.30%	Cooper - Jacob	1.20E+03	6.005E+02	2.4599E+03	6.08E+02	2.49E+03	642.92	2642.82
			Theis		5.304E+02	1.9204E+03	4.01E+02	1.72E+03		
			Theis Recovery		1.088E+03	4.3481E+03	1.09E+03	4.31E+03		

Table 19.Transmissivity of the five wells for Legedadi Deep Wells by using Kozeny correction factor as an adjustment factor on the drawdown.

Transmisivity m^2/day										
Well	Kozeny Correction factor		Method Used		Excle 2013		AquiferTest 2016.1		Geometric mean	
	From WWDSE result	Calculated		From WWDSE result	With No Drawdown Correction	With Drawdown Correction	With No Drawdown Correction	With Drawdown Correction	GeoMean No Correction	GeoMean Correction
LLA-2	-	0.4468	Cooper - Jacob	1.07E+01	1.604E+01	3.7616E+01	1.60E+01	3.76E+01	17.84	41.08
			Theis	-	9.376E+00	2.6444E+01	1.31E+01	2.97E+01		
			Theis Recovery	5.46E+00	9.446E+01	2.1333E+02	2.71E+01	6.21E+01		
LLA-3	-	0.7941	Cooper - Jacob	-	1.665E+03	2.1344E+03	1.66E+03	2.13E+03	1524.47	1958.06
			Theis	-	7.950E+02	9.1726E+02	1.40E+03	1.80E+03		
			Theis Recovery	-	-	-	-	-		
LLA-5	-	0.3743	Cooper - Jacob	4.09E+02	4.180E+02	1.1372E+03	4.18E+02	1.14E+03	693.73	1880.23
			Theis	-	9.047E+02	1.72E+03	4.16E+02	1.13E+03		
			Theis Recovery	-	1.918E+03	5.1310E+03	1.92E+03	5.16E+03		
LLA-PW3	-	0.7196	Cooper - Jacob	3.00E+03	3.164E+03	4.4226E+03	3.16E+03	4.42E+03	3051.12	4260.23
			Theis	-	3.510E+03	4.7637E+03	2.11E+03	2.95E+03		
			Theis Recovery	3.16E+03	4.264E+03	5.9388E+03	4.26E+03	5.93E+03		
LLA-PW4	-	0.6801	Cooper - Jacob	2.95E+03	3.015E+03	4.4686E+03	3.01E+03	4.46E+03	2946.37	4355.47
			Theis	-	2.881E+03	4.0336E+03	2.26E+03	3.35E+03		
			Theis Recovery	2.94E+03	3.763E+03	5.5407E+03	3.76E+03	5.53E+03		

Table 20.Storativity of the five wells in Legedadi Deep Wells by using well efficiency as a correction factor on the drawdown.

Storativity										
	Effecincy (η)		Method Used		Excle 2013		AquiferTest 2016.1		Geometric mean	
	From WWDSE result	Calculated		From WWDSE result	With No Drawdown Correction	With Drawdown Correction	With No Drawdown Correction	With Drawdown Correction	GeoMean No Correction	GeoMean Correction
LLA-1	-	62.42%	Cooper - Jacob		4.52E-01	6.65E-01	4.85E-01	5.00E-01	4.87E-01	6.19E-01
			Theis		1.56E-01	4.01E-01	4.90E-01	7.67E-01		
LLA-6	22.10%	22.60%	Cooper - Jacob		1.00E-67	2.20E-65	1.00E-29	1.00E-29	3.16E-30	3.16E-30
			Theis		7.75E-08	6.50E-09	1.00E-30	1.00E-30		
LLA-PW1	64.70%	69.60%	Cooper - Jacob		1.51E-03	1.93E-03	1.51E-03	1.93E-03	3.89E-17	3.89E-17
			Theis		1.43E-06	2.49E-08	1.00E-30	1.39E-03		
LLA-PW5	73.75%	52.53%	Cooper - Jacob		5.75E-35	1.93E-36	1.24E-11	8.24E-12	1.11E-09	1.11E-09
			Theis		2.98E-10	5.21E-10	1.00E-07	1.00E-07		
LLA-PW7	70.00%	25.30%	Cooper - Jacob		3.12E-13	8.15E-13	2.95E-13	7.61E-13	1.72E-10	1.72E-10
			Theis		9.68E-07	3.56E-09	1.00E-07	1.00E-07		

Table 21.Storativity of the five wells in Legedadi Deep Wells by using Kozeny correction factor as an adjustment factor on the drawdown.

Storativity										
	Kozeny Correction factor		Method Used		Excle 2013		AquiferTest 2016.1		Geometric mean	
	From WWDSE result	Calculated		From WWDSE result	With No Drawdown Correction	With Drawdown Correction	With No Drawdown Correction	With Drawdown Correction	GeoMean No Correction	GeoMean Correction
LLA-2	-	0.4468	Cooper - Jacob	1.44E+03	6.63E-01	1.38E+00	6.62E-01	1.38E+00	3.79E-04	1.30E+00
			Theis	-			2.17E-07	1.23E+00		
LLA-3	-	0.7941	Cooper - Jacob	-	8.43E-24	6.19E-24	8.40E-24	6.15E-24	1.26E-21	8.11E-22
			Theis	-	2.16E-08	1.28E-06	1.88E-19	1.07E-19		
LLA-5	-	0.3743	Cooper - Jacob	2.39E+03	9.16E-01	2.32E+00	9.17E-01	2.32E+00	9.24E-01	2.33E+00
			Theis	-	2.13E-04	4.77E-02	9.31E-01	2.35E+00		
LLA-PW3	-	0.7196	Cooper - Jacob	-	1.07E-01	1.44E-01	1.06E-01	1.43E-01	8.66E-02	1.17E-01
			Theis	-	9.47E-03	7.15E-03	7.08E-02	9.56E-02		
LLA-PW4	-	0.6801	Cooper - Jacob	-	1.05E-08	1.30E-08	1.07E-08	1.39E-08	9.28E-09	1.20E-08
			Theis	-	4.85E-08	8.12E-07	8.04E-09	1.04E-08		

4.6. Classification of Transmissivity for Legedadi Deep Wells.

The classification of transmissivity magnitude is based on Krasny 1970 paper which is discussed in the literature review part of this thesis. Accordingly the transmissivity values calculated for both the uncorrected drawdown data and the corrected drawdown have been classified. Here the geometric mean of the transmissivity values of the Cooper-Jacob, Theis method and recovery mothed is use in the classification. This classification based on the magnitudes is tabulated in table 22.

As it can be seen from table 22 when correction is done on the observed drawdowns it cause the aquifer transmissivity to be in a different class of magnitude. This is observed on well LLA-1, LAA-5, LLA-6 and LLA-PW7. Also the safe well yield that should be used for this wells is also not in the range as tabulated.

Even though this wells are sparsely located in Legedadi well filed, we can describe the variation in transmissivity of this well field. The lowest and highest transmissivity for the observed drawdowns is 9.58 m^2/day and 3051.12 m^2/day respectively where for the corrected drawdown 16.28 m^2/day and 4355.47 m^2/day are the lowest and highest. If we use this ten well as a sample population and determine the standard devotion the value is more than one. Thus based on the results of the studies in different hydrogeological sites we can fairly assume the well filed to be extremely heterogeneous from the hydrogeological environments points of view considering hydraulic heterogeneity

Table 22.Classification of transmissivity values for Legedadi Deep Wells.

Well index	Observed drawdown transmissivity values m^2/day	Corrected drawdown transmissivity values m^2/day	Class of transmissivity magnitude m^2/day		Designation of transmissivity magnitude		Q used in l/s	Approximated expected discharge in l/s of a single well at 5 m drawdown
			Observed drawdown	Corrected drawdown	Observed drawdown	Corrected drawdown		
LLA-1	9.58	16.28	V	III	low	Intermediate	15	0.5-5
LLA-2	17.84	41.08	III	III	Intermediate	Intermediate	20	0.5-5
LLA-3	1524.47	1958.06	I	I	Very High	Very High	52	>50
LLA-5	693.73	1880.23	II	I	High	Very High	50	>50
LLA-6	261.85	1184.91	II	I	High	Very High	38	>50
LLA-PW1	511.55	861.76	II	II	High	High	78	5-50
LLA-PW3	3051.12	4260.23	I	I	Very High	Very High	97	>50
LLA-PW4	2946.37	4355.47	I	I	Very High	Very High	88	>50
LLA-PW5	108.14	217.61	II	II	High	High	45	5-50
LLA-PW7	642.92	2642.82	II	I	High	Very High	80	>50

5. Conclusion

5.1. Conclusion

Based on the outcomes of the analysis of ten of the Legedadi deep well the following conclusions are reached.

Performing a step drawdown test, a test that lasts short period compared to other test, usually 8 to 10 hours, must be a done for all wells. As it's from these test that well yields are set. In doing this test, it assists in the determination the well efficiency of wells. Well efficiency in turn tell us whether the construction of the well is done perfectly or not. For some well in the Legedadi deep well major emphasis was not given to the well efficiency as it was mostly focused on getting a high well yield with no consideration on the well efficiency. Knowing a well has a low well efficiency and ignoring this low well efficiency is depraved way of developing any given well systems.

Another major focus that should be concentrated on during contraction of wells is that of its casing installation. The arrangement of blind and screen materials in any give well brands the aquifer as a partial penetrated aquifer making the approach of flow path to curve at the intake, this in turn case the head loss in the well to be grater. In Legedadi deep wells the effects of partial pentation has caused a large head loss in the two well specifically. As a result, the observed drawdown in this two wells drops significantly when the effect of partial penetration is considered. This head loss could have been avoided by designing the best combination of blind and screen length in this the wells.

The observed drawdown is expected to be worked out while the well efficiency is very low or the effects of partial penetration is high thus the actual aquifer parameters will result in unrealistic values. However, when major stress is given to the well drawdown loss by considering either the well efficiency or partial penetration the observed drawdown will have a lessor drawdown than originally thought. This corrected drawdown in turn can be used for describing the true nature of the aquifer.

Transmissivity values determined for the Ledadadi deep well were either overestimated or underestimated because some of them had low well efficiency and the effects of the partial penetration was not considered in other wells. This values in turn will have effect on the productivity of the well as the well could be over pumped or the full potential of the well is not recognized.

To discuss about storativity when a single well test is involved and considering that the values determined may describe the true nature of the aquifer, is a preconception idea by itself. But considering most well fields do not have observation well as it is the case of the Legedadi deep wells, storativity is determined. The storativity values for Legedadi deep for some well are in the accepted ranges where the result are for some are not acceptable. Thus it can be conclude that storativity values and single well test don't go hand in hand.

To summarize the values of the transmissivity values determined for Legedadi deep well when considering well efficiency and loss the effects of partial penetration lead to the will description the true nature of the aquifer properties where as storativity values and their interpretation based on a single well test should be taken lightly when trying to characterize aquifers in the Legedadi well fields.

5.2. Recommendation

Based on the outcomes of the analysis of ten of the Legedadi deep well the following recommendations are cited by this research.

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 aquifer property determination 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 research can be applied for future uses for contouring hydrogeological map for Legedadi areas.

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Appendix-1.Raw Step Drawdown Test.

i).Step Drawdown Test for LLA-1

Table A- 1. Step drawdown Tet for LLA-1 with extrapolated values.

Step 1			Step 2			Step 3			Step 4		
	7 lit/sec			13 lit/sec			17 lit/sec			20 lit/sec	
Time T	Water level	Drawdown	T1=T+120	Water level	Drawdown	T2=240+T	Water level	Drawdown	T3=360+T	Water level	Drawdown
0	6.50	0.00	120	21.09	14.59	240	43.00	36.50	360	57.80	51.30
1	11.30	4.80	121	23.20	16.70	241	44.50	38.00	361	58.40	51.90
2	11.50	5.00	122	24.43	17.93	242	45.20	38.70	362	58.71	52.21
3	11.94	5.44	123	25.51	19.01	243	45.90	39.40	363	58.86	52.36
4	12.40	5.90	124	26.42	19.92	244	46.80	40.30	364	58.95	52.45
5	12.80	6.30	125	27.20	20.70	245	47.30	40.80	365	59.05	52.55
6	13.20	6.70	126	27.97	21.47	246	47.95	41.45	366	59.19	52.69
7	13.55	7.05	127	28.86	22.36	247	48.60	42.10	367	59.21	52.71
8	13.85	7.35	128	29.51	23.01	248	49.01	42.51	368	59.29	52.79
9	14.05	7.55	129	30.12	23.62	249	49.50	43.00	369	59.38	52.88
10	14.20	7.70	130	30.86	24.36	250	49.90	43.40	370	59.47	52.97
12	14.40	7.90	132	31.85	25.35	252	50.57	44.07	372	59.57	53.07
14	15.30	8.80	134	32.86	26.36	254	51.15	44.65	374	59.66	53.16
16	16.13	9.63	136	33.57	27.07	256	51.60	45.10	376	59.75	53.25
18	16.63	10.13	138	34.24	27.74	258	52.00	45.50	378	59.88	53.38
20	16.96	10.46	140	34.88	28.38	260	52.35	45.85	380	59.95	53.45
25	17.64	11.14	145	36.06	29.56	265	53.00	46.50	385	60.25	53.75
30	18.18	11.68	150	37.04	30.54	270	53.55	47.05	390	60.56	54.06
35	18.60	12.10	155	37.80	31.30	275	54.03	47.53	395	60.81	54.31
40	18.82	12.32	160	38.50	32.00	280	54.40	47.90	400	61.10	54.60
45	19.00	12.50	165	38.90	32.40	285	54.72	48.22	405	61.42	54.92
50	19.15	12.65	170	39.39	32.89	290	55.04	48.54	410	61.66	55.16
55	19.34	12.84	175	40.09	33.59	295	55.30	48.80	415	61.95	55.45
60	19.46	12.96	180	40.56	34.06	300	55.55	49.05	420	62.57	56.07
70	19.76	13.26	190	41.05	34.55	310	55.95	49.45	430	64.07	57.57
80	20.06	13.56	200	41.51	35.01	320	56.36	49.86	440	67.50	61.00
90	20.40	13.90	210	41.93	35.43	330	56.61	50.11	450	69.97	63.47
100	20.69	14.19	220	42.30	35.80	340	56.95	50.45	460	73.10	66.60
120	21.09	14.59	240	43.00	36.50	360	57.80	51.30	480	79.10	72.60
121		14.68	241		36.58	361		51.28	481		
122		14.69	242		36.60	362		51.32	482		
123		14.71	243		36.64	363		51.38	483		
124		14.72	244		36.67	364		51.42	484		
125		14.77	245		36.72	365		51.44	485		
126		14.78	246		36.74	366		51.49	486		
127		14.80	247		36.78	367		51.53	487		
128		14.83	248		36.82	368		51.57	488		
129		14.85	249		36.86	369		51.61	489		
130		14.87	250		36.89	370		51.65	490		
132		14.92	252		36.97	372		51.72	492		
134		14.97	254		37.04	374		51.80	494		
136		15.01	256		37.11	376		51.88	496		
138		15.06	258		37.18	378		51.96	498		
140		15.11	260		37.26	380		52.04	500		
145		15.22	265		37.44	385		52.23	505		
150		15.34	270		37.62	390		52.43	510		
155		15.46	275		37.80	395		52.62	515		
160		15.58	280		37.98	400		52.82	520		
165		15.69	285		38.17	405		53.01	525		
170		15.81	290		38.35	410		53.21	530		
175		15.93	295		38.53	415		53.40	535		
180		16.05	300		38.71	420		53.60	540		
190		16.28	310		39.08	430		53.99	550		
200		16.52	320		39.44	440		54.38	560		
210		16.75	330		39.80	450		54.77	570		
220		16.99	340		40.17	460		55.16	580		
240		17.46	360		40.89	480		55.94	600		

- The step drawdown test for each step lasted 120 minutes and on each step the drawdown was extrapolated for additional 120 minutes to get the drawdown in each step.

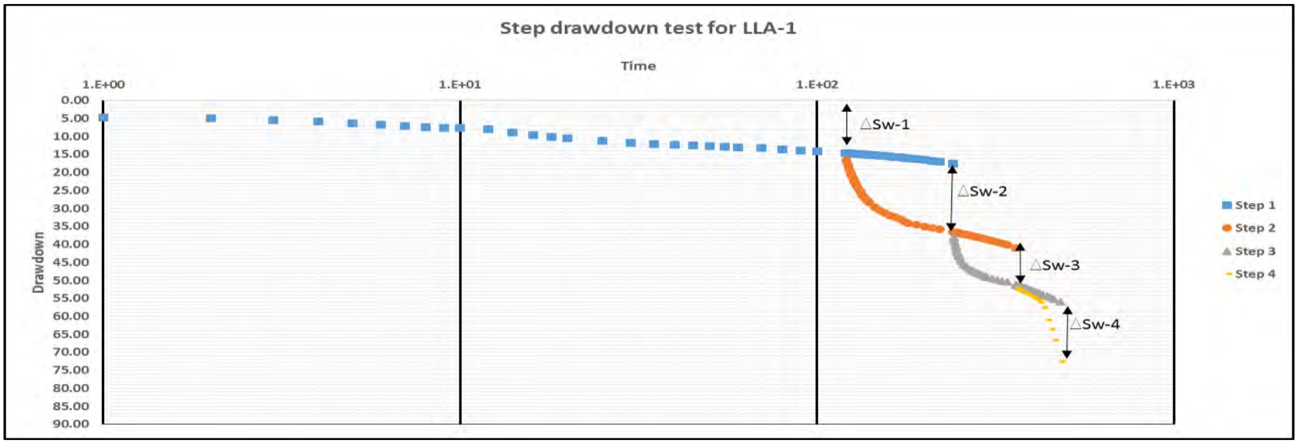


Figure A- 1.Step drawdown test for LLA-1.

Table A- 2.Values for change in each step with the corresponding *discharge*

Step	ΔSw	Sw	Q	Sw/Q
ΔSw-1	14.59	14.59	7	2.084285714
ΔSw-2	19.04	33.63458516	13	2.587275782
ΔSw-3	10.41	44.03968311	17	2.590569595
ΔSw-4	16.66	60.70207549	20	3.035103775

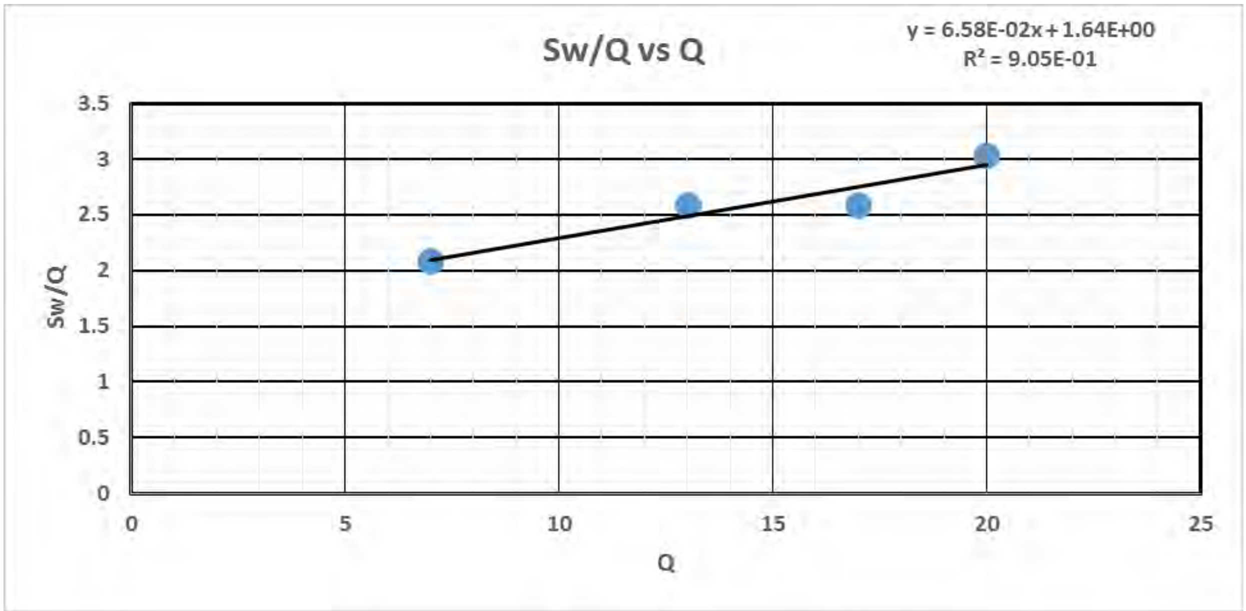


Figure A- 2.Sw/Q vs Q plot for LLA-1.

Table A- 3.Values for b, c and well efficiency for LLA-1.

Δ	Sum of Δ	Q	Sw/Q	b	c	Efficiency
14.59	14.59	7	2.0843	1.64E+00	6.58E-02	78.07%
19.04	33.63	13	2.5873	1.64E+00	6.58E-02	65.72%
10.41	44.04	17	2.5906	1.64E+00	6.58E-02	59.45%
16.66	60.70	20	3.0351	1.64E+00	6.58E-02	55.48%

Based on the values of B, V and the well efficiency the constant pumping rate of 15 lit/sec was selected for a safe yield for well LLA-1.

Table A- 4.Values for discharge in lit/s and well efficiency for LLA-1.

Q	Efficiency	%
7	0.7807	78.07%
13	0.6572	65.72%
15	0.6243	62.43%
17	0.5945	59.45%
20	0.5548	55.48%

ii).Step Drawdown Test for LLA-6.

Table A- 5.Step drawdown Test for LLA-6 with extrapolated values

Step 1			Step 2			Step 3			Step 4		
	15 lit/s			20 lit/s			25 lit/s			38 lit/s	
Time T	Water level	Drawdown	T1=T+120	Water level	Drawdown	T2=240+T	Water level	Drawdown	T3=360+T	Water level	Drawdown
0	32	0.00	120	46.10	13.90	240	63	30.61	360	73	41.15
1	49	16.80	121	49.20	17.00	241	71	38.85	361	96	64.10
2	48	16.27	122	54.31	22.11	242	73	40.60	362	103	70.40
3	48	16.26	123	54.67	22.47	243	73	40.85	363	105	72.70
4	48	16.25	124	55.95	23.75	244	73	41.20	364	106	74.20
5	48	16.20	125	56.05	23.85	245	73	41.25	365	106	74.23
6	48	15.80	126	56.15	23.95	246	74	41.70	366	106	74.10
7	47	15.20	127	56.16	23.96	247	74	41.75	367	106	73.80
8	47	15.15	128	56.10	23.90	248	74	41.90	368	105	73.05
9	47	15.05	129	56.04	23.84	249	74	41.80	369	105	72.80
10	47	14.98	130	56.04	23.84	250	74	41.70	370	105	73.20
12	47	14.94	132	56.04	23.84	252	73	41.10	372	106	73.55
14	47	14.90	134	56.04	23.84	254	73	41.00	374	106	74.10
16	47	14.90	136	59.95	27.75	256	73	41.10	376	108	75.65
18	47	14.80	138	60.47	28.27	258	74	41.30	378	109	76.75
20	47	14.74	140	62.50	30.30	260	74	41.30	380	109	76.78
25	47	14.74	145	62.85	30.65	265	74	42.02	385	109	76.80
30	47	14.66	150	62.80	30.60	270	75	42.35	390	109	76.84
35	47	14.66	155	62.70	30.50	275	75	42.35	395	109	76.87
40	47	14.65	160	62.35	30.15	280	75	42.35	400	109	76.91
45	47	14.54	165	62.65	30.45	285	75	42.35	405	109	76.96
50	47	14.52	170	62.75	30.55	290	75	42.35	410	109	76.97
55	47	14.50	175	62.70	30.50	295	77	44.92	415	109	76.99
60	47	14.53	180	62.70	30.50	300	77	44.95	420	109	77.00
70	47	14.45	190	62.65	30.45	310	73	40.90	430	109	77.00
80	46	14.20	200	62.70	30.50	320	73	40.90	440	109	77.01
90	46	13.96	210	62.80	30.60	330	73	40.90	450	109	77.03
100	46	13.90	220	62.80	30.60	340	73	40.90	460	109	77.10
120	46	13.90	240	62.81	30.61	360	73	41.15	480	109	77.10
121		13.77	241		30.65	361		41.09	481		
122		13.80	242		30.64	362		41.11	482		
123		13.81	243		30.63	363		41.12	483		
124		13.81	244		30.64	364		41.14	484		
125		13.78	245		30.65	365		41.13	485		
126		13.80	246		30.64	366		41.15	486		
127		13.79	247		30.64	367		41.16	487		
128		13.78	248		30.65	368		41.16	488		
129		13.78	249		30.65	369		41.17	489		
130		13.78	250		30.65	370		41.19	490		
132		13.77	252		30.65	372		41.20	492		
134		13.76	254		30.65	374		41.22	494		
136		13.75	256		30.66	376		41.23	496		
138		13.74	258		30.66	378		41.25	498		
140		13.73	260		30.66	380		41.27	500		
145		13.71	265		30.67	385		41.31	505		
150		13.69	270		30.68	390		41.35	510		
155		13.67	275		30.68	395		41.39	515		
160		13.65	280		30.69	400		41.43	520		
165		13.63	285		30.70	405		41.48	525		
170		13.61	290		30.70	410		41.52	530		
175		13.59	295		30.71	415		41.56	535		
180		13.56	300		30.72	420		41.60	540		
190		13.52	310		30.73	430		41.68	550		
200		13.48	320		30.75	440		41.77	560		
210		13.44	330		30.76	450		41.85	570		
220		13.39	340		30.78	460		41.94	580		
240		13.31	360		30.81	480		42.10	600		

- The step drawdown test for each step lasted 120 minutes and on each step the drawdown was extrapolated for additional 120 minutes to get the drawdown in each step.

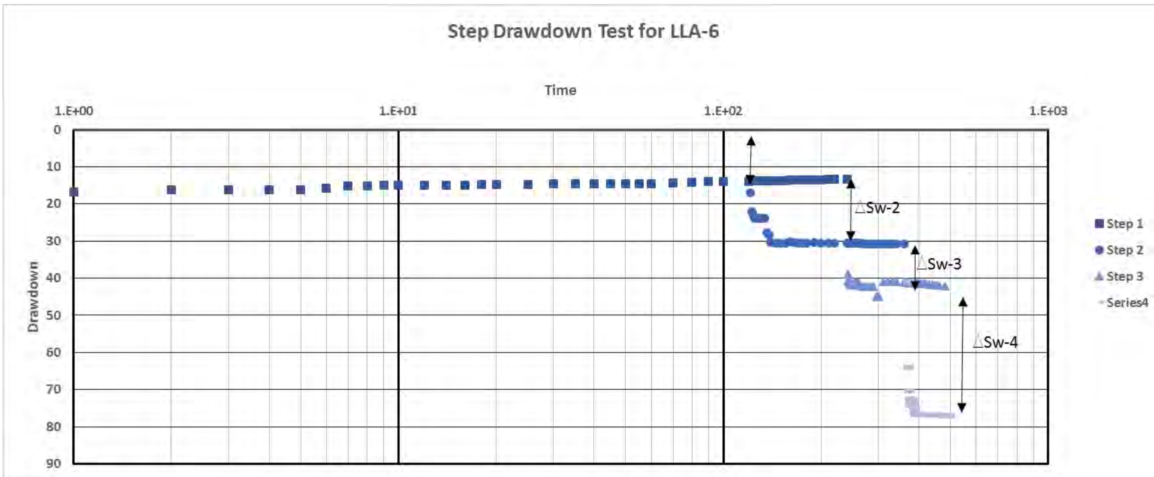


Figure A- 3. .Step drawdown test for LLA-6.

Table A- 6.Values for change in each step with the corresponding discharge

Step	ΔSw	Sw	Q	Sw/Q
ΔSw-1	13.90	13.90	15	0.93
ΔSw-2	17.30	31.20	20	1.56
ΔSw-3	10.34	41.54	25	1.66
ΔSw-4	35.00	76.54	38	2.01

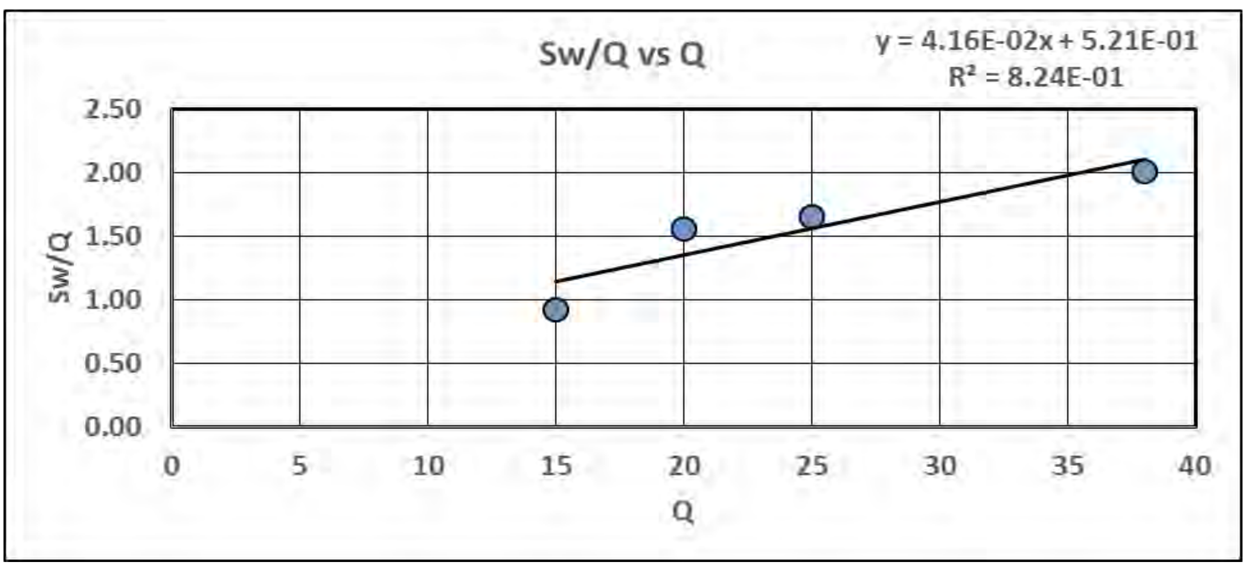


Figure A- 4.Sw/Q vs Q plot for LLA-1.

Table A- 7.Values for b, c and well efficiency for LLA-6.

∆	Sum of ∆	Q	Sw/Q	B	C	Efficiency
14.59	13.9	15	0.9267	5.21E-01	4.46E-02	43.78%
19.04	17.30	20	0.865	5.21E-01	4.46E-02	36.87%
10.41	10.34	25	0.4138	5.21E-01	4.46E-02	31.85%
16.66	35.00	38	0.921	5.21E-01	4.46E-02	23.51%

Based on the values of B, C and the well efficiency the constant pumping rate of 40 lit/sec was selected for a safe yield for well LLA-6, which with this well efficiency it should not have been adapted.

Table A- 8.Values for discharge in lit/s and well efficiency for LLA-6.

Q	Efficiency	%
15	0.4378	43.78%
20	0.3687	36.87%
25	0.3185	31.85%
38	0.2351	23.51%
40	0.2351	23.51%

iii).Step Drawdown Test for LLA-PW1.

Table A- 9.Step drawdown Test for LLA-PW1 with extrapolated values.

Time T	Water level	Drawdown	T1=T+120	Water level	Drawdown	T2=240+T	Water level	Drawdown	T3=360+T	Water level	Drawdown
0	12.80	0.00	120	20.90	8.10	240	23.17	10.37	360	23.39	10.59
1	18.23	5.43	121	21.05	8.25	241	23.17	10.37	361	23.41	10.61
2	18.78	5.98	122	22.00	9.20	242	23.17	10.37	362	23.43	10.63
3	18.64	5.84	123	23.36	10.56	243	23.17	10.37	363	23.44	10.64
4	18.20	5.40	124	22.56	9.76	244	23.17	10.37	364	23.45	10.65
5	17.72	4.92	125	22.75	9.95	245	23.17	10.37	365	23.45	10.65
6	17.56	4.76	126	22.83	10.03	246	23.17	10.37	366	23.46	10.66
7	17.58	4.78	127	22.90	10.10	247	23.19	10.39	367	23.47	10.67
8	17.88	5.08	128	22.92	10.12	248	23.20	10.40	368	23.48	10.68
9	17.90	5.10	129	22.94	10.14	249	23.20	10.40	369	23.49	10.69
10	18.02	5.22	130	22.95	10.15	250	23.20	10.40	370	23.50	10.70
12	18.05	5.25	132	22.96	10.16	252	23.20	10.40	372	23.51	10.71
14	18.10	5.30	134	22.98	10.18	254	23.21	10.41	374	23.52	10.72
16	18.58	5.78	136	23.00	10.20	256	23.21	10.41	376	23.53	10.73
18	19.28	6.48	138	23.02	10.22	258	23.21	10.41	378	23.54	10.74
20	19.82	7.02	140	23.03	10.23	260	23.22	10.42	380	23.55	10.75
25	20.40	7.60	145	23.05	10.25	265	23.23	10.43	385	23.56	10.76
30	20.57	7.77	150	23.06	10.26	270	23.23	10.43	390	23.57	10.77
35	20.68	7.88	155	23.10	10.30	275	23.24	10.44	395	23.58	10.78
40	20.72	7.92	160	23.11	10.31	280	23.25	10.45	400	23.59	10.79
45	20.76	7.96	165	23.12	10.32	285	23.26	10.46	405	23.60	10.80
50	20.70	7.90	170	23.13	10.33	290	23.27	10.47	410	23.61	10.81
55	20.72	7.92	175	23.14	10.34	295	23.28	10.48	415	23.62	10.82
60	20.72	7.92	180	23.14	10.34	300	23.28	10.48	420	23.63	10.83
70	20.75	7.95	190	23.14	10.34	310	23.29	10.49	430	23.64	10.84
80	20.76	7.96	200	23.16	10.36	320	23.32	10.52	440	23.65	10.85
90	20.82	8.02	210	23.17	10.37	330	23.33	10.53	450	23.66	10.86
100	20.84	8.04	220	23.17	10.37	340	23.34	10.54	460	23.67	10.87
120	20.90	8.10	240	23.17	10.37	360	23.39	10.59	480	23.68	10.88
121		8.11	241		10.38	361		10.59	481		
122		8.11	242		10.37	362		10.59	482		
123		8.11	243		10.37	363		10.59	483		
124		8.11	244		10.37	364		10.60	484		
125		8.12	245		10.38	365		10.60	485		
126		8.12	246		10.37	366		10.60	486		
127		8.12	247		10.38	367		10.60	487		
128		8.13	248		10.38	368		10.60	488		
129		8.13	249		10.38	369		10.60	489		
130		8.13	250		10.38	370		10.61	490		
132		8.14	252		10.38	372		10.61	492		
134		8.14	254		10.38	374		10.62	494		
136		8.15	256		10.38	376		10.62	496		
138		8.16	258		10.38	378		10.62	498		
140		8.16	260		10.38	380		10.63	500		
145		8.18	265		10.38	385		10.64	505		
150		8.19	270		10.38	390		10.65	510		
155		8.21	275		10.38	395		10.66	515		
160		8.22	280		10.38	400		10.67	520		
165		8.24	285		10.38	405		10.68	525		
170		8.25	290		10.38	410		10.69	530		
175		8.27	295		10.38	415		10.70	535		
180		8.28	300		10.38	420		10.71	540		
190		8.31	310		10.38	430		10.73	550		
200		8.34	320		10.39	440		10.75	560		
210		8.38	330		10.39	450		10.77	570		
220		8.41	340		10.39	460		10.79	580		
240		8.47	360		10.39	480		10.83	600		

- The step drawdown test for each step lasted 120 minutes and on each step the drawdown was extrapolated for additional 120 minutes to get the drawdown in each step.

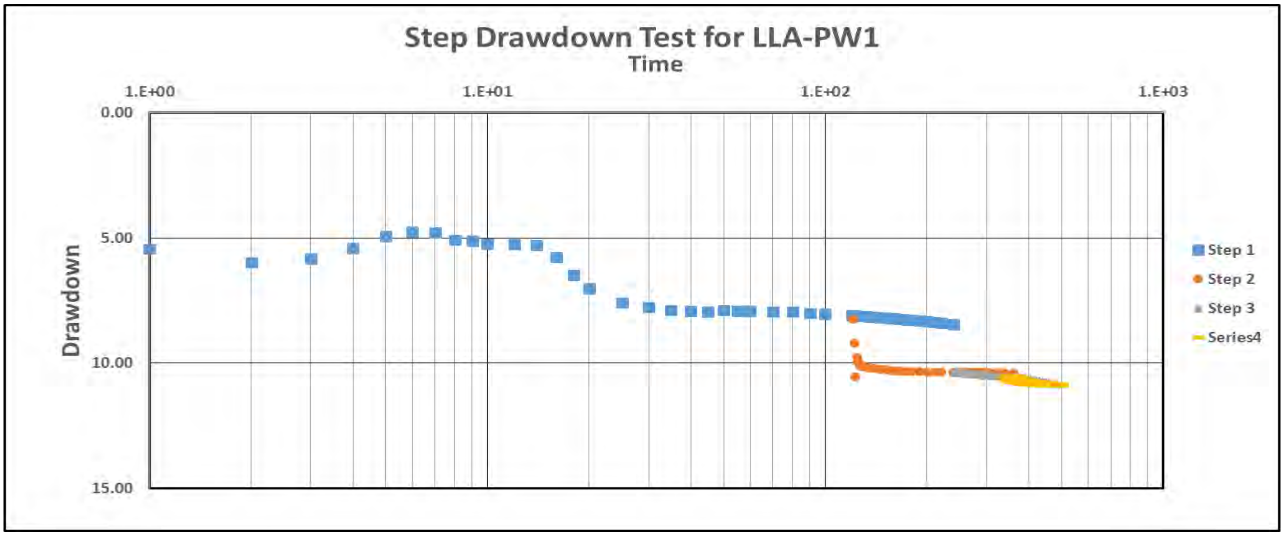


Figure A- 5.Step drawdown test for LLA-PW1.

Table A- 10.Values for change in each step with the corresponding discharge.

Step	∆Sw	Sw	Q	Sw/Q
∆Sw-1	8.10	8.10	48	0.16875
∆Sw-2	1.90	10.00	58	0.17248157
∆Sw-3	0.20	10.20	68	0.15002272
∆Sw-4	0.05	10.25	78	0.13138781

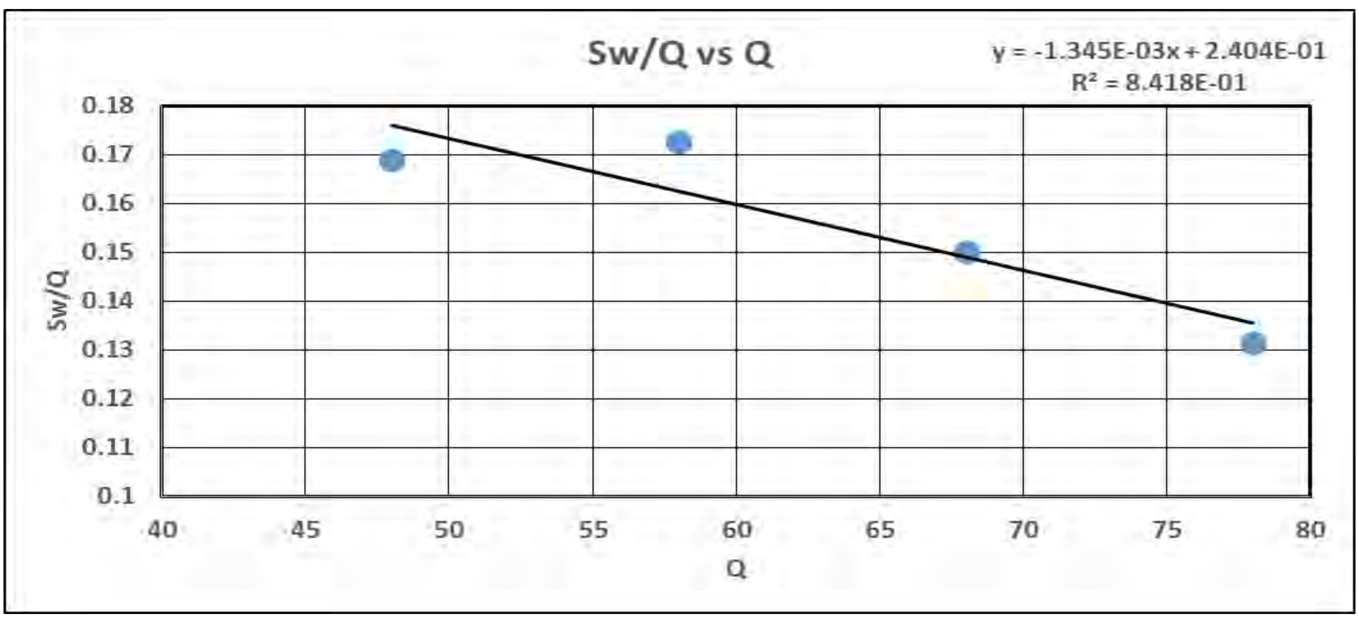


Figure A- 6.Sw/Q vs Q plot for LLA-PW1.

Table A- 11.Values for b, c and well efficiency for LLA-PW1.

Δ	Sum of Δ	Q	Sw/Q	B	C	Efficiency
8.10	8.10	48	0.1688	2.40E-01	1.35E-03	78.83%
1.90	10.00	58	0.1725	2.40E-01	1.35E-03	75.50%
0.20	10.20	68	0.15	2.40E-01	1.35E-03	72.44%
0.05	10.25	78	0.1314	2.40E-01	1.35E-03	69.62%

Based on the values of B, C and the well efficiency the constant pumping rate of 78 lit/sec was selected for a safe yield for well LLA-PW1.

Table A- 12.Values for discharge in lit/s and well efficiency for LLA-PW1.

Q	Efficiency	%
4147	0.7883	78.82%
5011	0.7550	75.49%
5875	0.7244	72.43%
6739	0.6962	69.61%

iv).Step Drawdown Test for LLA-PW5

Table A- 13.Step drawdown Test for LLA-PW5 with extrapolated values.

Step 1			Step 2			Step 3			Step 4		
	35 lit/s			40 lit/s			45 lit/s			50 lit/s	
Time T	Water level	Drawdown	T1=T+120	Water level	Drawdown	T2=240+T	Water level	Drawdown	T3=360+T	Water level	Drawdown
0	14.22	0.00	120	45.00	30.78	240	54.43	40.21	360	57.62	43.40
1	44.50	30.28	121	47.80	33.58	241	56.36	42.14	361	67.28	53.06
2	42.10	27.88	122	48.70	34.48	242	56.62	42.40	362	68.90	54.68
3	42.36	28.14	123	54.90	40.68	243	56.71	42.49	363	69.82	55.60
4	53.20	38.98	124	52.90	38.68	244	56.83	42.61	364	70.42	56.20
5	52.80	38.58	125	53.03	38.81	245	56.87	42.65	365	70.82	56.60
6	52.90	38.68	126	53.20	38.98	246	56.92	42.70	366	71.07	56.85
7	53.10	38.88	127	52.85	38.63	247	56.95	42.73	367	71.31	57.09
8	53.14	38.92	128	52.82	38.60	248	56.99	42.77	368	71.39	57.17
9	53.28	39.06	129	52.78	38.56	249	56.98	42.76	369	71.34	57.12
10	49.02	34.80	130	52.80	38.58	250	56.95	42.73	370	71.42	57.20
12	46.65	32.43	132	52.82	38.60	252	56.98	42.76	372	71.46	57.24
14	44.85	30.63	134	52.75	38.53	254	56.02	41.80	374	71.50	57.28
16	44.34	30.12	136	52.79	38.57	256	56.05	41.83	376	71.43	57.21
18	44.21	29.99	138	52.84	38.62	258	57.08	42.86	378	71.80	57.58
20	44.26	30.04	140	52.86	38.64	260	57.11	42.89	380	72.01	57.79
25	44.21	29.99	145	52.90	38.68	265	57.18	42.96	385	72.40	58.18
30	44.27	30.05	150	52.85	38.63	270	57.24	43.02	390	72.18	57.96
35	44.20	29.98	155	52.90	38.68	275	57.54	43.32	395	72.35	58.13
40	44.47	30.25	160	53.02	38.80	280	57.43	43.21	400	72.03	57.81
45	44.54	30.32	165	53.31	39.09	285	57.35	43.13	405	72.24	58.02
50	44.57	30.35	170	53.47	39.25	290	57.28	43.06	410	72.16	57.94
55	44.60	30.38	175	53.48	39.26	295	57.31	43.09	415	71.98	57.76
60	44.64	30.42	180	53.44	39.22	300	57.37	43.15	420	71.82	57.60
70	44.67	30.45	190	53.60	39.38	310	57.45	43.23	430	71.75	57.53
80	44.70	30.48	200	53.62	39.40	320	57.46	43.24	440	71.76	57.54
90	44.80	30.58	210	53.72	39.50	330	57.39	43.17	450	72.26	58.04
100	44.90	30.68	220	53.68	39.46	340	57.56	43.34	460	72.36	58.14
120	45.00	30.78	240	54.43	40.21	360	57.62	43.40	480	72.85	58.63
121		30.80	241		40.05	361		43.39	481		
122		30.81	242		40.10	362		43.40	482		
123		30.81	243		40.15	363		43.41	483		
124		30.81	244		40.20	364		43.41	484		
125		30.83	245		40.17	365		43.42	485		
126		30.83	246		40.23	366		43.42	486		
127		30.84	247		40.25	367		43.43	487		
128		30.84	248		40.27	368		43.43	488		
129		30.85	249		40.30	369		43.44	489		
130		30.86	250		40.33	370		43.44	490		
132		30.87	252		40.38	372		43.45	492		
134		30.88	254		40.43	374		43.46	494		
136		30.90	256		40.48	376		43.47	496		
138		30.91	258		40.53	378		43.48	498		
140		30.92	260		40.58	380		43.49	500		
145		30.95	265		40.71	385		43.51	505		
150		30.99	270		40.83	390		43.54	510		
155		31.02	275		40.96	395		43.56	515		
160		31.05	280		41.09	400		43.59	520		
165		31.08	285		41.21	405		43.61	525		
170		31.12	290		41.34	410		43.64	530		
175		31.15	295		41.47	415		43.66	535		
180		31.18	300		41.59	420		43.68	540		
190		31.24	310		41.85	430		43.73	550		
200		31.31	320		42.10	440		43.78	560		
210		31.37	330		42.35	450		43.83	570		
220		31.44	340		42.61	460		43.88	580		
240		31.57	360		43.11	480		43.98	600		
230		31.50	350		42.86	470		43.93	590		
240		31.57	360		43.11	480		43.98	600		

- The step drawdown test for each step lasted 120 minutes and on each step the drawdown was extrapolated for additional 120 minutes to get the drawdown in each step.

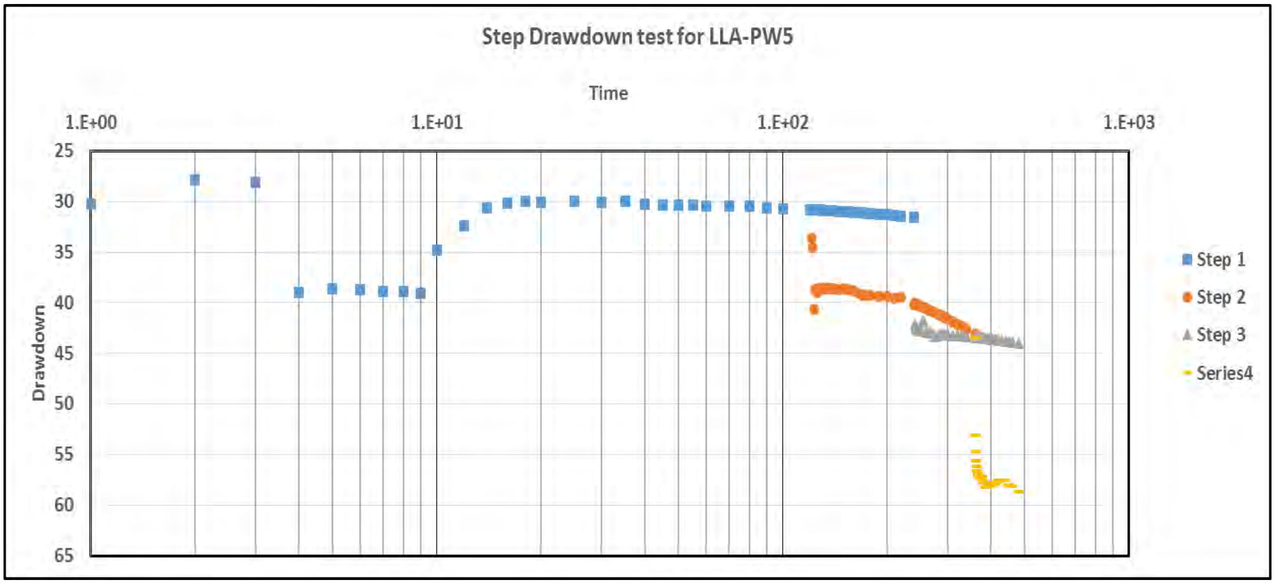


Figure A- 7.Values for change in each step with the corresponding discharge.

Table A- 14.Values for change in each step with the corresponding discharge.

Step	∆Sw	Sw	Q	Sw/Q
∆Sw-1	30.78	30.78	35.00	0.88
∆Sw-2	8.64	39.42	40.00	0.99
∆Sw-3	0.29	39.71	45.00	0.88
∆Sw-4	14.65	54.36	50.00	1.09

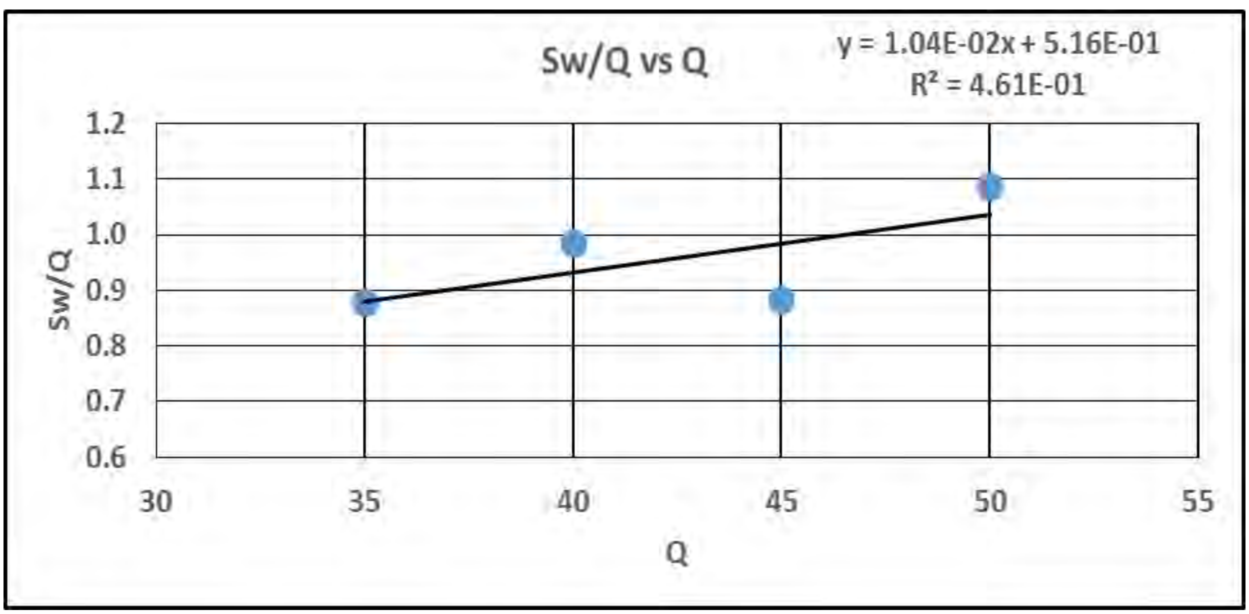


Figure A- 8.Sw/Q vs Q plot for LLA-PW5

Table A- 15.Values for b, c and well efficiency for LLA-PW5.

∆	Sum of ∆	Q	Sw/Q	B	C	Efficiency
30.78	30.78	35	0.8794	5.16E-01	1.04E-02	58.64%
8.64	39.42	40	0.9856	5.16E-01	1.04E-02	55.36%
0.29	39.71	45	0.8824	5.16E-01	1.04E-02	52.44%
14.65	54.36	50	1.0873	5.16E-01	1.04E-02	49.81%

Based on the values of B, C and the well efficiency the constant pumping rate of 45 lit/sec was selected for a safe yield for well LLA-PW5.

Table A- 16.Values for discharge in lit/s and well efficiency for LLA-PW5.

Q	Efficiency	%
35	0.5864	58.72%
40	0.5536	55.45%
45	0.5244	52.53%
50	0.4981	49.90%

v).Step Drawdown Test for LLA-PW7.

Table A- 17.Step drawdown Test for LLA-PW7 with extrapolated values.

Step 1			Step 2			Step 3			Step 4		
	50 lit/s			60 lit/s			70 lit/s			80 lit/s	
Time T	Water level	Drawdown	T1=T+120	Water level	Drawdown	T2=240+T	Water level	Drawdown	T3=360+T	Water level	Drawdown
0	34	0.00	120	43	8.97	240	51	17.04	360	58	23.90
1	41	7.04	121	47	13.09	241	54	20.59	361	64	29.89
2	46	12.54	122	48	14.09	242	55	21.19	362	65	31.41
3	49	14.79	123	48	14.39	243	56	21.99	363	66	32.34
4	44	10.57	124	49	15.39	244	56	22.59	364	67	32.89
5	44	10.07	125	49	15.54	245	57	22.79	365	67	33.17
6	44	10.06	126	50	15.69	246	57	22.94	366	67	33.24
7	43	9.61	127	50	15.89	247	57	23.03	367	67	33.47
8	43	9.34	128	50	16.19	248	57	23.12	368	67	33.64
9	43	9.02	129	50	16.31	249	57	23.22	369	68	33.79
10	43	8.89	130	50	16.34	250	57	23.29	370	68	33.88
12	42	8.65	132	50	16.52	252	57	23.31	372	68	33.99
14	42	8.61	134	51	16.69	254	57	23.34	374	68	34.09
16	42	8.11	136	51	16.73	256	57	23.35	376	68	34.09
18	42	8.47	138	51	16.77	258	57	23.37	378	68	34.15
20	42	8.56	140	51	16.84	260	57	23.39	380	68	34.17
25	43	8.72	145	51	16.86	265	57	23.47	385	68	34.27
30	43	8.72	150	51	16.91	270	57	23.55	390	68	34.34
35	42	8.64	155	51	16.96	275	57	23.65	395	68	34.36
40	42	8.68	160	51	16.98	280	57	23.65	400	68	34.40
45	42	8.64	165	51	16.98	285	57	23.67	405	68	34.47
50	42	8.64	170	51	16.99	290	58	23.69	410	68	34.51
55	42	8.61	175	51	16.99	295	58	23.77	415	68	34.55
60	42	8.61	180	51	16.99	300	58	23.79	420	68	34.59
70	42	8.63	190	51	17.00	310	58	23.80	430	68	34.66
80	42	8.65	200	51	17.00	320	58	23.82	440	69	34.70
90	43	8.75	210	51	17.02	330	58	23.84	450	69	34.75
100	43	8.85	220	51	17.03	340	58	23.86	460	69	34.81
110	43	8.96	230	51	17.03	350	58	23.88	470	69	34.83
120	43	8.97	240	51	17.04	360	58	23.90	480	69	34.86
121		9.01	241		17.04	361		23.90	481		
122		9.02	242		17.04	362		23.90	482		
123		9.02	243		17.04	363		23.91	483		
124		9.02	244		17.04	364		23.91	484		
125		9.04	245		17.04	365		23.91	485		
126		9.04	246		17.04	366		23.91	486		
127		9.04	247		17.05	367		23.91	487		
128		9.05	248		17.05	368		23.92	488		
129		9.06	249		17.05	369		23.92	489		
130		9.06	250		17.05	370		23.92	490		
132		9.07	252		17.05	372		23.92	492		
134		9.09	254		17.05	374		23.93	494		
136		9.10	256		17.05	376		23.93	496		
138		9.11	258		17.05	378		23.94	498		
140		9.12	260		17.06	380		23.94	500		
145		9.15	265		17.06	385		23.95	505		
150		9.18	270		17.06	390		23.96	510		
155		9.21	275		17.07	395		23.97	515		
160		9.24	280		17.07	400		23.98	520		
165		9.27	285		17.07	405		23.99	525		
170		9.31	290		17.08	410		24.00	530		
175		9.34	295		17.08	415		24.01	535		
180		9.37	300		17.09	420		24.02	540		
190		9.43	310		17.09	430		24.04	550		
200		9.49	320		17.10	440		24.06	560		
210		9.55	330		17.11	450		24.08	570		
220		9.61	340		17.12	460		24.10	580		
230		9.67	350		17.12	470		24.12	590		
240		9.73	360		17.13	480		24.14	600		

- The step drawdown test for each step lasted 120 minutes and on each step the drawdown was extrapolated for additional 120 minutes to get the drawdown in each step.

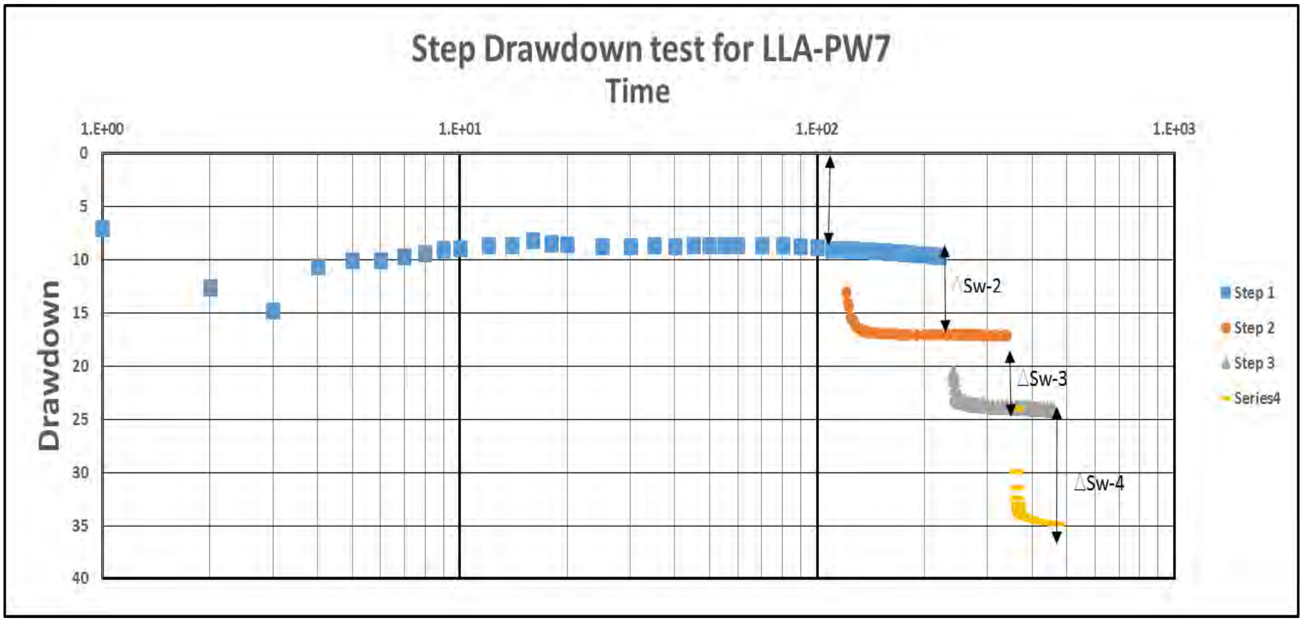


Figure A- 9.Step drawdown test for LLA-PW7.

Table A- 18.Values for change in each step with the corresponding discharge.

Step	∆Sw	Sw	Q	Sw/Q
∆Sw-1	8.97	8.97	50	0.18
∆Sw-2	7.31	16.28	60	0.27
∆Sw-3	6.77	23.05	70	0.33
∆Sw-4	10.72	33.77	80	0.42

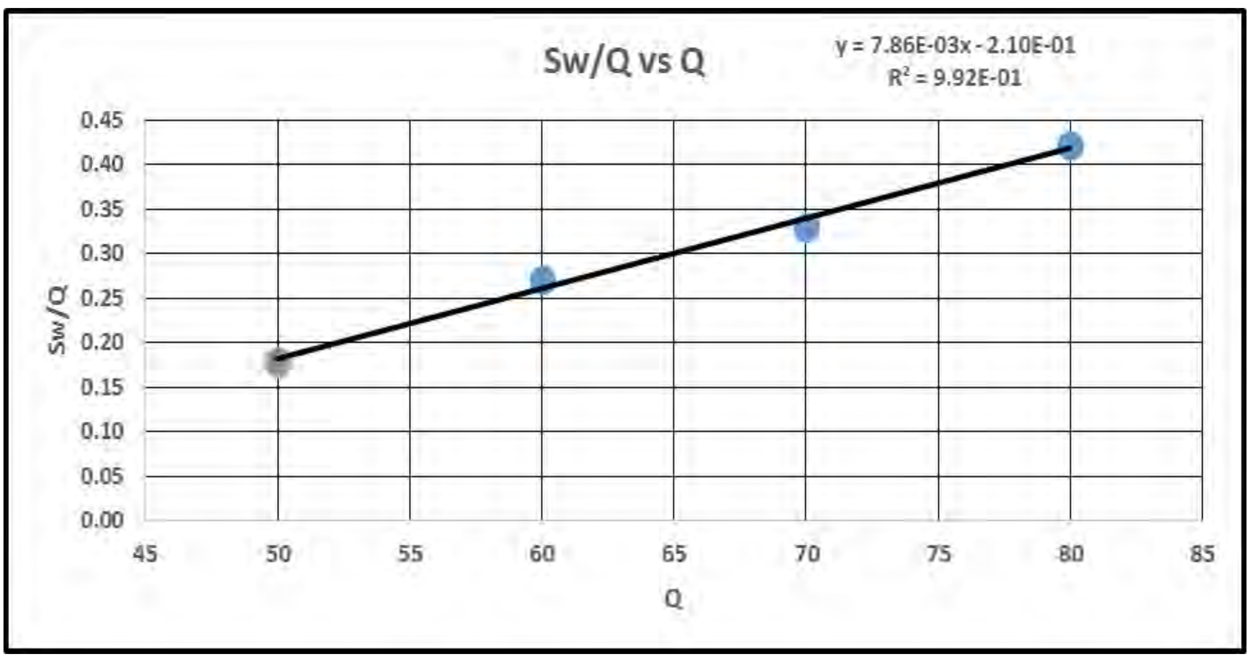


Figure A- 10.Sw/Q vs Q plot for LLA-PW7.

Table A- 19.Values for b, c and well efficiency for LLA-PW7.

Δ	Sum of Δ	Q	Sw/Q	B	C	Efficiency
8.97	8.97	50	0.1794	2.10E-01	7.86E-03	34.83%
7.31	16.28	60	0.2713	2.10E-01	7.86E-03	30.81%
6.77	23.05	70	0.3292	2.10E-01	7.86E-03	27.62%
10.72	33.77	80	0.4221	2.10E-01	7.86E-03	25.04%

Based on the values of B, C and the well efficiency the constant pumping rate of 80 lit/sec was selected for a safe yield for well LLA-PW7. Which is contradicts the well efficiency thus it's better to use low pumping discharge or abandon the well.

Table A- 20.Values for discharge in lit/s and well efficiency for LLA-PW7.

Q	Efficiency	%
50	0.3483	34.83%
60	0.3081	30.08%
70	0.2762	27.62%
80	0.2504	25.50%

Appendix-2 Casing Arrangement

Effect of partial penetration determined by using Kozeny correction factor which is given by:-

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

Table A- 21.Kozeny correction factor for LLA-2

A	B	C	D	E	F	G	H	I	J	K
r'	0.1525									
From(m)	To(m)	Length(m) (B)	Blined length(m)	Screen length(m) (L)	2L/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)	Mult Col (H*I)	F
0	46	46	46							
46	52	6		6	78.68852	0.115385	6.853588614	0.112731244	1.772613569	0.204532
52	70	18	18							
70	88	18		18	236.0656	0.5	6.997369518	0.065085414	1.455426692	0.727713
88	118	30	30							
118	124	6		6	78.68852	0.166667	6.657395614	0.112731244	1.750496488	0.291749
124	154	30	30							
154	166	12		12	157.377	0.285714	5.663118961	0.079713027	1.451424354	0.414693
166	196	30	30							
196	214	18		18	236.0656	0.375	4.114496766	0.065085414	1.267793725	0.475423
214	226	12	12							
226	250	24		24	314.7541	0.666667	6.989480049	0.056365622	1.39396639	0.929311
									GeoMean	0.446804

Table A- 22.Kozeny correction factor for LLA-3.

A	B	C	D	E	F	G	H	I	J	K
r'	0.127									
From(m)	To(m)	Length(m) (B)	Blined length(m)	Screen length(m) (L)	2L/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)	Mult Col (H*I)	F
0	29	29	29							
29	147.1	118.1	118.1							
147.1	183.56	36.46		36.46	574.17323	0.556981	6.1929254	0.041732897	1.258448717	0.700932
183.56	189.37	5.81	5.81							
189.37	207.3	17.93		17.93	282.3622	0.755265	6.9749613	0.059510927	1.415086415	1.068766
207.3	236.57	29.27	29.27							
236.57	266.52	29.95		29.95	471.65354	0.505741	6.9912488	0.046045633	1.321916479	0.668548
266.52	301.5	34.98	34.98							
									GeoMean	0.79414

Table A- 23.Kozeny correction factor for LLA-5.

r'	0.127									
From(m)	To(m)	Length(m)	Blined length(m)	Screen length(m) (L)	2L/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L	Mult Col (H	F
0	127.44	127.44	127.44							
127.44	139.12	11.68		11.68	183.937	0.083956	6.9275845	0.073734	1.510796	0.126841
139.12	144.96	5.84	5.84							
144.96	174.16	29.2		29.2	459.8425	0.833333	6.9749613	0.046633	1.325265	1.104387
174.16	180	5.84	5.84							
									GeoMean	0.374275

Table A- 24.Kozeny correction factor for LLA-PW3.

r'	0.178	r''	0.1015							
From(m)	To(m)	Length(m)	Blined length(m)	Screen length(m) (L)	2L/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)	Mult Col (H*I)	F
-1	118.76	119.76	119.76							
118.76	130.44	11.68		11.68	131.236	0.088862	6.918017651	0.087291827	1.603886398	0.142524
130.44	141.22	10.78	10.78							
141.22	164.56	23.34		23.34	262.2472	0.684056	6.987714021	0.061751083	1.431498907	0.979226
164.56	185.47	20.91	20.91							
185.47	214.75	29.28		29.28	328.9888	0.583383	6.994842452	0.055132726	1.385644733	0.808362
214.75	225.6	10.85	10.85							
225.6	242.26	16.66		16.66	187.191	0.605598	6.993798612	0.055192558	1.386005637	0.839362
242.26	253.78	11.52	11.52							
253.78	271.01	17.23		17.23	339.5074	0.599304	6.994116073	0.054271945	1.379584281	0.826791
271.01	283.17	12.16	12.16							
283.17	294.67	11.5		11.5	226.601	0.486052	6.997647299	0.066430742	1.464858902	0.711998
294.67	300.43	5.76	5.76							
300.43	311.97	11.54		11.54	227.3892	0.667052	6.989443499	0.066315511	1.463508516	0.976236
311.97	318.08	6.11	6.11							
318.08	329.6	11.52		11.52	226.9951	0.653432	6.9906505	0.066373051	1.463990805	0.956618
329.6	335.37	5.77	5.77							
335.37	346.89	11.52		11.52	226.9951	0.666281	6.989516473	0.066373051	1.463915536	0.975379
346.89	358.42	11.53	11.53							
358.42	370	11.58		11.58	228.1773	0.501082	6.997346656	0.066200877	1.463230486	0.733198
									GeoMean	0.719596

* In table B_2-4 below the highlighted raw (from 225.6m-370m) radius of the casing used is r''=0.1015m

Table A- 25.Kozeny correction factor for LLA-PW5.

r'	0.178	r''	0.1015							
From(m)	To(m)	Length(m)	Blined length(m)	Screen length(m) (L)	2L/r	L/B	[7COS(3.1L/2B)]	SQRT(R/2L)	Mult Col (H*I)	F
-1	116.46	117.46	117.46							
116.46	133.86	17.4		17.4	195.5056	0.129023	6.811346075	0.071518826	1.487139477	0.191875
133.86	139.66	5.8	5.8							
139.66	157.06	17.4		17.4	195.5056	0.75	6.976337523	0.071518826	1.498939472	1.124205
157.06	162.86	5.8	5.8							
162.86	180.26	17.4		17.4	195.5056	0.75	6.976337523	0.071518826	1.498939472	1.124205
180.26	197.66	17.4	17.4							
197.66	203.46	5.8		5.8	65.16854	0.25	6.999707708	0.123874241	1.86708348	0.466771
203.46	215.06	11.6	11.6							
215.06	226.64	11.58		11.58	130.1124	0.499569	6.99737858	0.087667924	1.613445655	0.806027
226.66	232.46	5.8	5.8							
232.46	249.5	17.04	17.04							
249.5	255.24	5.74		5.74	113.1034	0.251975	6.9997015	0.094029056	1.658175326	0.417819
255.24	272.39	17.15	17.15							
272.39	278.14	5.75		5.75	113.3005	0.251092	6.999704289	0.093947256	1.657603013	0.41621
278.14	295.32	17.18	17.18							
295.32	301.01	5.69		5.69	112.1182	0.248798	6.999711439	0.094441286	1.661061747	0.413268
301.01	306.74	5.73	5.73							
306.74	318.23	11.49		11.49	226.4039	0.667247	6.989424913	0.066459644	1.46451469	0.977194
318.23	335.46	17.23	17.23							
335.46	341.22	5.76		5.76	113.4975	0.250544	6.999706009	0.093865669	1.65703209	0.415159
341.22	346.97	5.75	5.75							
346.97	358.46	11.49		11.49	226.4039	0.666473	6.989498332	0.066459644	1.464519569	0.976063
358.46	364.2	5.74	5.74							
364.2	375.6	11.4		11.4	224.6305	0.665111	6.989626122	0.066721469	1.466358121	0.975291
375.6	387.06	11.46	11.46							
387.06	392.79	5.73		5.73	112.9064	0.333333	6.999342349	0.09411107	1.658715599	0.552905
392.79	398.54	5.75	5.75							
398.54	410.02	11.48		11.48	226.2069	0.66628	6.989516599	0.066488583	1.464723057	0.975915
410.02	415.72	5.7	5.7							
415.72	433.01	17.29		17.29	340.6897	0.752066	6.975809073	0.054177695	1.377933259	1.036297
433.01	444.53	11.52	11.52							
444.53	456.08	11.55		11.55	227.5862	0.50065	6.997355801	0.066286797	1.4638323	0.732868
456.08	461.82	5.74	5.74							
461.82	473.27	11.45		11.45	225.6158	0.666085	6.989534946	0.066575629	1.465332687	0.976036
473.27	479.3	6.03	6.03							
479.3	490.51	11.21		11.21	220.8867	0.650232	6.990910393	0.067284529	1.470380113	0.956088
490.51	502	11.49	11.49							
									GeoMean	0.680076

* In table B_2-4 below the highlighted raw (from 232.46m-500m) radius of the casing used is r''=0.1015m

Appendix-3 Drawdown –Time Plots for Uncorrected and Corrected Drawdown

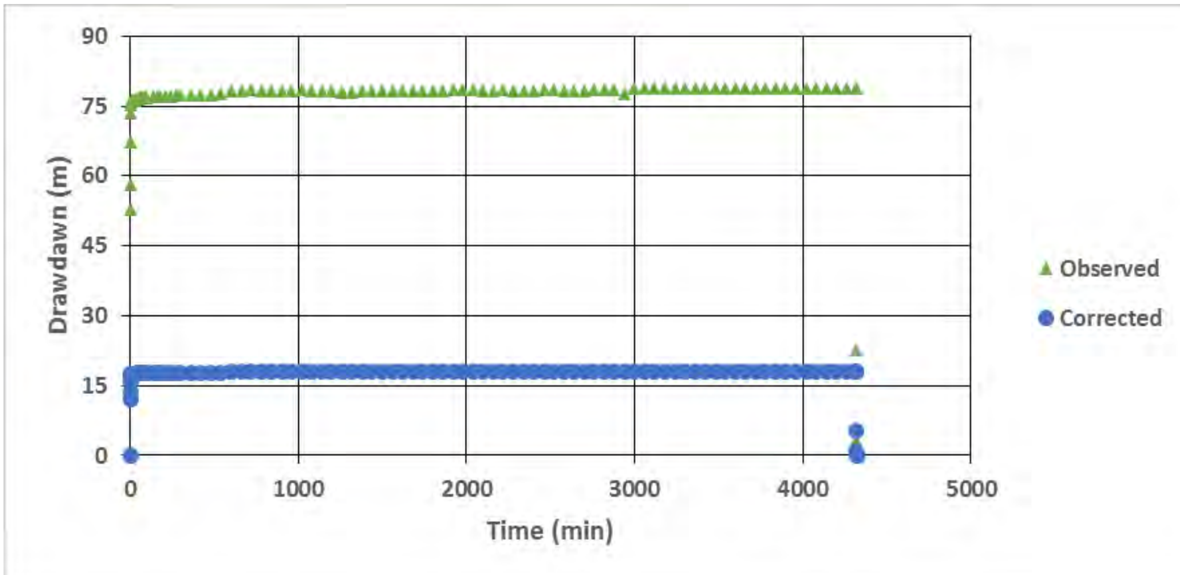


Figure A- 11.Plot for observed and corrected drawdown for LLA-6.

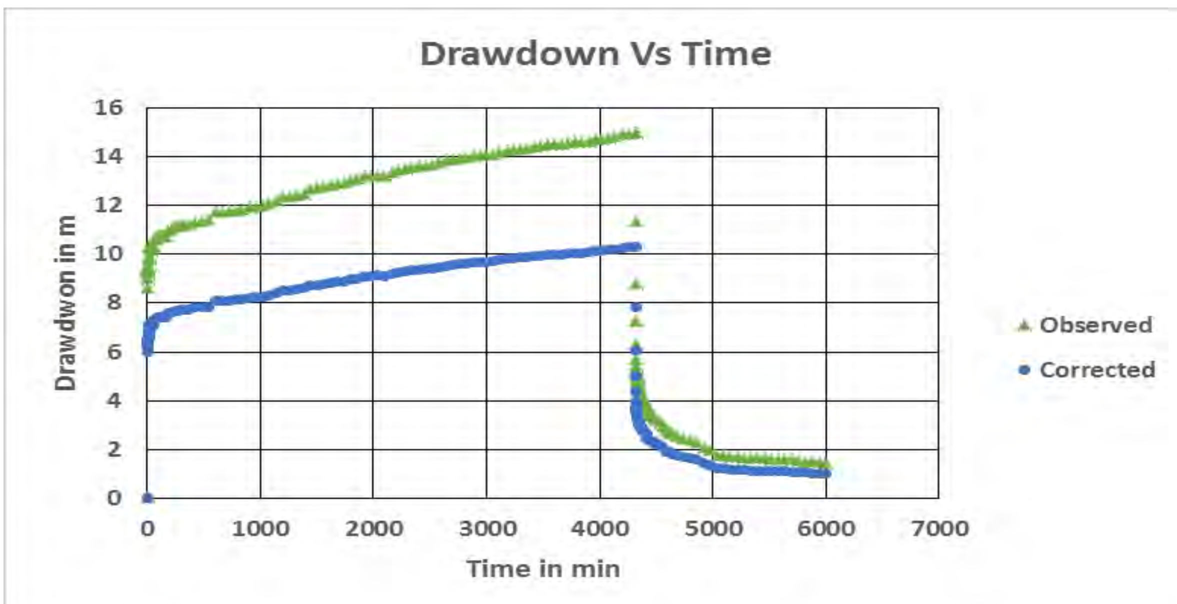


Figure A- 12. Plot for observed and corrected drawdown for LLA-PW1.

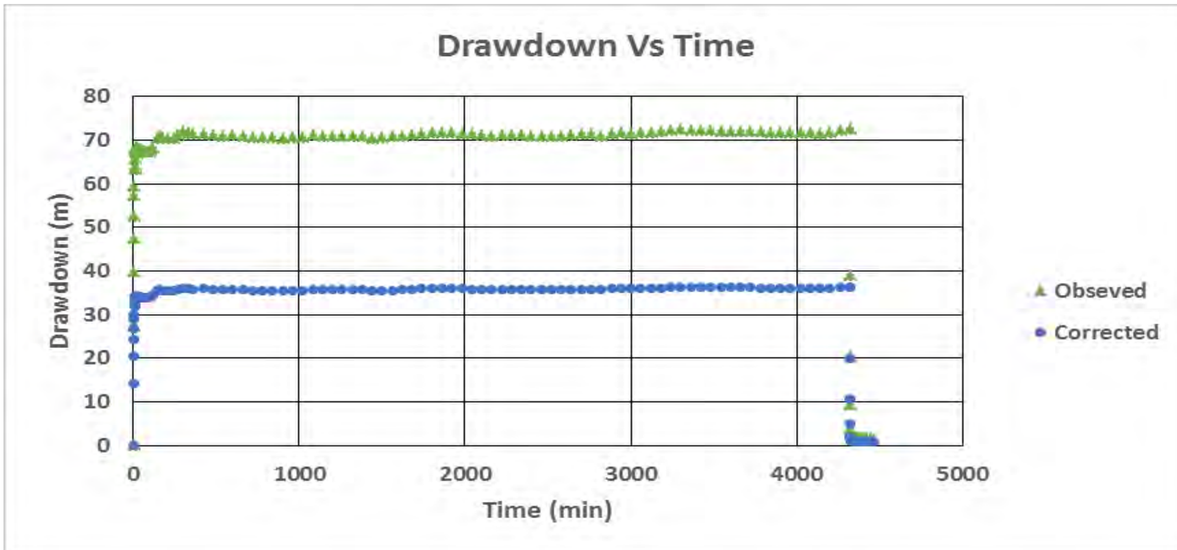


Figure A- 13. Plot for observed and corrected drawdown for LLA-PW5.

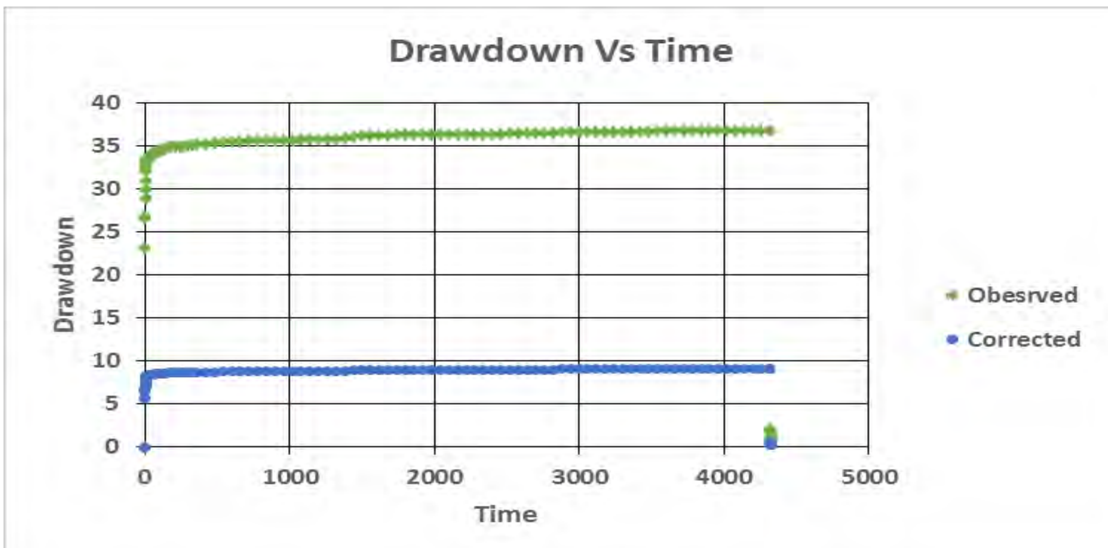


Figure A- 14.Plot for observed and corrected drawdown for LLA-PW7.

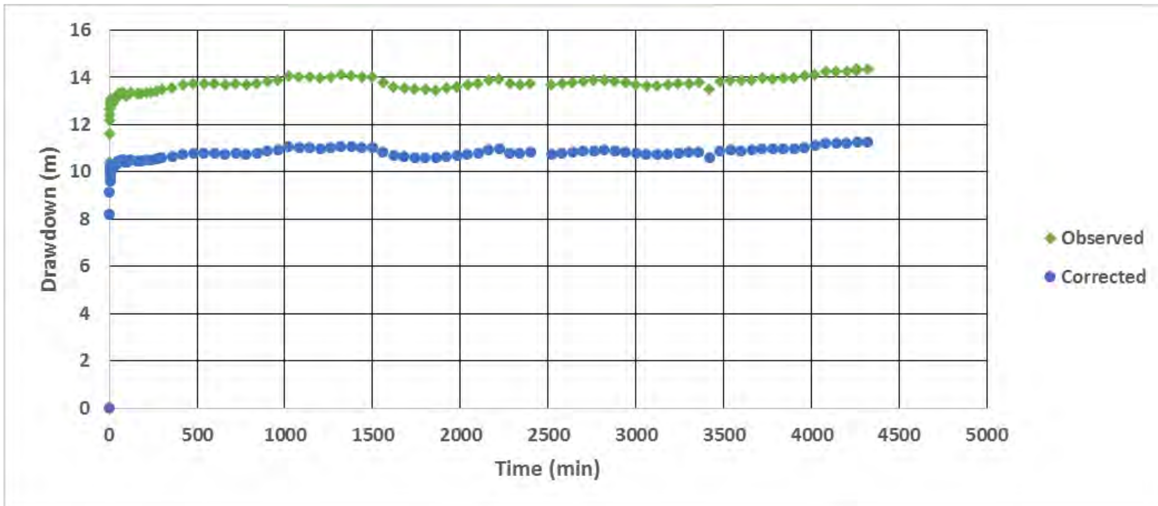


Figure A- 15.Plot for observed and corrected drawdown for LLA-3.

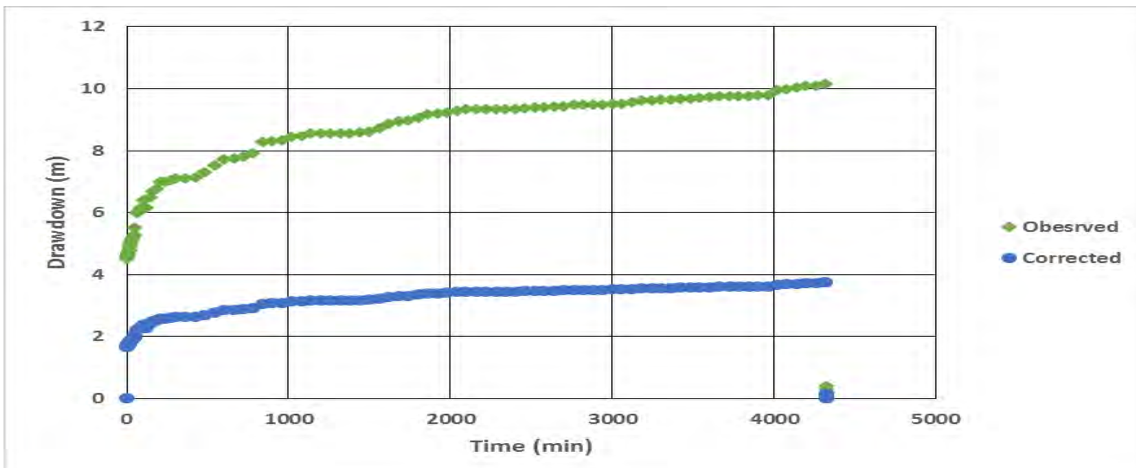


Figure A- 16.Plot for observed and corrected drawdown for LLA-5.

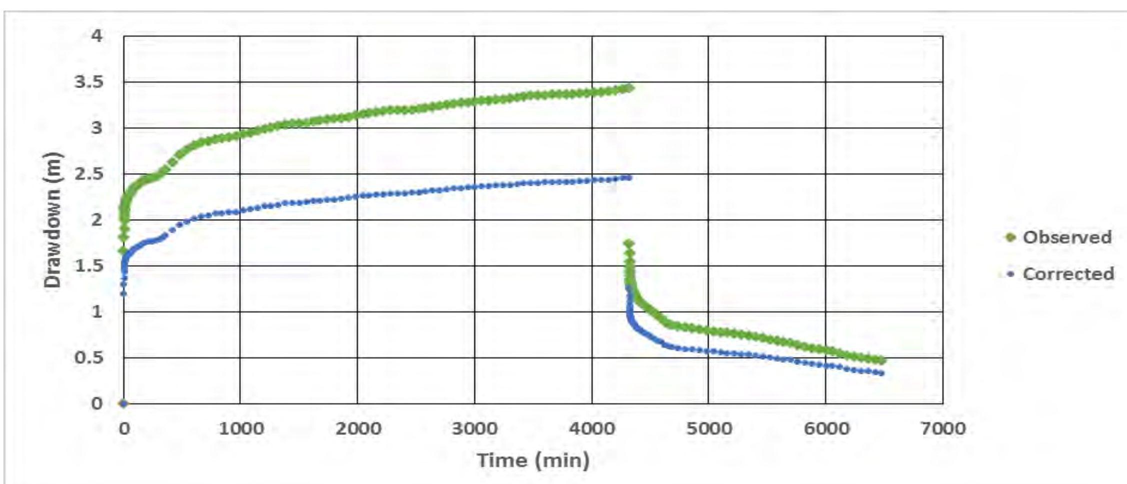


Figure A- 17.Plot for observed and corrected drawdown for LLA-PW3.

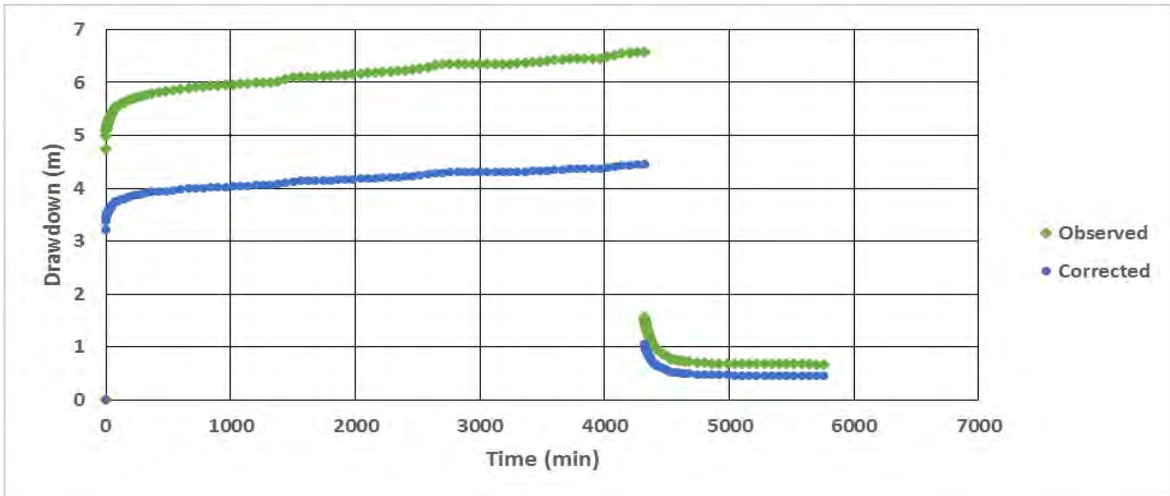
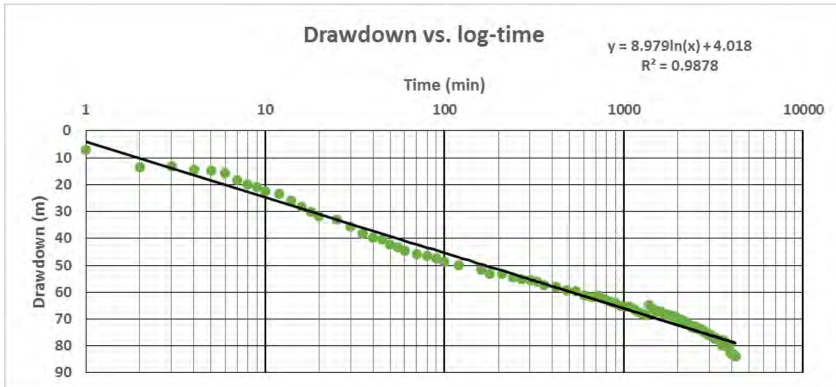


Figure A- 18.Plot for observed and corrected drawdown for LLA-PW4.

Appendix-4 Best Fit line for Cooper-Jacob Analysis.

(a).Observed Drawdown



(b).Corrected Drawdown

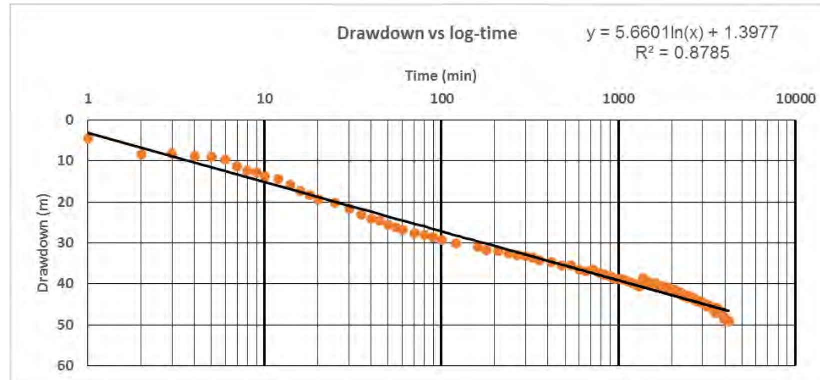
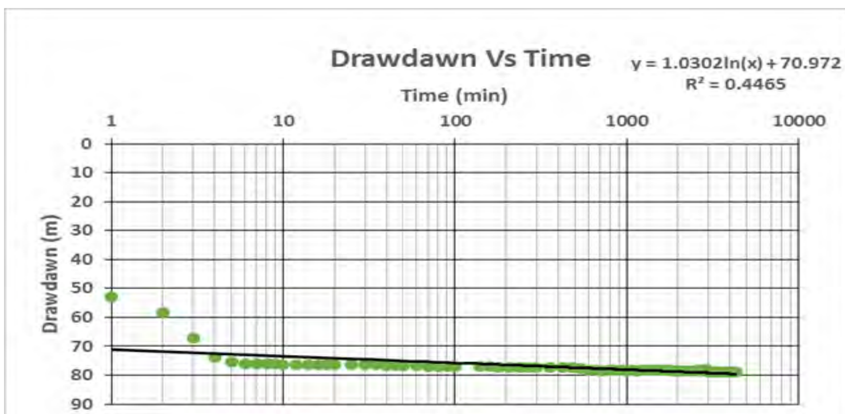


Figure A- 19.Best fit line for LLA-1 (a & b).

(c).Observed drawdown



(d) Corrected Drawdown

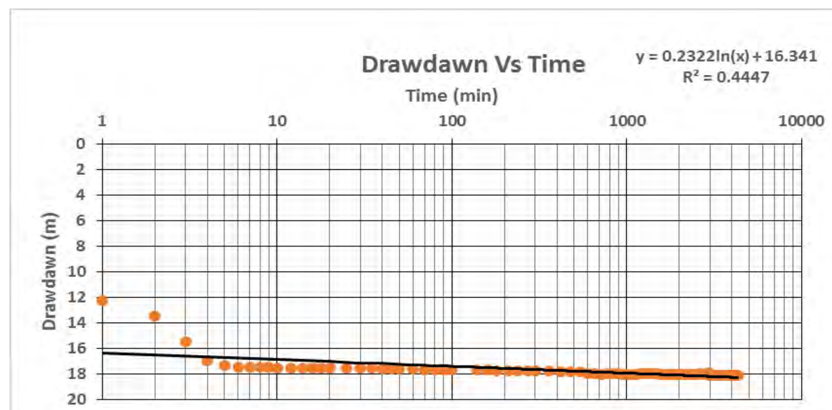
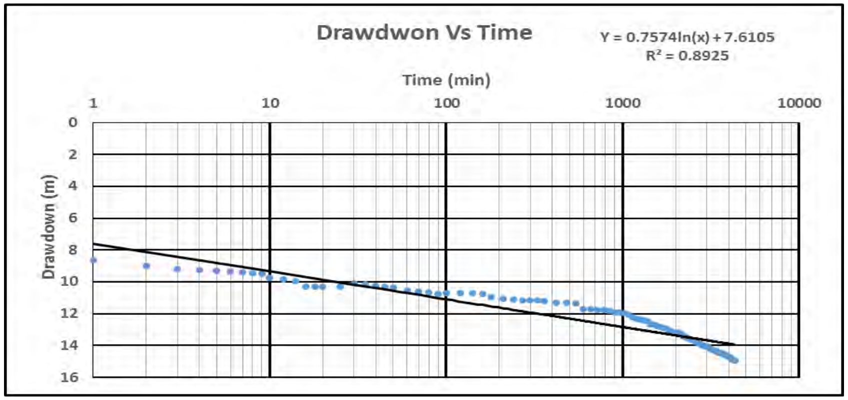


Figure A- 20.Best fit line for LLA-6 (c & d).

(e).Observed drawdown



(f) .Corrected Drawdown

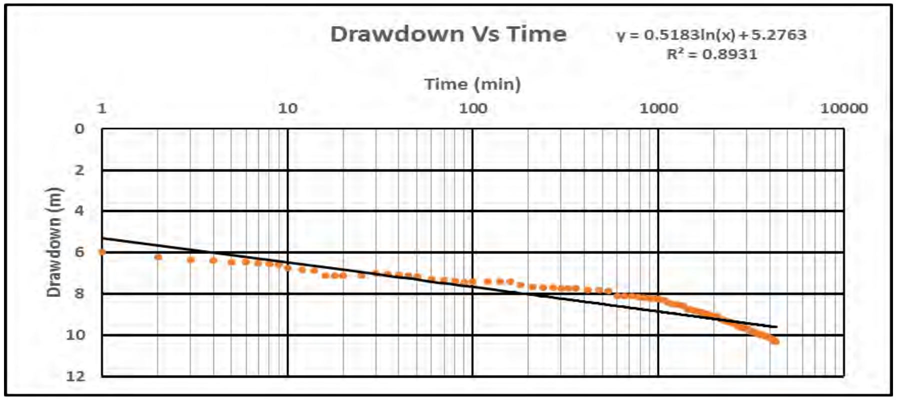
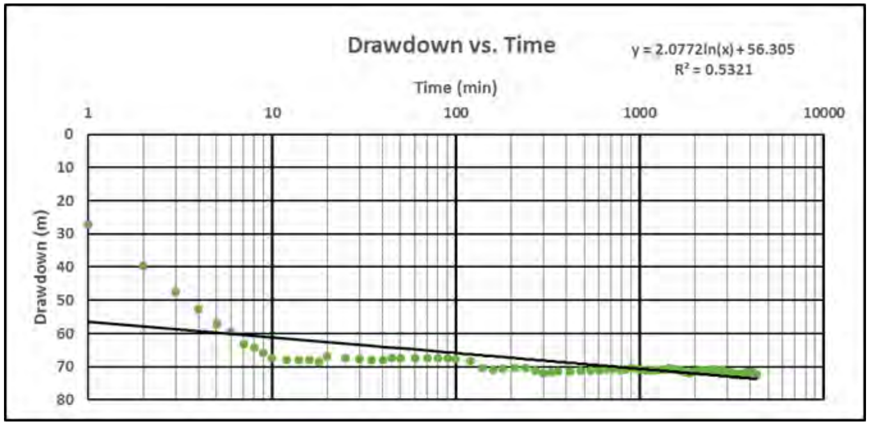


Figure A- 21.Best fit line for LLA-PW1 (e & f).

(g).Observed drawdown



(h) .Corrected Drawdown

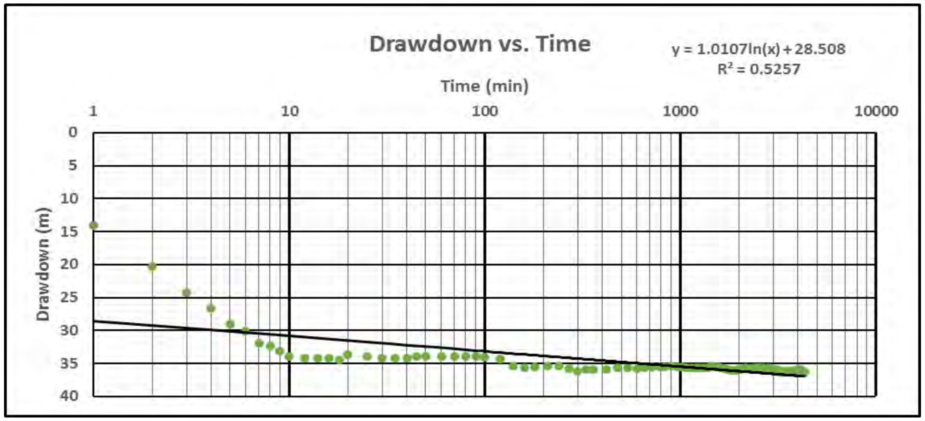
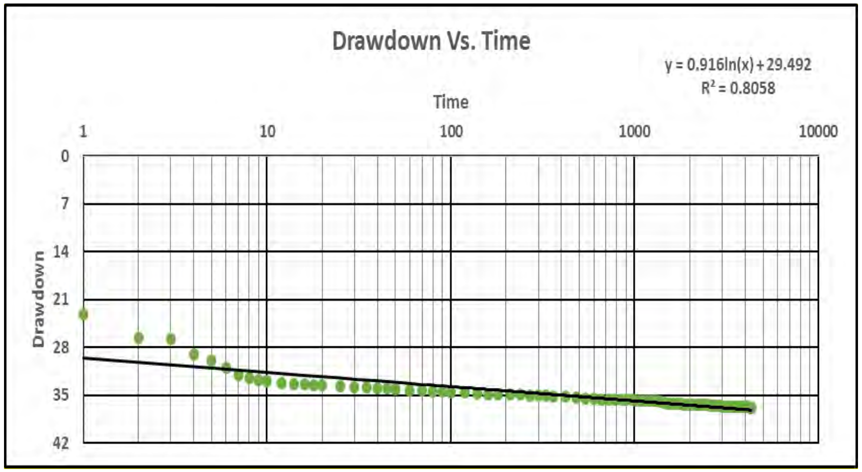


Figure A- 22.Best fit line for LLA-PW5 (g & h).

(i).Observed drawdown



(j) .Corrected Drawdown

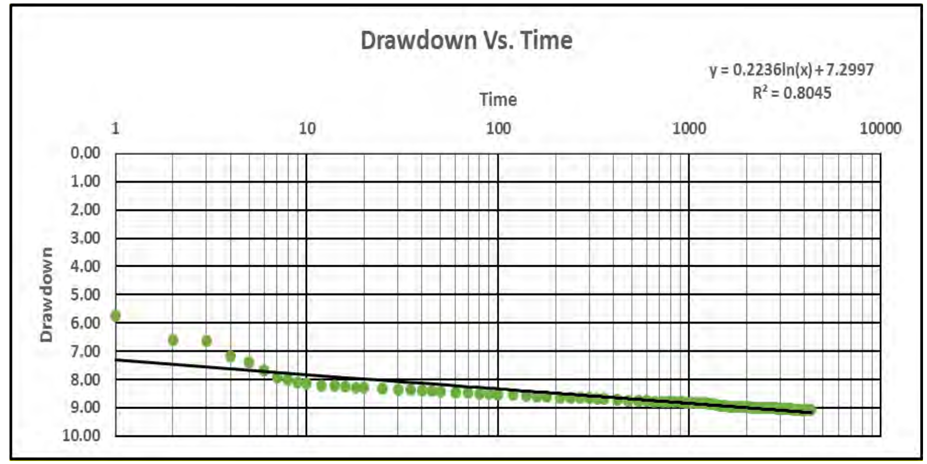
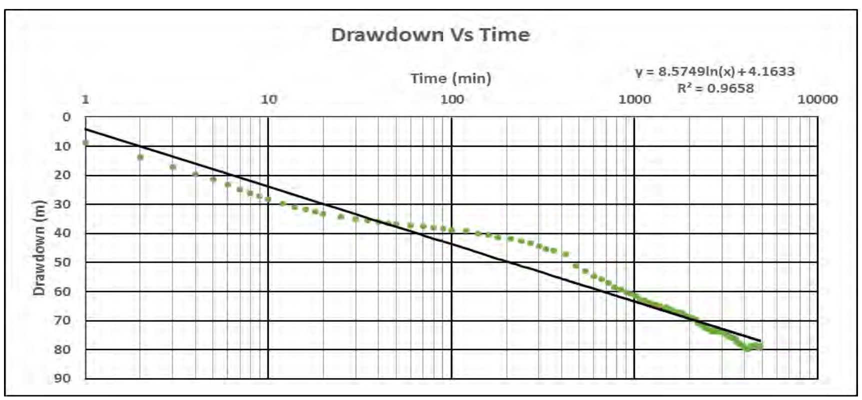


Figure A- 23.Best fit line for LLA-PW1 (i & j).

(k).Observed drawdown



(l) .Corrected Drawdown

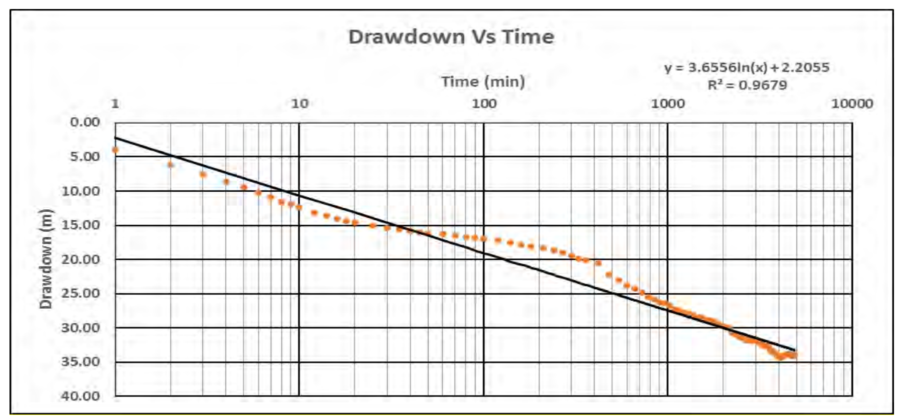
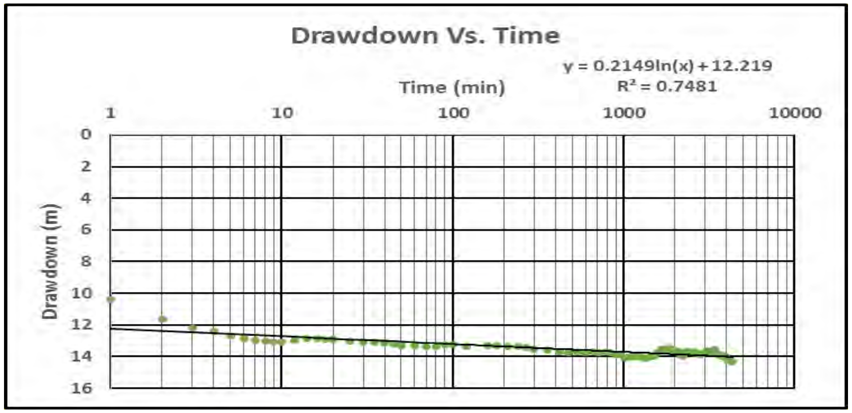


Figure A- 24.Best fit line for LLA-2 (k & l).

(m).Observed drawdown



(n) .Corrected Drawdown

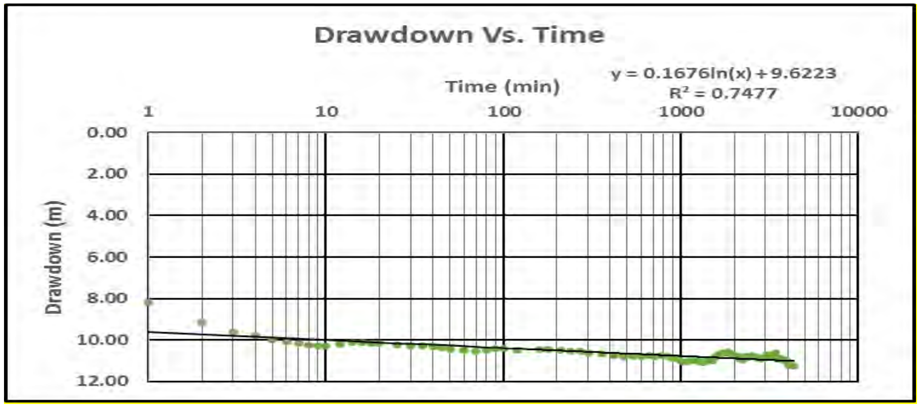
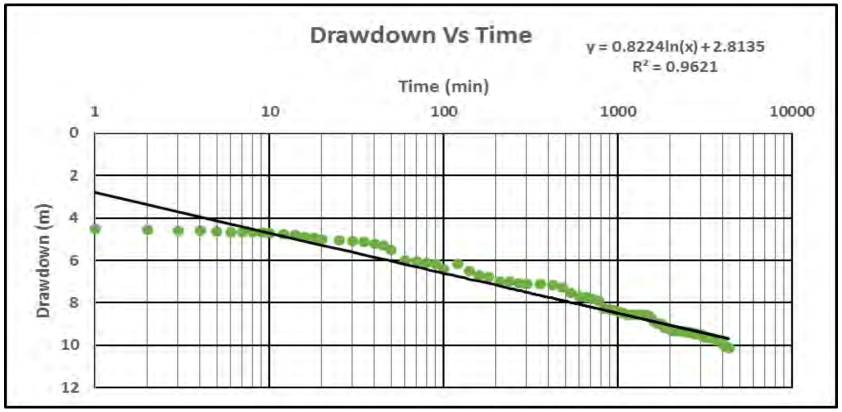


Figure A- 25.Best fit line for LLA-3 (m & n).

(o).Observed drawdown



(p) .Corrected Drawdown

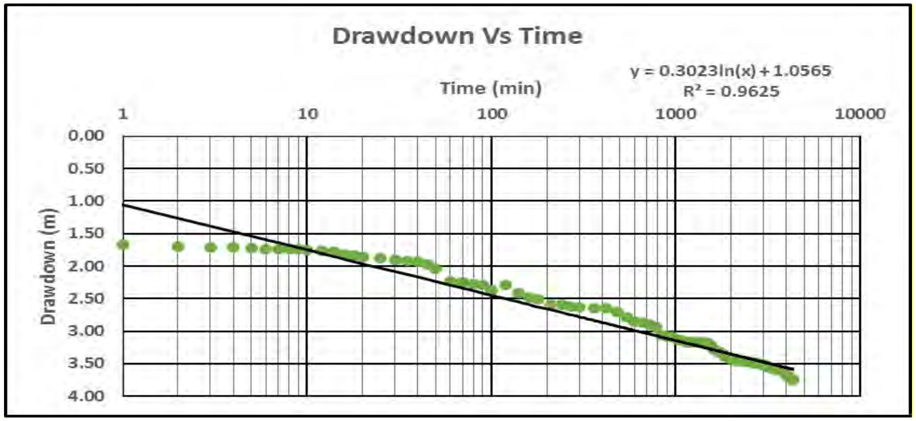
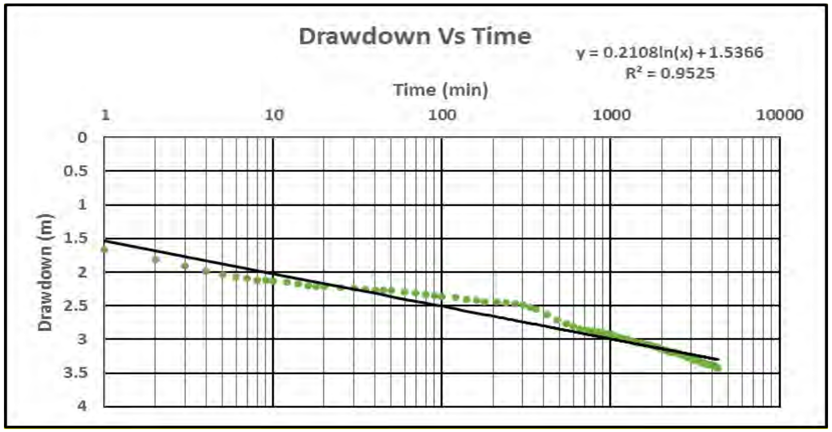


Figure A- 26.Best fit line for LLA-3 (m & n).

(q).Observed drawdown



(r) .Corrected Drawdown

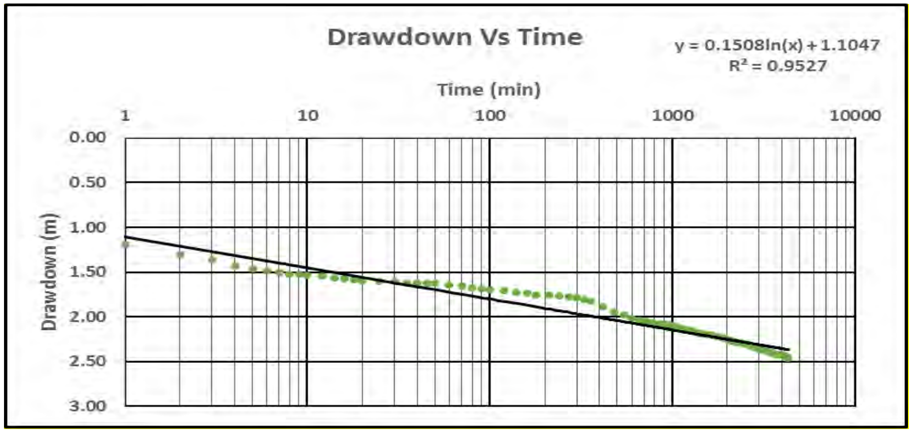
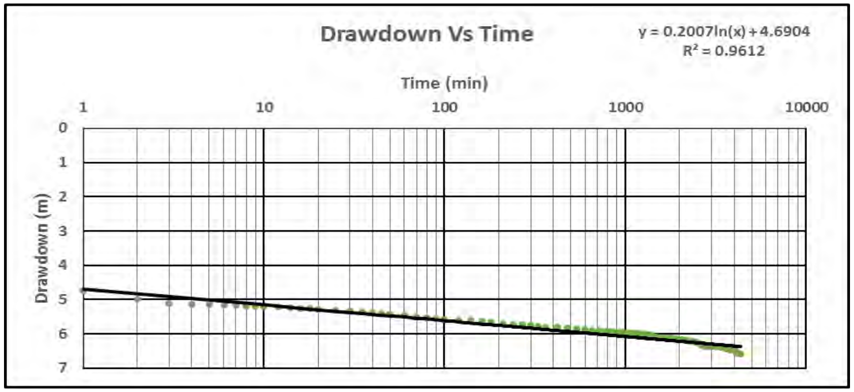


Figure A- 27.Best fit line for LLA-PW3 (q & r).

(s).Observed drawdown



(r) .Corrected Drawdown

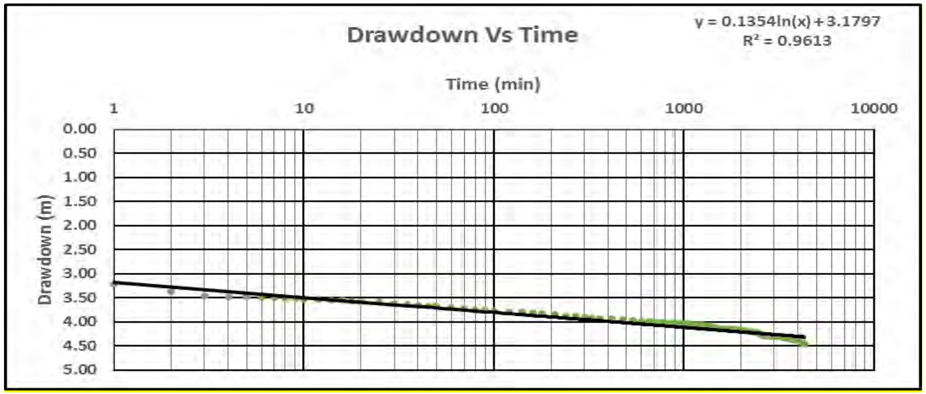
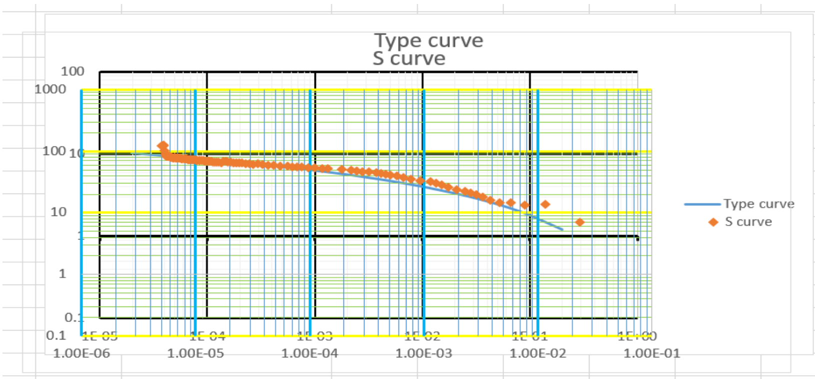


Figure A- 28.Best fit line for LLA-PW4 (q & r).

Appendix-5 Overlap of the type and s curve for the Theis Analysis.

(a). Overlap of observed drawdown



(b). Overlap of corrected drawdown

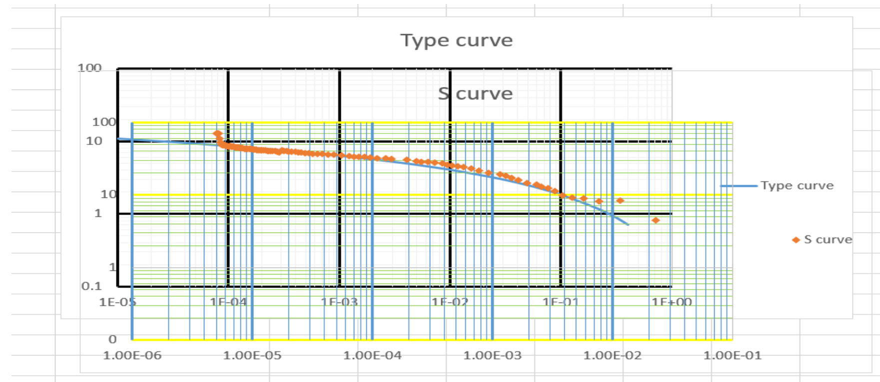
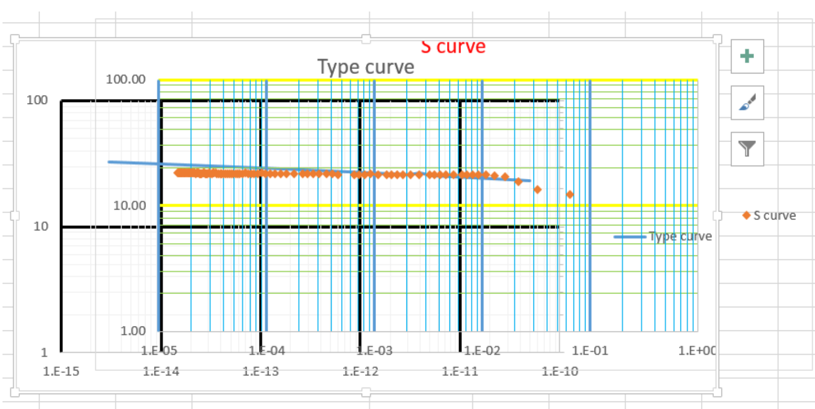


Figure A- 29.Type curve and S curve for LLA-1 (a & b).

(c). Overlap of observed drawdown



(d). Overlap of corrected drawdown

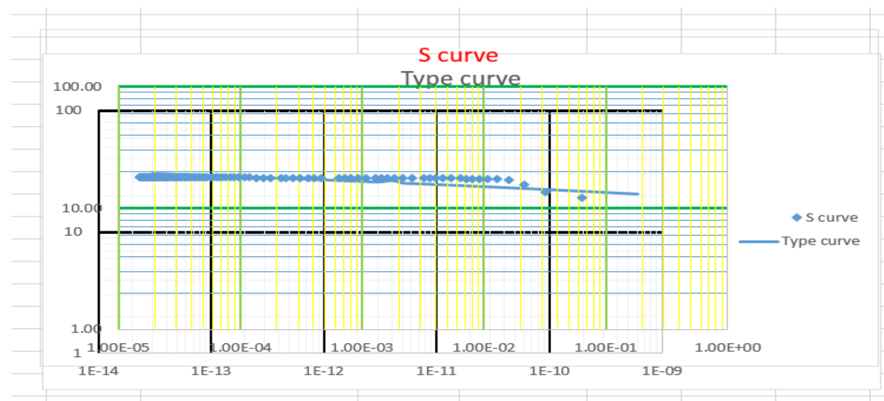
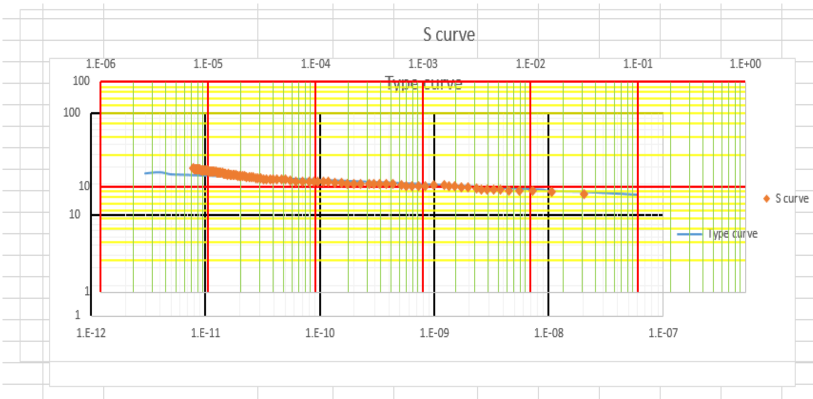


Figure A- 30.Type curve and S curve for LLA-6 (c & d).

(e). Overlap of observed drawdown



(f). Overlap of corrected drawdown

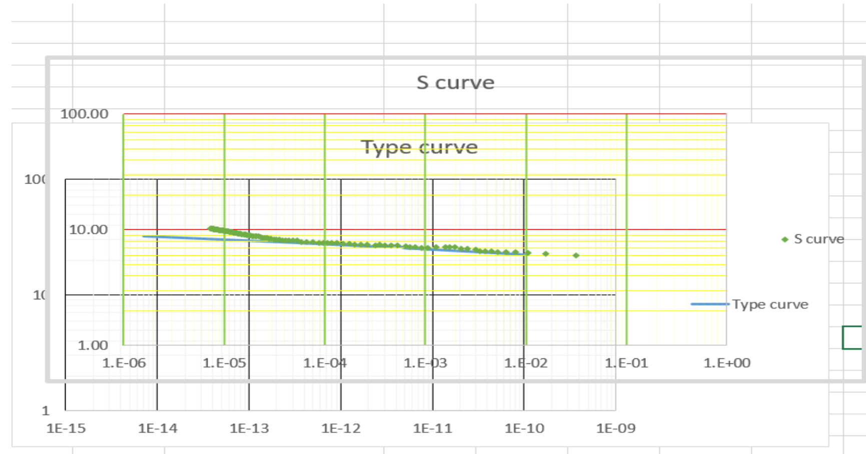
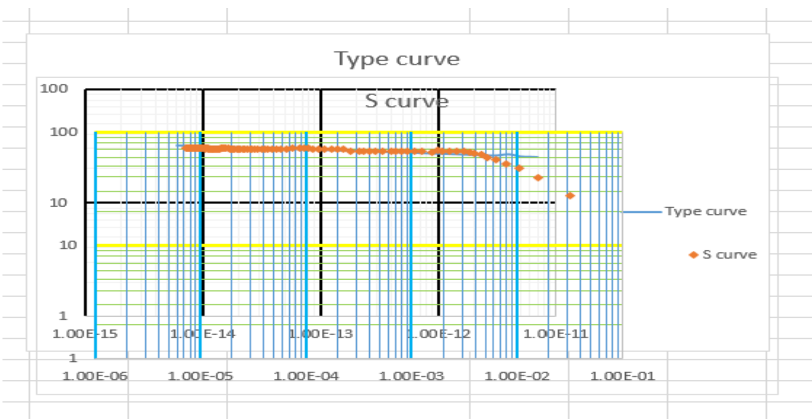


Figure A- 31.Type curve and S curve for LLA-PW1 (e & f).

(g).Overlap of observed drawdown



(h). Overlap of corrected drawdown

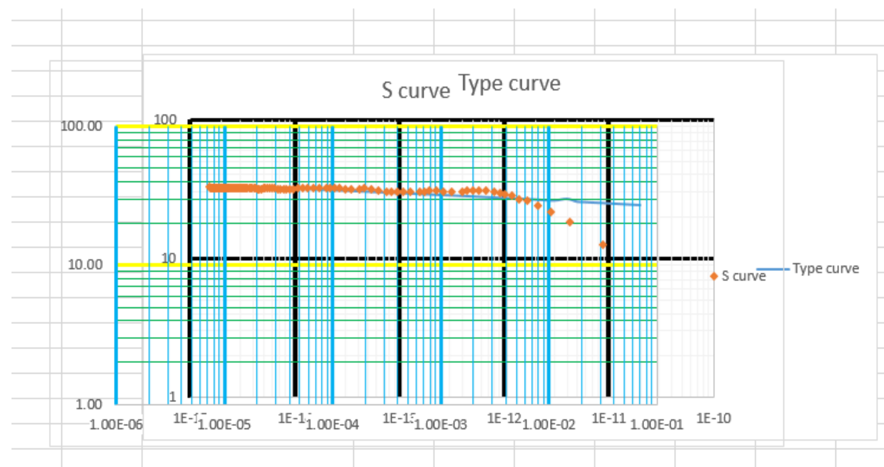


Figure A- 32.Type curve and S curve for LLA-PW5 (g & h*).*

(i). Overlap of observed drawdown

(j). Overlap of corrected drawdown

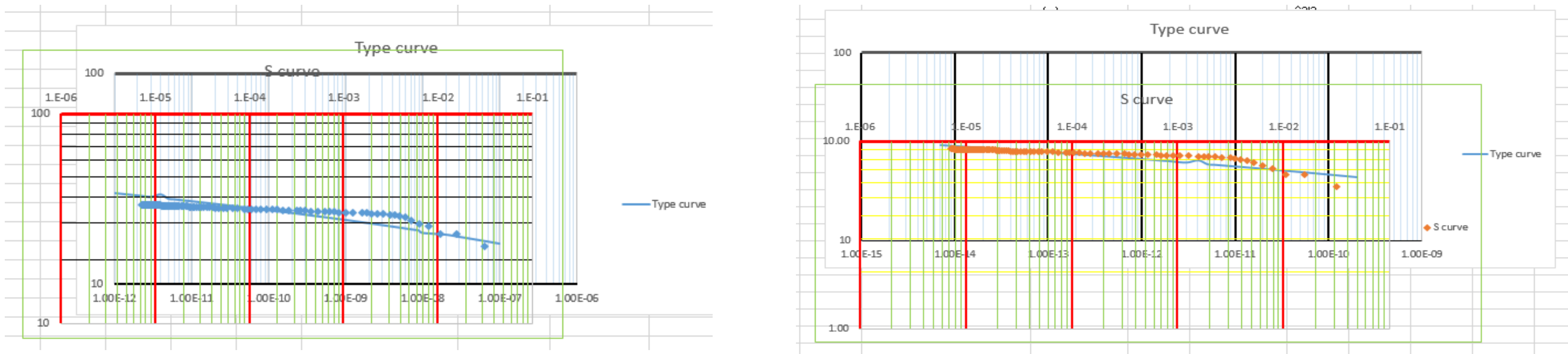


Figure A- 33.Type curve and S curve for LLA-PW7 (i & j).

(k). Overlap of observed drawdown

(l). Overlap of corrected drawdown

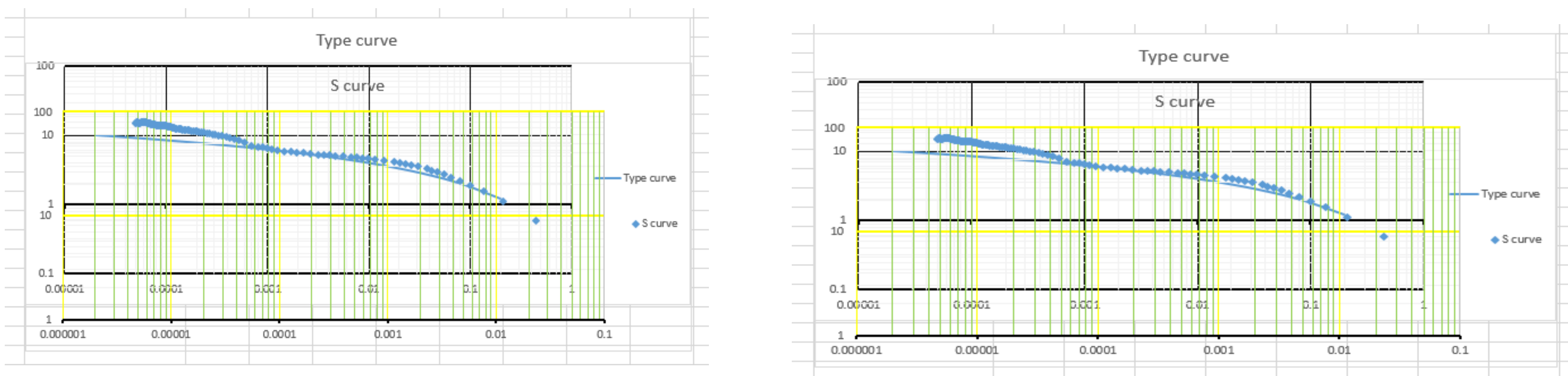
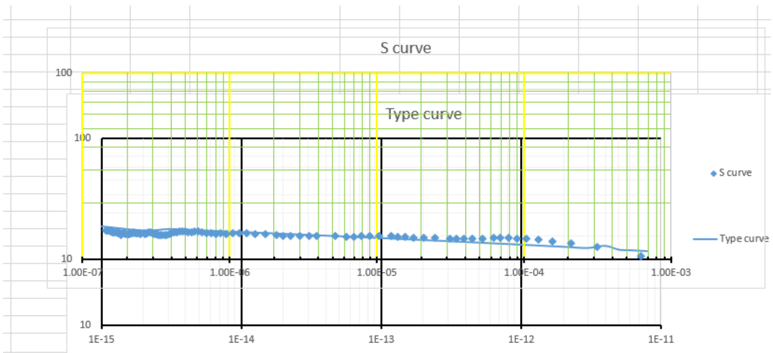


Figure A- 34.Type curve and S curve for LLA-2 (k & l).

(m).Overlap of observed drawdown



(n). Overlap of corrected drawdown

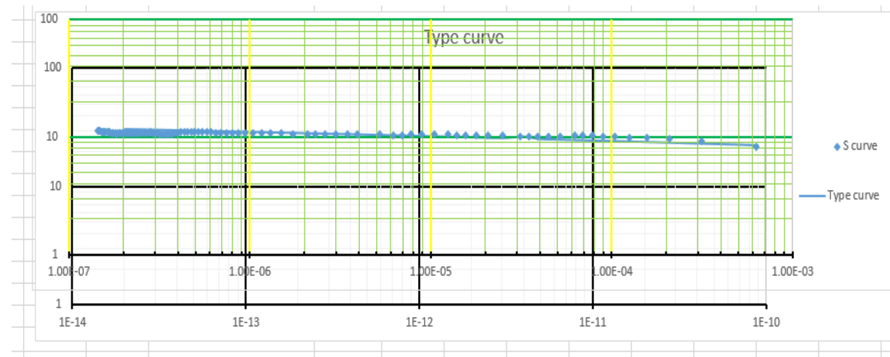
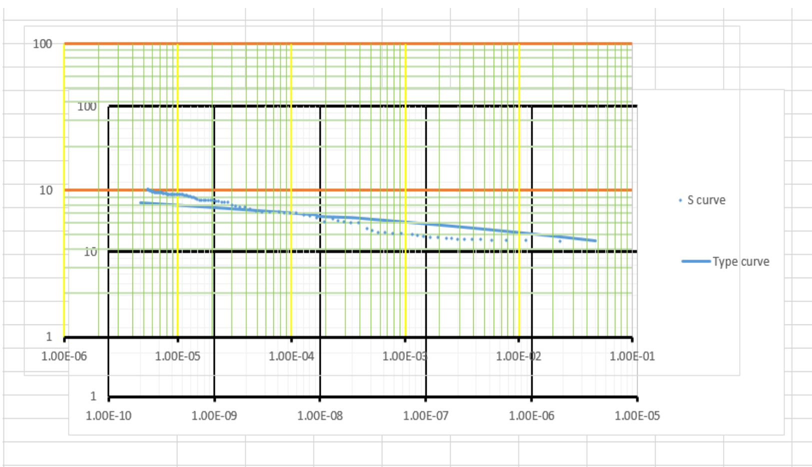


Figure A- 35.Type curve and S curve for LLA-3 (m & n).

(o).Overlap of observed drawdown



(p). Overlap of corrected drawdown

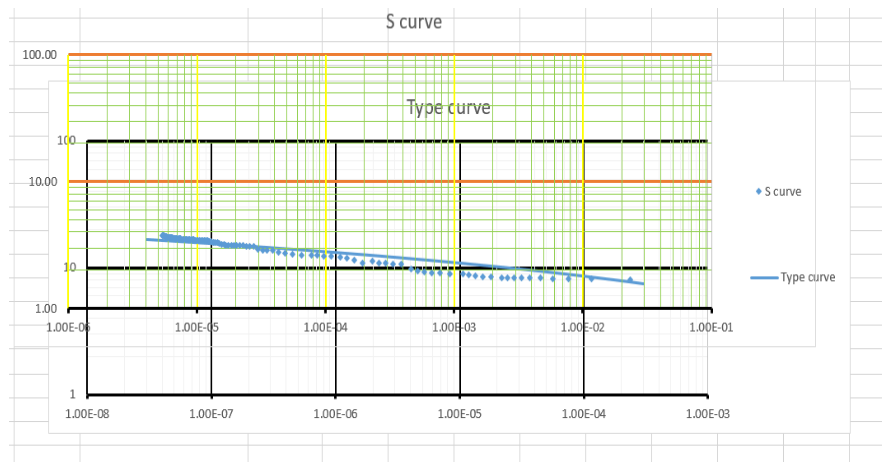
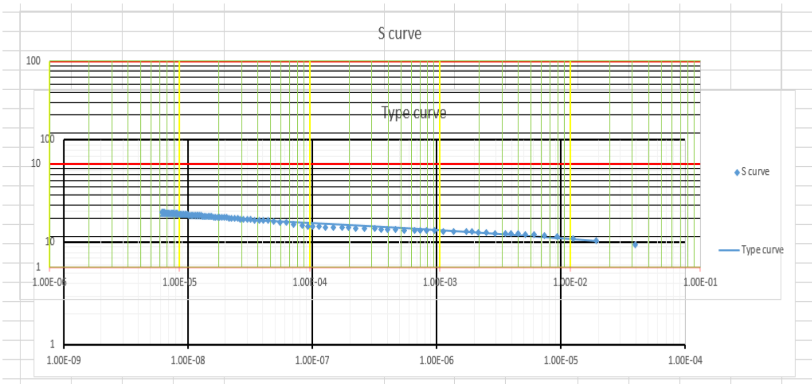


Figure A- 36.Type curve and S curve for LLA-5 (o & p).

(q).Overlap of observed drawdown



(r). Overlap of corrected drawdown

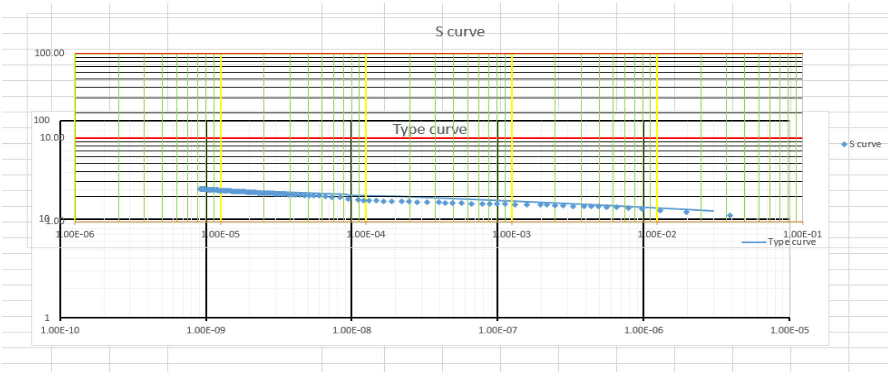
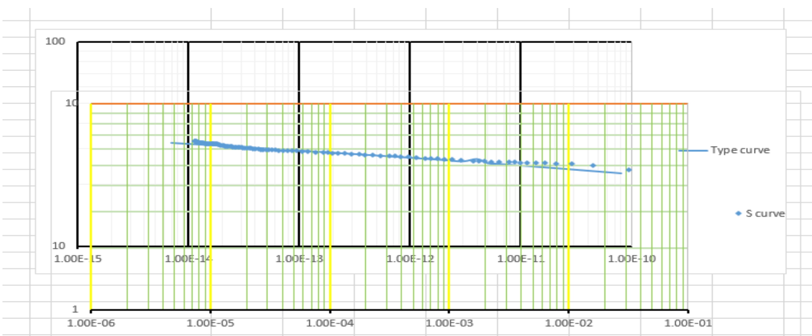


Figure A- 37.Type curve and S curve for LLA-PW3 (q &r).

(s).Overlap of observed drawdown



(t). Overlap of corrected drawdown

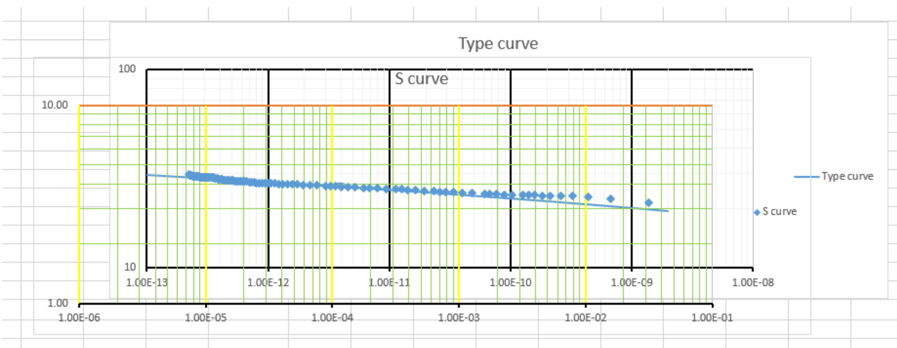
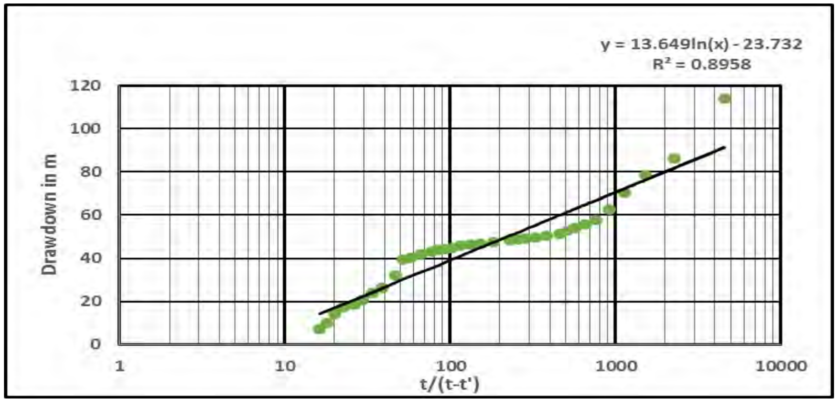


Figure A- 38.Type curve and S curve for LLA-PW4 (s & t).

Appendix-6 Best Fit Line for the Residual Drawdown.

(a). Observed residual drawdown



(b). Corrected residual drawdown

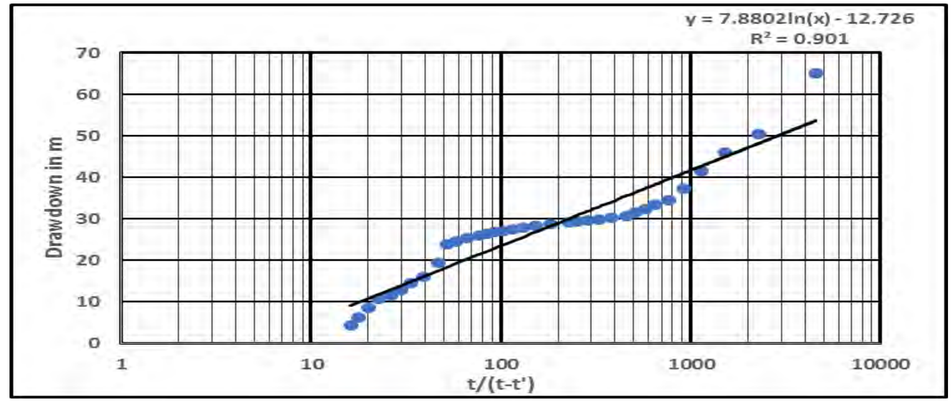
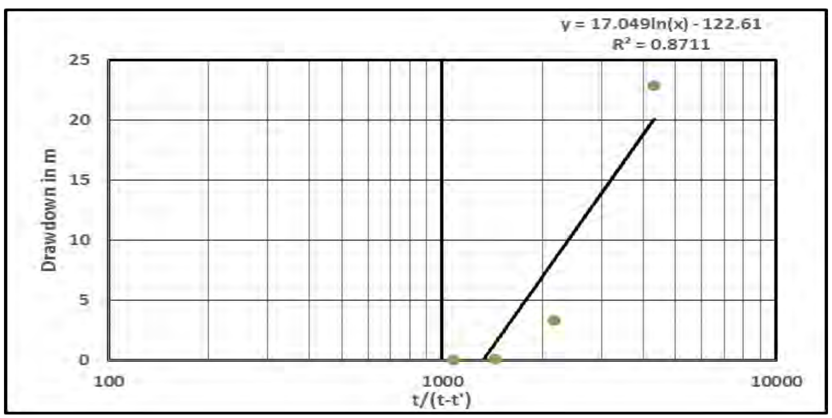


Figure A- 39.Residual drawdown plots for LLA-1 (a & b).

(c). Observed residual drawdown



(d). Corrected residual drawdown

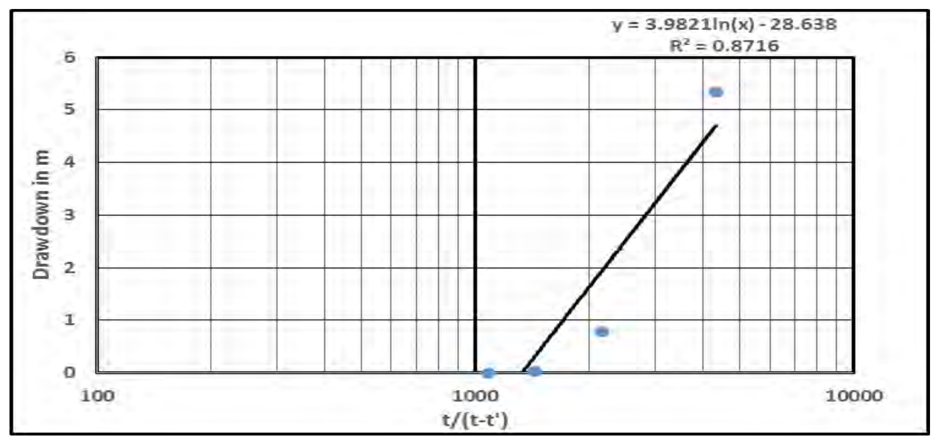
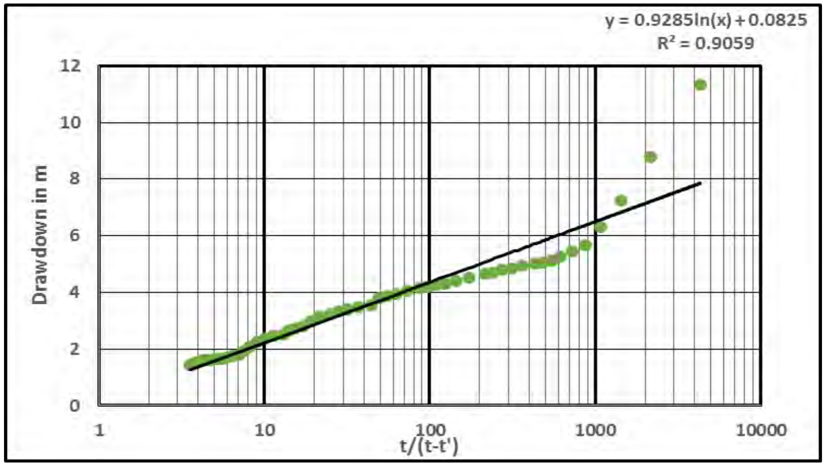


Figure A- 40.Residual drawdown plots for LLA-6 (c & d).

(e). Observed residual drawdown



(f). Corrected residual drawdown

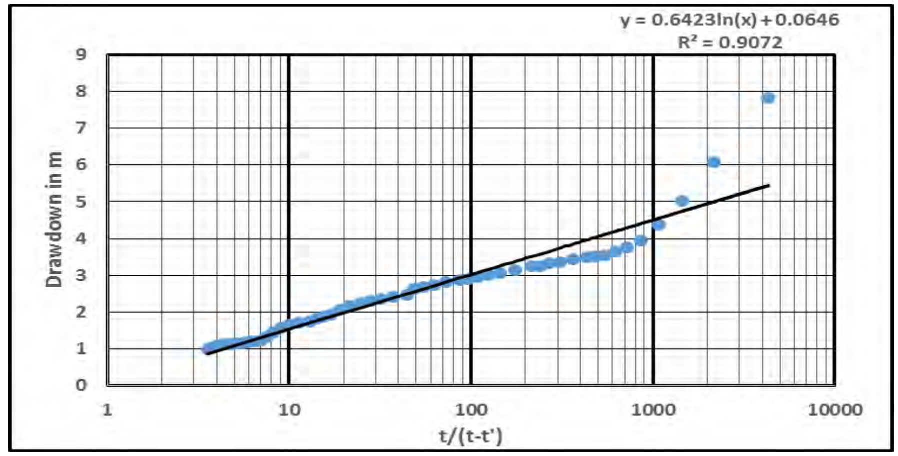
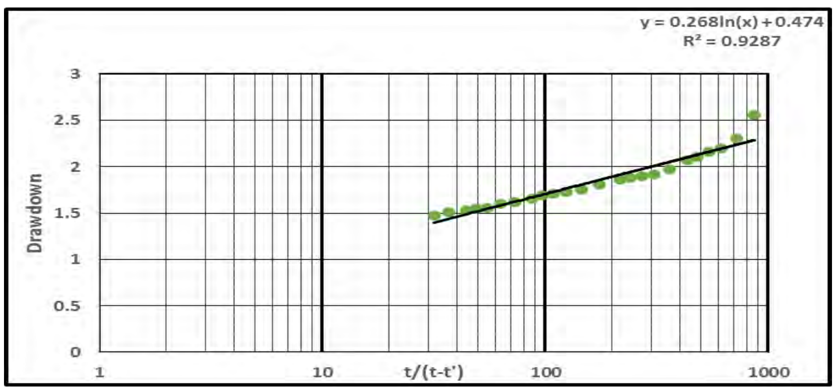


Figure A- 41.Residual drawdown plots for LLA-PW1 (e & f)

(g). Observed residual drawdown



(h). Corrected residual drawdown

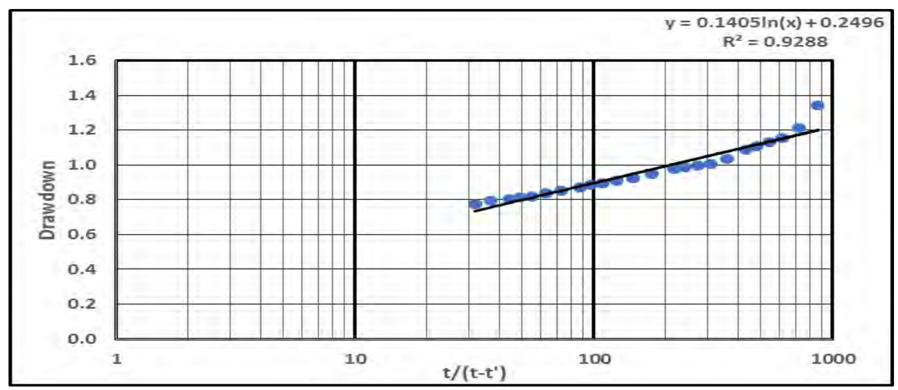
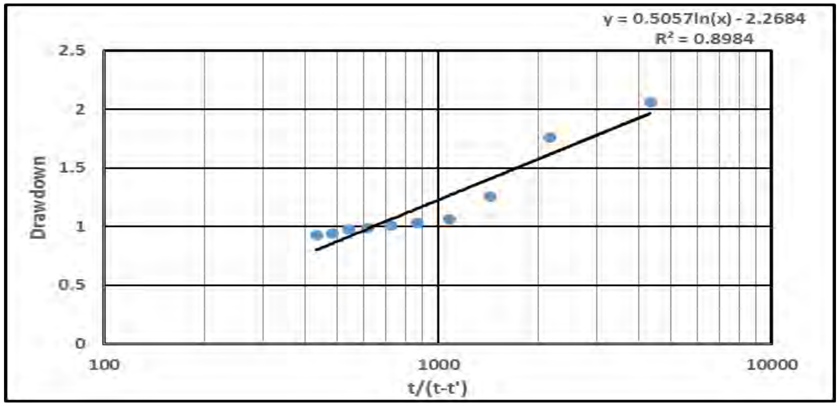


Figure A- 42.Residual drawdown plots for LLA-PW5 (g & h).

(i). Observed residual drawdown



(j). Corrected residual drawdown

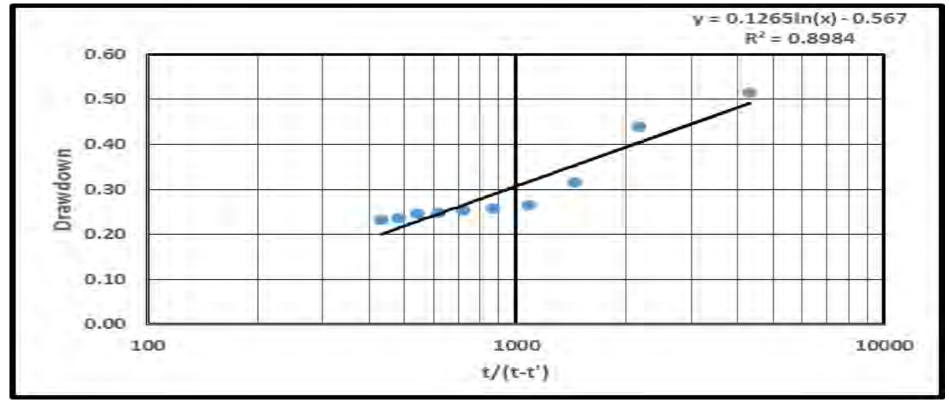
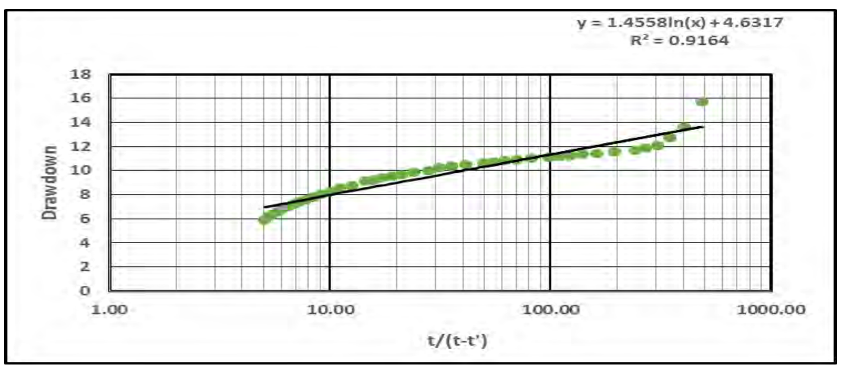


Figure A- 43.Residual drawdown plots for LLA-PW7 (i & j).

(k). Observed residual drawdown



(j). Corrected residual drawdown

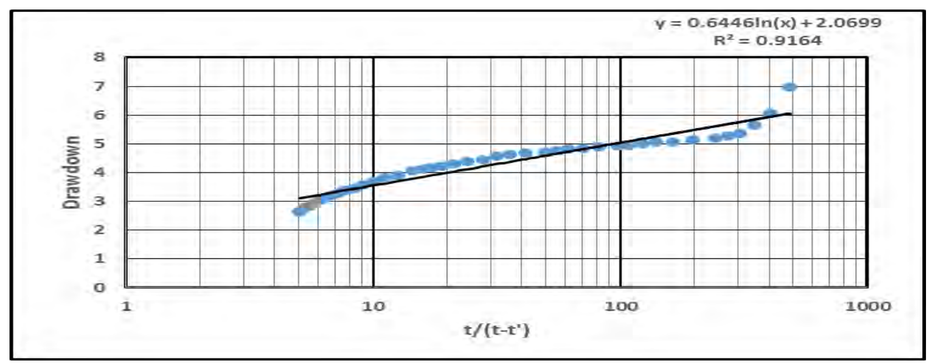
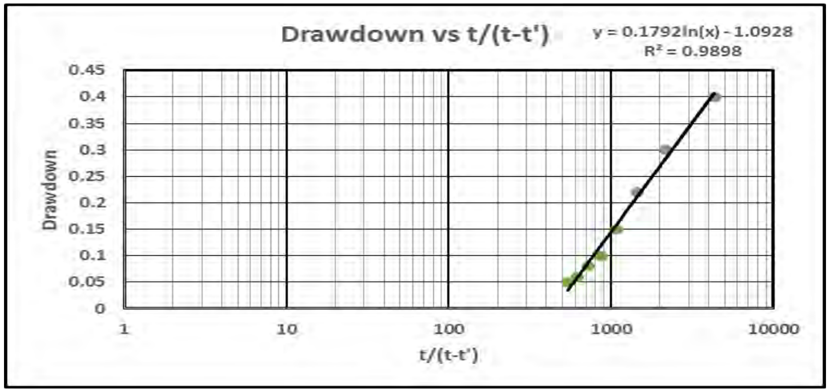


Figure A- 44.Residual drawdown plots for LLA-2 (k& l).

m). Observed recovery drawdown



(n). Corrected recovery drawdown

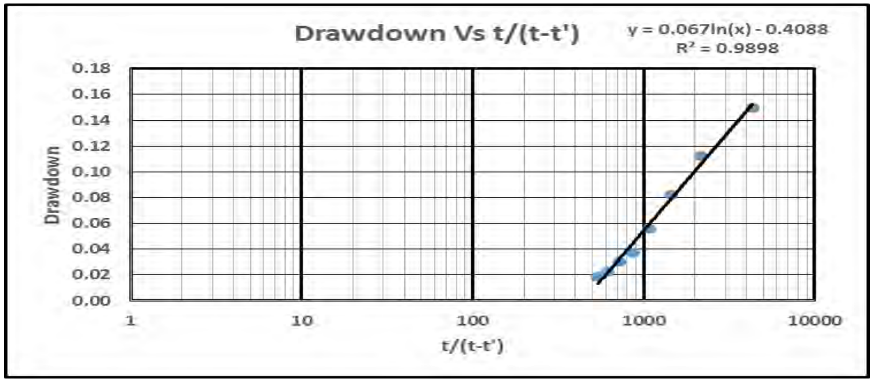
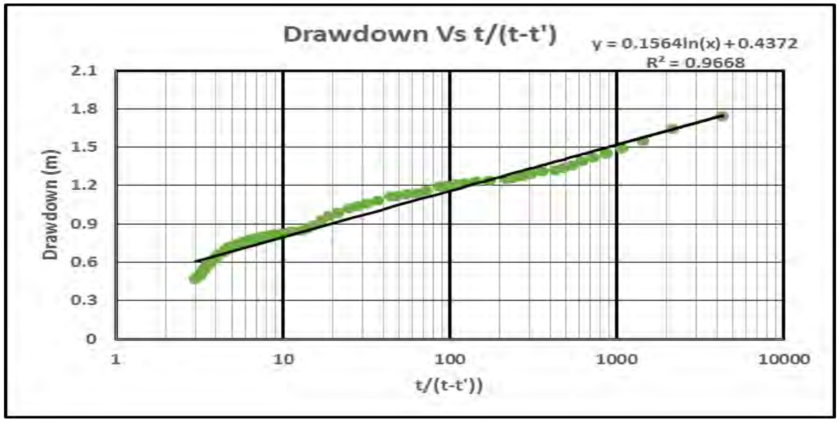


Figure A- 45.Residual drawdown plots for LLA-5 (m & n).

(o). Observed recovery drawdown



(p). Corrected recovery drawdown

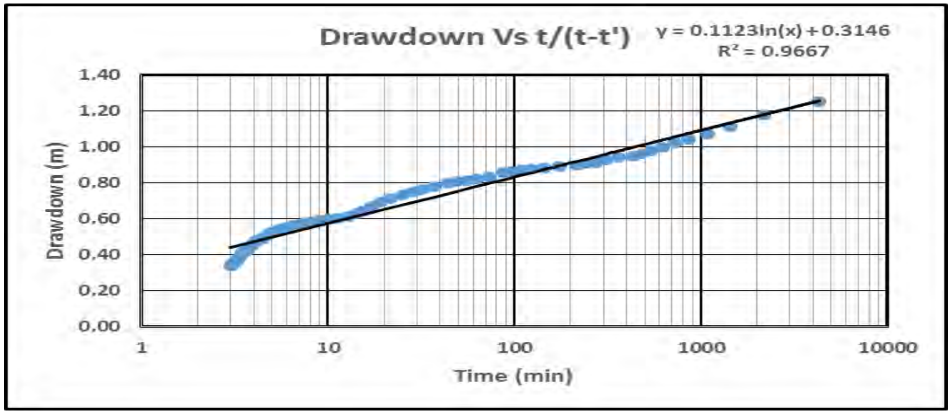
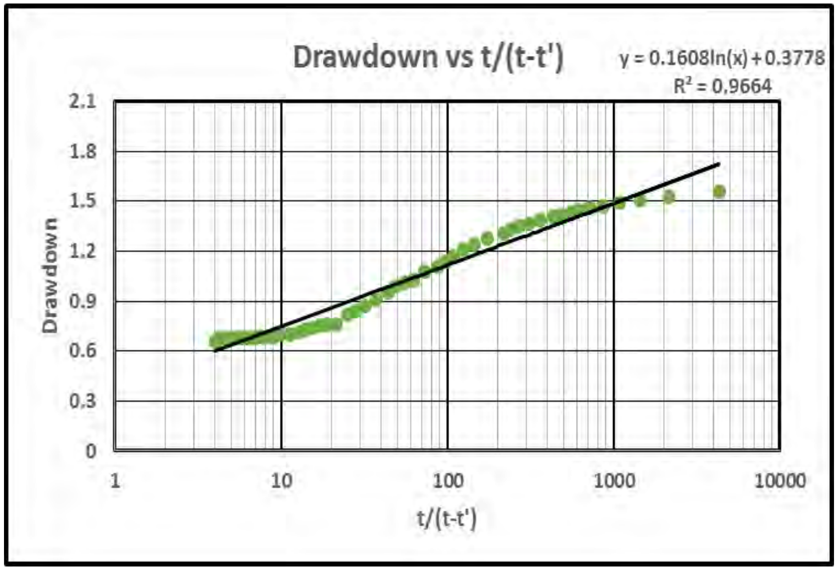


Figure A- 46.Residual drawdown plots for LLA-PW3 (o & p).

(q). Observed recovery drawdown



(r). Corrected recovery drawdown

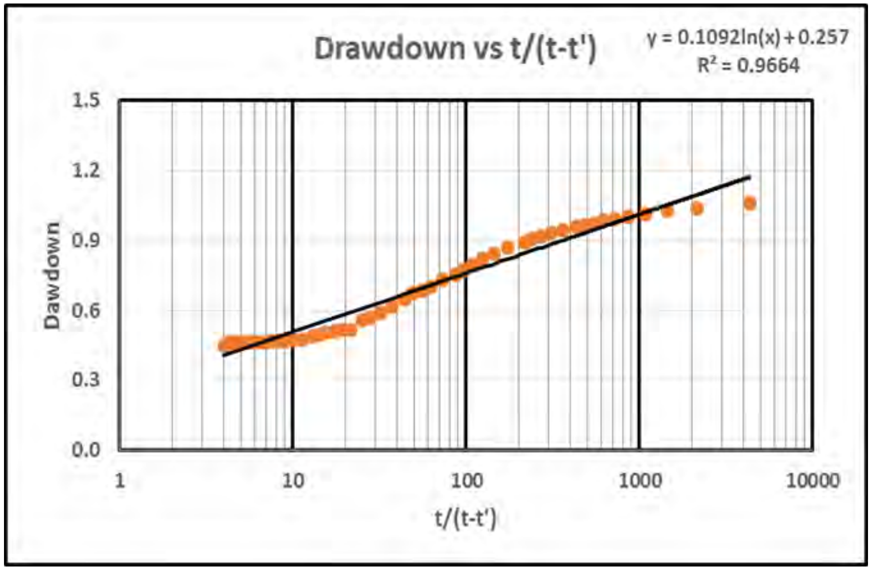


Figure A- 47.Residual drawdown plots for LLA-PW4 (q & r).

Appendix-7 Raw Constant Pumping and Recovery Test Data

Table A- 26.Constant pumping test and recovery test for LLA-1.

Time, min	Water Level	Drawdowns(Sa)	Correction for Well loss(Sw)	Drawdown after Well loss correction (Sa)	Correction for unconfind Aquifer (Sc)
0	7.3	0	0	0.00	0.00
1	14.4	7.1	2.67	4.43	4.41
2	20.86	13.56	5.10	8.46	8.38
3	20.47	13.17	4.95	8.22	8.14
4	21.69	14.39	5.41	8.98	8.89
5	22.11	14.81	5.57	9.24	9.14
6	23.06	15.76	5.92	9.84	9.72
7	25.64	18.34	6.89	11.45	11.29
8	27.29	19.99	7.51	12.48	12.29
9	28.1	20.8	7.82	12.98	12.78
10	29.75	22.45	8.44	14.01	13.78
12	30.74	23.44	8.81	14.63	14.38
14	33.32	26.02	9.78	16.24	15.93
16	35.5	28.2	10.60	17.60	17.24
18	37.43	30.13	11.32	18.81	18.39
20	39	31.7	11.91	19.79	19.33
25	40.48	33.18	12.47	20.71	20.21
30	42.99	35.69	13.41	22.28	21.69
35	45.3	38	14.28	23.72	23.06
40	47	39.7	14.92	24.78	24.06
45	47.85	40.55	15.24	25.31	24.56
50	49.55	42.25	15.88	26.37	25.55
55	50.6	43.3	16.27	27.03	26.17
60	51.8	44.5	16.72	27.78	26.87
70	53	45.7	17.17	28.53	27.57
80	53.9	46.6	17.51	29.09	28.09
90	54.75	47.45	17.83	29.62	28.59
100	56.1	48.8	18.34	30.46	29.37
120	57.45	50.15	18.85	31.30	30.15
160	58.85	51.55	19.37	32.18	30.96

180	60.36	53.06	19.94	33.12	31.83
210	60.63	53.33	20.04	33.29	31.98
240	61.74	54.44	20.46	33.98	32.62
270	62.44	55.14	20.72	34.42	33.02
300	62.8	55.5	20.86	34.64	33.23
330	63.5	56.2	21.12	35.08	33.63
360	64.7	57.4	21.57	35.83	34.32
420	65.4	58.1	21.83	36.27	34.72
480	66.7	59.4	22.32	37.08	35.46
540	66.9	59.6	22.40	37.20	35.57
600	68.52	61.22	23.01	38.21	36.49
660	69.2	61.9	23.26	38.64	36.88
720	68.6	61.3	23.04	38.26	36.54
780	69.9	62.6	23.53	39.07	37.28
840	70.85	63.55	23.88	39.67	37.82
900	71.3	64	24.05	39.95	38.07
960	72.44	65.14	24.48	40.66	38.71
1020	72.6	65.3	24.54	40.76	38.80
1080	72.8	65.5	24.61	40.89	38.92
1140	73.56	66.26	24.90	41.36	39.35
1200	74.49	67.19	25.25	41.94	39.87
1260	75.23	67.93	25.53	42.40	40.29
1320	75.89	68.59	25.78	42.81	40.66
1380	72.09	64.79	24.35	40.44	38.52
1440	73.46	66.16	24.86	41.30	39.29
1500	74.44	67.14	25.23	41.91	39.84
1560	74.4	67.1	25.22	41.88	39.82
1620	74.55	67.25	25.27	41.98	39.90
1680	75.46	68.16	25.61	42.55	40.41
1740	75.4	68.1	25.59	42.51	40.38
1800	75.9	68.6	25.78	42.82	40.66
1860	76.15	68.85	25.87	42.98	40.80
1920	76.3	69	25.93	43.07	40.89
1980	77.3	70	26.31	43.69	41.45
2040	77.5	70.2	26.38	43.82	41.56
2100	77.5	70.2	26.38	43.82	41.56
2160	78.15	70.85	26.63	44.22	41.92
2220	78.5	71.2	26.76	44.44	42.12
2280	78.9	71.6	26.91	44.69	42.34
2340	79.8	72.5	27.25	45.25	42.84

2400	80.3	73	27.43	45.57	43.12
2460	80.83	73.53	27.63	45.90	43.42
2520	80.1	72.8	27.36	45.44	43.01
2580	80.6	73.3	27.55	45.75	43.29
2640	81	73.7	27.70	46.00	43.51
2700	81.05	73.75	27.72	46.03	43.54
2760	82	74.7	28.07	46.63	44.07
2820	82.1	74.8	28.11	46.69	44.12
2880	82.52	75.22	28.27	46.95	44.36
2940	82.7	75.4	28.34	47.06	44.46
3000	83.2	75.9	28.52	47.38	44.73
3060	83.3	76	28.56	47.44	44.79
3120	83.8	76.5	28.75	47.75	45.07
3180	84.43	77.13	28.99	48.14	45.42
3240	84.1	76.8	28.86	47.94	45.23
3300	84.8	77.5	29.12	48.38	45.62
3360	85	77.7	29.20	48.50	45.73
3420	85.3	78	29.31	48.69	45.90
3480	85.3	78	29.31	48.69	45.90
3540	87.2	79.9	30.03	49.87	46.95
3600	85.2	77.9	29.27	48.63	45.84
3660	85.7	78.4	29.46	48.94	46.12
3720	86.8	79.5	29.88	49.62	46.72
3780	87.3	80	30.06	49.94	47.00
3840	87.1	79.8	29.99	49.81	46.89
3900	88.9	81.6	30.67	50.93	47.88
3960	90	82.7	31.08	51.62	48.48
4020	90.1	82.8	31.12	51.68	48.54
4080	90.6	83.3	31.30	52.00	48.81
4140	90.9	83.6	31.42	52.18	48.98
4200	91.1	83.8	31.49	52.31	49.09
4260	98.1	90.8	34.12	56.68	52.90
4320	110	102.7	38.59	64.11	59.27
4380	130.6	123.3	46.34	76.96	69.99
4440	132.1	124.8	46.90	77.90	70.76
4500	131.58	124.28	46.70	77.58	70.49
4560	131.66	124.36	46.73	77.63	70.53
4560	131.66	124.36	46.73	77.63	70.53
4561	121.11	113.81	42.77	71.04	65.10
4562	93.51	86.21	32.40	53.81	50.40

4563	85.62	78.32	29.43	48.89	46.07
4564	77.56	70.26	26.40	43.86	41.59
4565	69.86	62.56	23.51	39.05	37.25
4566	64.91	57.61	21.65	35.96	34.44
4567	63.04	55.74	20.95	34.79	33.37
4568	61.53	54.23	20.38	33.85	32.50
4569	59.98	52.68	19.80	32.88	31.61
4570	58.59	51.29	19.27	32.02	30.81
4572	57.71	50.41	18.94	31.47	30.30
4574	57.05	49.75	18.70	31.05	29.92
4576	56.6	49.3	18.53	30.77	29.66
4578	56.25	48.95	18.40	30.55	29.46
4580	55.85	48.55	18.25	30.30	29.22
4585	55	47.7	17.93	29.77	28.73
4590	54.2	46.9	17.63	29.27	28.27
4595	53.6	46.3	17.40	28.90	27.92
4600	53.05	45.75	17.19	28.56	27.60
4605	52.2	44.9	16.87	28.03	27.10
4610	51.7	44.4	16.69	27.71	26.81
4615	51	43.7	16.42	27.28	26.40
4620	50.45	43.15	16.22	26.93	26.08
4630	49.3	42	15.78	26.22	25.41
4640	47.7	40.4	15.18	25.22	24.47
4650	46.67	39.37	14.80	24.57	23.86
4660	39.35	32.05	12.04	20.01	19.53
4680	33.5	26.2	9.85	16.35	16.04
4700	31.2	23.9	8.98	14.92	14.66
4720	28.16	20.86	7.84	13.02	12.82
4740	26.1	18.8	7.07	11.73	11.57
4770	24.7	17.4	6.54	10.86	10.72
4800	21.3	14	5.26	8.74	8.65
4830	17.6	10.3	3.87	6.43	6.38
4860	14.4	7.10	2.67	4.43	4.41

Table A- 27.Constant pumping test and recovery test for LLA-6.

Time, min	Water Level	Drawdowns(Sa)	Correction for Well loss(Sw)	Drawdown after Well loss correction (Sa)	Correction for unconfind Aquifer(Sc)
0	7.3	0	0	0.00	0.00
1	14.4	7.1	2.67	4.43	4.41
2	20.86	13.56	5.10	8.46	8.38
3	20.47	13.17	4.95	8.22	8.14
4	21.69	14.39	5.41	8.98	8.89
5	22.11	14.81	5.57	9.24	9.14
6	23.06	15.76	5.92	9.84	9.72
7	25.64	18.34	6.89	11.45	11.29
8	27.29	19.99	7.51	12.48	12.29
9	28.1	20.8	7.82	12.98	12.78
10	29.75	22.45	8.44	14.01	13.78
12	30.74	23.44	8.81	14.63	14.38
14	33.32	26.02	9.78	16.24	15.93
16	35.5	28.2	10.60	17.60	17.24
18	37.43	30.13	11.32	18.81	18.39
20	39	31.7	11.91	19.79	19.33
25	40.48	33.18	12.47	20.71	20.21
30	42.99	35.69	13.41	22.28	21.69
35	45.3	38	14.28	23.72	23.06
40	47	39.7	14.92	24.78	24.06
45	47.85	40.55	15.24	25.31	24.56
50	49.55	42.25	15.88	26.37	25.55
55	50.6	43.3	16.27	27.03	26.17
60	51.8	44.5	16.72	27.78	26.87
70	53	45.7	17.17	28.53	27.57
80	53.9	46.6	17.51	29.09	28.09
90	54.75	47.45	17.83	29.62	28.59
100	56.1	48.8	18.34	30.46	29.37
120	57.45	50.15	18.85	31.30	30.15
160	58.85	51.55	19.37	32.18	30.96
180	60.36	53.06	19.94	33.12	31.83
210	60.63	53.33	20.04	33.29	31.98
240	61.74	54.44	20.46	33.98	32.62

270	62.44	55.14	20.72	34.42	33.02
300	62.8	55.5	20.86	34.64	33.23
330	63.5	56.2	21.12	35.08	33.63
360	64.7	57.4	21.57	35.83	34.32
420	65.4	58.1	21.83	36.27	34.72
480	66.7	59.4	22.32	37.08	35.46
540	66.9	59.6	22.40	37.20	35.57
600	68.52	61.22	23.01	38.21	36.49
660	69.2	61.9	23.26	38.64	36.88
720	68.6	61.3	23.04	38.26	36.54
780	69.9	62.6	23.53	39.07	37.28
840	70.85	63.55	23.88	39.67	37.82
900	71.3	64	24.05	39.95	38.07
960	72.44	65.14	24.48	40.66	38.71
1020	72.6	65.3	24.54	40.76	38.80
1080	72.8	65.5	24.61	40.89	38.92
1140	73.56	66.26	24.90	41.36	39.35
1200	74.49	67.19	25.25	41.94	39.87
1260	75.23	67.93	25.53	42.40	40.29
1320	75.89	68.59	25.78	42.81	40.66
1380	72.09	64.79	24.35	40.44	38.52
1440	73.46	66.16	24.86	41.30	39.29
1500	74.44	67.14	25.23	41.91	39.84
1560	74.4	67.1	25.22	41.88	39.82
1620	74.55	67.25	25.27	41.98	39.90
1680	75.46	68.16	25.61	42.55	40.41
1740	75.4	68.1	25.59	42.51	40.38
1800	75.9	68.6	25.78	42.82	40.66
1860	76.15	68.85	25.87	42.98	40.80
1920	76.3	69	25.93	43.07	40.89
1980	77.3	70	26.31	43.69	41.45
2040	77.5	70.2	26.38	43.82	41.56
2100	77.5	70.2	26.38	43.82	41.56
2160	78.15	70.85	26.63	44.22	41.92
2220	78.5	71.2	26.76	44.44	42.12
2280	78.9	71.6	26.91	44.69	42.34
2340	79.8	72.5	27.25	45.25	42.84
2400	80.3	73	27.43	45.57	43.12
2460	80.83	73.53	27.63	45.90	43.42

2520	80.1	72.8	27.36	45.44	43.01
2580	80.6	73.3	27.55	45.75	43.29
2640	81	73.7	27.70	46.00	43.51
2700	81.05	73.75	27.72	46.03	43.54
2760	82	74.7	28.07	46.63	44.07
2820	82.1	74.8	28.11	46.69	44.12
2880	82.52	75.22	28.27	46.95	44.36
2940	82.7	75.4	28.34	47.06	44.46
3000	83.2	75.9	28.52	47.38	44.73
3060	83.3	76	28.56	47.44	44.79
3120	83.8	76.5	28.75	47.75	45.07
3180	84.43	77.13	28.99	48.14	45.42
3240	84.1	76.8	28.86	47.94	45.23
3300	84.8	77.5	29.12	48.38	45.62
3360	85	77.7	29.20	48.50	45.73
3420	85.3	78	29.31	48.69	45.90
3480	85.3	78	29.31	48.69	45.90
3540	87.2	79.9	30.03	49.87	46.95
3600	85.2	77.9	29.27	48.63	45.84
3660	85.7	78.4	29.46	48.94	46.12
3720	86.8	79.5	29.88	49.62	46.72
3780	87.3	80	30.06	49.94	47.00
3840	87.1	79.8	29.99	49.81	46.89
3900	88.9	81.6	30.67	50.93	47.88
3960	90	82.7	31.08	51.62	48.48
4020	90.1	82.8	31.12	51.68	48.54
4080	90.6	83.3	31.30	52.00	48.81
4140	90.9	83.6	31.42	52.18	48.98
4200	91.1	83.8	31.49	52.31	49.09
4260	98.1	90.8	34.12	56.68	52.90
4320	110	102.7	38.59	64.11	59.27
4380	130.6	123.3	46.34	76.96	69.99
4440	132.1	124.8	46.90	77.90	70.76
4500	131.58	124.28	46.70	77.58	70.49
4560	131.66	124.36	46.73	77.63	70.53
4560	131.66	124.36	46.73	77.63	70.53
4561	121.11	113.81	42.77	71.04	65.10
4562	93.51	86.21	32.40	53.81	50.40
4563	85.62	78.32	29.43	48.89	46.07
4564	77.56	70.26	26.40	43.86	41.59

4565	69.86	62.56	23.51	39.05	37.25
4566	64.91	57.61	21.65	35.96	34.44
4567	63.04	55.74	20.95	34.79	33.37
4568	61.53	54.23	20.38	33.85	32.50
4569	59.98	52.68	19.80	32.88	31.61
4570	58.59	51.29	19.27	32.02	30.81
4572	57.71	50.41	18.94	31.47	30.30
4574	57.05	49.75	18.70	31.05	29.92
4576	56.6	49.3	18.53	30.77	29.66
4578	56.25	48.95	18.40	30.55	29.46
4580	55.85	48.55	18.25	30.30	29.22
4585	55	47.7	17.93	29.77	28.73
4590	54.2	46.9	17.63	29.27	28.27
4595	53.6	46.3	17.40	28.90	27.92
4600	53.05	45.75	17.19	28.56	27.60
4605	52.2	44.9	16.87	28.03	27.10
4610	51.7	44.4	16.69	27.71	26.81
4615	51	43.7	16.42	27.28	26.40
4620	50.45	43.15	16.22	26.93	26.08
4630	49.3	42	15.78	26.22	25.41
4640	47.7	40.4	15.18	25.22	24.47
4650	46.67	39.37	14.80	24.57	23.86
4660	39.35	32.05	12.04	20.01	19.53
4680	33.5	26.2	9.85	16.35	16.04
4700	31.2	23.9	8.98	14.92	14.66
4720	28.16	20.86	7.84	13.02	12.82
4740	26.1	18.8	7.07	11.73	11.57
4770	24.7	17.4	6.54	10.86	10.72
4800	21.3	14	5.26	8.74	8.65
4830	17.6	10.3	3.87	6.43	6.38
4860	14.4	7.10	2.67	4.43	4.41

Table A- 28.Constant pumping test and recovery test for LLA-PW1.

Time in (Min)	Water Level	Drawdowns(Sa)	Correction for Well loss(Sw)	Drawdown after Well loss correction (Sa)	Correction for unconfind Aquifer(Sc)
0	12.86	0	0.00	0.00	0.00
1	21.5	8.64	2.63	6.01	5.98
2	21.86	9	2.74	6.26	6.22
3	22.05	9.19	2.79	6.40	6.36
4	22.1	9.24	2.81	6.43	6.39
5	22.18	9.32	2.83	6.49	6.44
6	22.21	9.35	2.84	6.51	6.47
7	22.25	9.39	2.85	6.54	6.49
8	22.32	9.46	2.87	6.59	6.54
9	22.36	9.5	2.89	6.61	6.57
10	22.61	9.75	2.96	6.79	6.74
12	22.73	9.87	3.00	6.87	6.82
14	22.8	9.94	3.02	6.92	6.87
16	23.15	10.29	3.13	7.16	7.11
18	23.16	10.3	3.13	7.17	7.12
20	23.17	10.31	3.13	7.18	7.12
25	23.18	10.32	3.14	7.18	7.13
30	22.98	10.12	3.08	7.04	6.99
35	23.02	10.16	3.09	7.07	7.02
40	23.1	10.24	3.11	7.13	7.08
45	23.16	10.3	3.13	7.17	7.12
50	23.22	10.36	3.15	7.21	7.16
60	23.43	10.57	3.21	7.36	7.30
70	23.45	10.59	3.22	7.37	7.32
80	23.51	10.65	3.24	7.41	7.36
90	23.61	10.75	3.27	7.48	7.43
100	23.56	10.7	3.25	7.45	7.39
120	23.57	10.71	3.25	7.46	7.40
140	23.58	10.72	3.26	7.46	7.41
160	23.6	10.74	3.26	7.48	7.42
180	23.8	10.94	3.32	7.62	7.56
210	23.92	11.06	3.36	7.70	7.64
240	23.98	11.12	3.38	7.74	7.68
270	24	11.14	3.39	7.75	7.69
300	24.03	11.17	3.39	7.78	7.71
330	24.04	11.18	3.40	7.78	7.72
360	24.06	11.2	3.40	7.80	7.73
420	24.18	11.32	3.44	7.88	7.82

480	24.19	11.33	3.44	7.89	7.82
540	24.24	11.38	3.46	7.92	7.86
600	24.57	11.71	3.56	8.15	8.08
660	24.6	11.74	3.57	8.17	8.10
720	24.62	11.76	3.57	8.19	8.12
780	24.65	11.79	3.58	8.21	8.14
840	24.7	11.84	3.60	8.24	8.17
900	24.76	11.9	3.62	8.28	8.21
960	24.8	11.94	3.63	8.31	8.24
1020	24.85	11.99	3.64	8.35	8.28
1080	24.92	12.06	3.67	8.39	8.32
1140	25.06	12.2	3.71	8.49	8.42
1200	25.18	12.32	3.74	8.58	8.50
1260	25.22	12.36	3.76	8.60	8.53
1320	25.28	12.42	3.77	8.65	8.57
1380	25.33	12.47	3.79	8.68	8.60
1440	25.53	12.67	3.85	8.82	8.74
1500	25.55	12.69	3.86	8.83	8.75
1560	25.61	12.75	3.87	8.88	8.79
1620	25.7	12.84	3.90	8.94	8.86
1680	25.73	12.87	3.91	8.96	8.88
1740	25.78	12.92	3.93	8.99	8.91
1800	25.87	13.01	3.95	9.06	8.97
1860	25.93	13.07	3.97	9.10	9.01
1920	26.02	13.16	4.00	9.16	9.07
1980	26.05	13.19	4.01	9.18	9.10
2040	26.09	13.23	4.02	9.21	9.12
2100	26.06	13.2	4.01	9.19	9.10
2160	26.2	13.34	4.05	9.29	9.20
2220	26.28	13.42	4.08	9.34	9.25
2280	26.36	13.5	4.10	9.40	9.31
2340	26.4	13.54	4.11	9.43	9.33
2400	26.44	13.58	4.13	9.45	9.36
2460	26.48	13.62	4.14	9.48	9.39
2520	26.53	13.67	4.15	9.52	9.42
2580	26.6	13.74	4.18	9.56	9.47
2640	26.7	13.84	4.21	9.63	9.54
2700	26.75	13.89	4.22	9.67	9.57
2760	26.8	13.94	4.24	9.70	9.61
2820	26.84	13.98	4.25	9.73	9.63
2880	26.89	14.03	4.26	9.77	9.67
2940	26.9	14.04	4.27	9.77	9.68
3000	26.92	14.06	4.27	9.79	9.69

3060	26.95	14.09	4.28	9.81	9.71
3120	27.06	14.2	4.32	9.88	9.78
3180	27.1	14.24	4.33	9.91	9.81
3240	27.12	14.26	4.33	9.93	9.83
3300	27.17	14.31	4.35	9.96	9.86
3360	27.21	14.35	4.36	9.99	9.89
3420	27.25	14.39	4.37	10.02	9.91
3480	27.3	14.44	4.39	10.05	9.95
3540	27.34	14.48	4.40	10.08	9.98
3600	27.35	14.49	4.40	10.09	9.98
3660	27.37	14.51	4.41	10.10	10.00
3720	27.42	14.56	4.42	10.14	10.03
3780	27.45	14.59	4.43	10.16	10.05
3840	27.45	14.59	4.43	10.16	10.05
3900	27.48	14.62	4.44	10.18	10.07
3960	27.55	14.69	4.46	10.23	10.12
4020	27.58	14.72	4.47	10.25	10.14
4080	27.63	14.77	4.49	10.28	10.17
4140	27.67	14.81	4.50	10.31	10.20
4200	27.75	14.89	4.53	10.36	10.26
4260	27.79	14.93	4.54	10.39	10.28
4320	27.82	14.96	4.55	10.41	10.30
4320	27.82	14.96	4.55	10.41	10.30
4321	24.2	11.34	3.45	7.89	7.83
4322	21.63	8.77	2.67	6.10	6.07
4323	20.11	7.25	2.20	5.05	5.02
4324	19.19	6.33	1.92	4.41	4.39
4325	18.54	5.68	1.73	3.95	3.94
4326	18.3	5.44	1.65	3.79	3.77
4327	18.13	5.27	1.60	3.67	3.65
4328	17.99	5.13	1.56	3.57	3.56
4329	17.92	5.06	1.54	3.52	3.51
4330	17.88	5.02	1.53	3.49	3.48
4332	17.8	4.94	1.50	3.44	3.43
4334	17.7	4.84	1.47	3.37	3.36
4336	17.65	4.79	1.46	3.33	3.32
4338	17.56	4.7	1.43	3.27	3.26
4340	17.53	4.67	1.42	3.25	3.24
4345	17.38	4.52	1.37	3.15	3.14
4350	17.28	4.42	1.34	3.08	3.07
4355	17.18	4.32	1.31	3.01	3.00
4360	17.11	4.25	1.29	2.96	2.95
4365	17.04	4.18	1.27	2.91	2.90

4370	17.01	4.15	1.26	2.89	2.88
4380	16.91	4.05	1.23	2.82	2.81
4390	16.82	3.96	1.20	2.76	2.75
4400	16.72	3.86	1.17	2.69	2.68
4410	16.65	3.79	1.15	2.64	2.63
4420	16.4	3.54	1.08	2.46	2.46
4440	16.33	3.47	1.05	2.42	2.41
4460	16.25	3.39	1.03	2.36	2.35
4480	16.2	3.34	1.02	2.32	2.32
4500	16.09	3.23	0.98	2.25	2.24
4530	16	3.14	0.95	2.19	2.18
4560	15.83	2.97	0.90	2.07	2.06
4590	15.64	2.78	0.84	1.94	1.93
4620	15.58	2.72	0.83	1.89	1.89
4650	15.5	2.64	0.80	1.84	1.83
4680	15.38	2.52	0.77	1.75	1.75
4740	15.32	2.46	0.75	1.71	1.71
4800	15.24	2.38	0.72	1.66	1.65
4860	15.13	2.27	0.69	1.58	1.58
4920	14.95	2.09	0.64	1.45	1.45
4980	14.8	1.94	0.59	1.35	1.35
5040	14.64	1.78	0.54	1.24	1.24
5100	14.6	1.74	0.53	1.21	1.21
5160	14.58	1.72	0.52	1.20	1.20
5220	14.55	1.69	0.51	1.18	1.17
5280	14.52	1.66	0.50	1.16	1.15
5340	14.51	1.65	0.50	1.15	1.15
5400	14.5	1.64	0.50	1.14	1.14
5460	14.49	1.63	0.50	1.13	1.13
5520	14.48	1.62	0.49	1.13	1.13
5580	14.47	1.61	0.49	1.12	1.12
5640	14.46	1.6	0.49	1.11	1.11
5700	14.44	1.58	0.48	1.10	1.10
5760	14.4	1.54	0.47	1.07	1.07
5820	14.37	1.51	0.46	1.05	1.05
5880	14.35	1.49	0.45	1.04	1.04
5940	14.33	1.47	0.45	1.02	1.02
6000	14.3	1.44	0.44	1.00	1.00

Table A- 29.Constant pumping test and recovery test for LLA-PW5.

Time, min	Water Level	Drawdown(Sa)	Correction for Well loss(Sw)	Drawdown after Well loss correction (Sa)	Correction for confind Aquifer(Sc)
0	14	0	0	0.00	0.00
1	41	27.23	12.93	14.30	14.06
2	54	39.71	18.85	20.86	20.35
3	62	47.57	22.58	24.99	24.25
4	67	52.56	24.95	27.61	26.71
5	71	57.21	27.16	30.05	28.99
6	74	59.46	28.23	31.23	30.09
7	78	63.26	30.03	33.23	31.93
8	78	64.16	30.46	33.70	32.37
9	80	65.77	31.22	34.55	33.14
10	82	67.43	32.01	35.42	33.94
12	82	67.91	32.24	35.67	34.17
14	82	67.98	32.27	35.71	34.21
16	82	68.03	32.29	35.74	34.23
18	83	68.56	32.55	36.01	34.49
20	81	66.86	31.74	35.12	33.67
25	82	67.41	32.00	35.41	33.93
30	82	67.83	32.20	35.63	34.14
35	82	67.91	32.24	35.67	34.17
40	82	67.92	32.24	35.68	34.18
45	82	67.48	32.03	35.45	33.97
50	82	67.42	32.00	35.42	33.94
60	82	67.49	32.04	35.45	33.97
70	82	67.46	32.02	35.44	33.96
80	82	67.47	32.03	35.44	33.96
90	82	67.48	32.03	35.45	33.97
100	82	67.72	32.15	35.57	34.08
120	82	68.16	32.36	35.80	34.30
140	85	70.48	33.46	37.02	35.41
160	85	71.01	33.71	37.30	35.66
180	85	70.74	33.58	37.16	35.53
210	85	70.42	33.43	36.99	35.38
240	85	70.37	33.40	36.97	35.36

270	85	71.2	33.80	37.40	35.75
300	86	72.02	34.19	37.83	36.15
330	86	71.64	34.01	37.63	35.97
360	86	71.42	33.90	37.52	35.86
420	86	71.52	33.95	37.57	35.91
480	85	71.11	33.76	37.35	35.71
540	85	71.04	33.72	37.32	35.68
600	85	71.14	33.77	37.37	35.73
660	85	70.99	33.70	37.29	35.65
720	85	70.67	33.55	37.12	35.50
780	85	70.79	33.60	37.19	35.56
840	85	70.76	33.59	37.17	35.54
900	85	70.46	33.45	37.01	35.40
960	85	70.62	33.52	37.10	35.48
1020	85	70.75	33.59	37.16	35.54
1080	85	71.11	33.76	37.35	35.71
1140	85	71.03	33.72	37.31	35.67
1200	85	71.06	33.73	37.33	35.69
1260	85	70.97	33.69	37.28	35.64
1320	85	70.97	33.69	37.28	35.64
1380	85	70.96	33.68	37.28	35.64
1440	85	70.46	33.45	37.01	35.40
1500	85	70.66	33.54	37.12	35.50
1560	85	70.86	33.64	37.22	35.59
1620	85	71.01	33.71	37.30	35.66
1680	86	71.26	33.83	37.43	35.78
1740	86	71.61	33.99	37.62	35.95
1800	86	71.78	34.07	37.71	36.03
1860	86	71.82	34.09	37.73	36.05
1920	86	71.71	34.04	37.67	36.00
1980	86	71.48	33.93	37.55	35.89
2040	86	71.43	33.91	37.52	35.86
2100	85	71.25	33.82	37.43	35.78
2160	85	71.07	33.74	37.33	35.69
2220	85	71.2	33.80	37.40	35.75
2280	86	71.35	33.87	37.48	35.83
2340	85	71.24	33.82	37.42	35.77
2400	85	71.03	33.72	37.31	35.67
2460	85	71.01	33.71	37.30	35.66

2520	85	71.01	33.71	37.30	35.66
2580	85	70.94	33.68	37.26	35.63
2640	85	71.11	33.76	37.35	35.71
2700	86	71.39	33.89	37.50	35.85
2760	86	71.46	33.92	37.54	35.88
2820	85	70.92	33.67	37.25	35.62
2880	86	71.57	33.97	37.60	35.93
2940	86	71.72	34.05	37.67	36.00
3000	86	71.56	33.97	37.59	35.93
3060	86	71.78	34.07	37.71	36.03
3120	86	71.66	34.02	37.64	35.97
3180	86	71.96	34.16	37.80	36.12
3240	87	72.44	34.39	38.05	36.35
3300	87	72.46	34.40	38.06	36.36
3360	87	72.4	34.37	38.03	36.33
3420	86	72.23	34.29	37.94	36.25
3480	86	72.23	34.29	37.94	36.25
3540	86	72.14	34.24	37.90	36.20
3600	86	72.16	34.25	37.91	36.21
3660	86	72.12	34.24	37.88	36.19
3720	86	72.06	34.21	37.85	36.17
3780	86	71.97	34.16	37.81	36.12
3840	86	71.76	34.06	37.70	36.02
3900	86	71.71	34.04	37.67	36.00
3960	86	71.71	34.04	37.67	36.00
4020	86	71.69	34.03	37.66	35.99
4080	86	71.67	34.02	37.65	35.98
4140	86	71.56	33.97	37.59	35.93
4200	86	71.88	34.12	37.76	36.08
4260	87	72.41	34.37	38.04	36.33
4320	87	72.48	34.41	38.07	36.37
4320	87	72.48	34.41	38.07	36.37
4321	53	38.96	18.49	20.47	19.97
4322	35	20.56	9.76	10.80	10.66
4323	24	9.36	4.44	4.92	4.89
4324	18	3.76	1.78	1.98	1.97
4325	17	2.56	1.22	1.34	1.34
4326	17	2.31	1.10	1.21	1.21
4327	16	2.2	1.04	1.16	1.15
4328	16	2.16	1.03	1.13	1.13

4329	16	2.11	1.00	1.11	1.11
4330	16	2.07	0.98	1.09	1.09
4332	16	1.97	0.94	1.03	1.03
4334	16	1.92	0.91	1.01	1.01
4336	16	1.9	0.90	1.00	1.00
4338	16	1.88	0.89	0.99	0.99
4340	16	1.86	0.88	0.98	0.98
4345	16	1.81	0.86	0.95	0.95
4350	16	1.76	0.84	0.92	0.92
4355	16	1.73	0.82	0.91	0.91
4360	16	1.71	0.81	0.90	0.90
4365	16	1.69	0.80	0.89	0.89
4370	16	1.66	0.79	0.87	0.87
4380	16	1.62	0.77	0.85	0.85
4390	16	1.6	0.76	0.84	0.84
4400	16	1.56	0.74	0.82	0.82
4410	16	1.55	0.74	0.81	0.81
4420	16	1.53	0.73	0.80	0.80
4440	16	1.51	0.72	0.79	0.79
4460	16	1.48	0.70	0.78	0.78

Table A- 30.Constant pumping test and recovery test for LLA-7.

Time in (Min)	Water Level	Drawdown(Sa)	Correction for Well loss(Sw)	Drawdown after Well loss correction (Sa)	Correction for unconfined Aquifer(Sc)
0	33.84	0	0.00	0.00	0.00
1	56.98	23.14	17.35	5.79	5.74
2	60.48	26.64	19.97	6.67	6.60
3	60.6	26.76	20.06	6.70	6.63
4	62.8	28.96	21.71	7.25	7.17
5	63.75	29.91	22.42	7.49	7.40
6	64.85	31.01	23.25	7.76	7.67
7	65.85	32.01	24.00	8.01	7.92
8	66.25	32.41	24.30	8.11	8.01
9	66.57	32.73	24.54	8.19	8.09
10	66.76	32.92	24.68	8.24	8.14
12	67.04	33.2	24.89	8.31	8.21
14	67.14	33.3	24.97	8.33	8.23
16	67.22	33.38	25.02	8.36	8.25
18	67.35	33.51	25.12	8.39	8.28
20	67.4	33.56	25.16	8.40	8.29
25	67.52	33.68	25.25	8.43	8.32
30	67.62	33.78	25.32	8.46	8.35
35	67.7	33.86	25.38	8.48	8.37
40	67.8	33.96	25.46	8.50	8.39
45	67.85	34.01	25.50	8.51	8.40
50	67.95	34.11	25.57	8.54	8.43
60	68.05	34.21	25.65	8.56	8.45
70	68.13	34.29	25.71	8.58	8.47
80	68.27	34.43	25.81	8.62	8.51
90	68.27	34.43	25.81	8.62	8.51
100	68.36	34.52	25.88	8.64	8.53
120	68.39	34.55	25.90	8.65	8.53
140	68.53	34.69	26.01	8.68	8.57
160	68.73	34.89	26.16	8.73	8.62
180	68.76	34.92	26.18	8.74	8.62
210	68.77	34.93	26.19	8.74	8.63
240	68.77	34.93	26.19	8.74	8.63
270	68.83	34.99	26.23	8.76	8.64
300	68.89	35.05	26.28	8.77	8.66
330	68.92	35.08	26.30	8.78	8.66
360	68.99	35.15	26.35	8.80	8.68
420	69.09	35.25	26.43	8.82	8.71

480	69.24	35.4	26.54	8.86	8.74
540	69.3	35.46	26.58	8.88	8.76
600	69.33	35.49	26.61	8.88	8.76
660	69.41	35.57	26.67	8.90	8.78
720	69.42	35.58	26.67	8.91	8.79
780	69.45	35.61	26.70	8.91	8.79
840	69.47	35.63	26.71	8.92	8.80
900	69.48	35.64	26.72	8.92	8.80
960	69.52	35.68	26.75	8.93	8.81
1020	69.55	35.71	26.77	8.94	8.82
1080	69.57	35.73	26.79	8.94	8.82
1140	69.6	35.76	26.81	8.95	8.83
1200	69.63	35.79	26.83	8.96	8.84
1260	69.68	35.84	26.87	8.97	8.85
1320	69.68	35.84	26.87	8.97	8.85
1380	69.8	35.96	26.96	9.00	8.88
1440	69.98	36.14	27.09	9.05	8.92
1500	70.04	36.2	27.14	9.06	8.94
1560	70.07	36.23	27.16	9.07	8.94
1620	70.1	36.26	27.18	9.08	8.95
1680	70.13	36.29	27.21	9.08	8.96
1740	70.14	36.3	27.21	9.09	8.96
1800	70.14	36.3	27.21	9.09	8.96
1860	70.15	36.31	27.22	9.09	8.96
1920	70.17	36.33	27.24	9.09	8.97
1980	70.22	36.38	27.27	9.11	8.98
2040	70.23	36.39	27.28	9.11	8.98
2100	70.24	36.4	27.29	9.11	8.99
2160	70.25	36.41	27.30	9.11	8.99
2220	70.25	36.41	27.30	9.11	8.99
2280	70.25	36.41	27.30	9.11	8.99
2340	70.25	36.41	27.30	9.11	8.99
2400	70.25	36.41	27.30	9.11	8.99
2460	70.25	36.41	27.30	9.11	8.99
2520	70.28	36.44	27.32	9.12	9.00
2580	70.3	36.46	27.33	9.13	9.00
2640	70.3	36.46	27.33	9.13	9.00
2700	70.31	36.47	27.34	9.13	9.00
2760	70.34	36.5	27.36	9.14	9.01
2820	70.38	36.54	27.39	9.15	9.02
2880	70.44	36.6	27.44	9.16	9.03
2940	70.44	36.6	27.44	9.16	9.03
3000	70.47	36.63	27.46	9.17	9.04

3060	70.49	36.65	27.48	9.17	9.05
3120	70.5	36.66	27.48	9.18	9.05
3180	70.5	36.66	27.48	9.18	9.05
3240	70.5	36.66	27.48	9.18	9.05
3300	70.52	36.68	27.50	9.18	9.05
3360	70.52	36.68	27.50	9.18	9.05
3420	70.53	36.69	27.51	9.18	9.06
3480	70.55	36.71	27.52	9.19	9.06
3540	70.56	36.72	27.53	9.19	9.06
3600	70.56	36.72	27.53	9.19	9.06
3660	70.56	36.72	27.53	9.19	9.06
3720	70.56	36.72	27.53	9.19	9.06
3780	70.56	36.72	27.53	9.19	9.06
3840	70.56	36.72	27.53	9.19	9.06
3900	70.56	36.72	27.53	9.19	9.06
3960	70.56	36.72	27.53	9.19	9.06
4020	70.56	36.72	27.53	9.19	9.06
4080	70.57	36.73	27.54	9.19	9.07
4140	70.57	36.73	27.54	9.19	9.07
4200	70.57	36.73	27.54	9.19	9.07
4260	70.6	36.76	27.56	9.20	9.07
4320	70.65	36.81	27.60	9.21	9.09
4320	70.65	36.81	27.60	9.21	9.09
4321	35.9	2.06	1.54	0.52	0.52
4322	35.6	1.76	1.32	0.44	0.44
4323	35.1	1.26	0.94	0.32	0.32
4324	34.9	1.06	0.79	0.27	0.27
4325	34.87	1.03	0.77	0.26	0.26
4326	34.85	1.01	0.76	0.25	0.25
4327	34.83	0.99	0.74	0.25	0.25
4328	34.82	0.98	0.73	0.25	0.25
4329	34.78	0.94	0.70	0.24	0.24
4330	34.77	0.93	0.70	0.23	0.23

Table A- 31.Constant pumping test and recovery test for LLA-2.

Time	Water Level	Draw down, m	Drawdown Corrected for Partial Penetration	Correction for unconfind Aquifer(Sc)
0	9.69	0	0.00	0.00
1	18.56	8.87	3.96	3.95
2	23.53	13.84	6.18	6.15
3	26.69	17	7.60	7.54
4	29.24	19.55	8.74	8.66
5	31.13	21.44	9.58	9.49
6	32.9	23.21	10.37	10.26
7	34.48	24.79	11.08	10.95
8	35.78	26.09	11.66	11.52
9	36.75	27.06	12.09	11.94
10	37.82	28.13	12.57	12.41
12	39.48	29.79	13.31	13.13
14	40.62	30.93	13.82	13.63
16	41.5	31.81	14.21	14.01
18	42.25	32.56	14.55	14.33
20	42.82	33.13	14.80	14.58
25	43.84	34.15	15.26	15.02
30	44.62	34.93	15.61	15.36
35	45.1	35.41	15.82	15.57
40	45.64	35.95	16.06	15.80
45	46.3	36.61	16.36	16.09
50	46.52	36.83	16.46	16.18
60	46.88	37.19	16.62	16.34
70	47.16	37.47	16.74	16.46
80	47.7	38.01	16.98	16.69
90	48.1	38.41	17.16	16.86
100	48.45	38.76	17.32	17.01
120	48.84	39.15	17.49	17.18
140	49.62	39.93	17.84	17.52
160	50.35	40.66	18.17	17.83
180	51	41.31	18.46	18.11
210	51.5	41.81	18.68	18.33
240	52.34	42.65	19.06	18.69
270	52.93	43.24	19.32	18.94
300	53.98	44.29	19.79	19.39
330	55.1	45.41	20.29	19.87
360	55.63	45.94	20.53	20.10
420	56.73	47.04	21.02	20.57
480	60.74	51.05	22.81	22.28

540	62.56	52.87	23.62	23.06
600	64.27	54.58	24.39	23.78
660	65.4	55.71	24.89	24.26
720	66.78	57.09	25.51	24.85
780	68.24	58.55	26.16	25.47
840	68.98	59.29	26.49	25.78
900	70.02	60.33	26.96	26.22
960	70.49	60.8	27.17	26.42
1020	71.1	61.41	27.44	26.68
1080	72.45	62.76	28.04	27.25
1140	72.76	63.07	28.18	27.38
1200	73.55	63.86	28.53	27.71
1260	73.96	64.27	28.72	27.88
1320	74.21	64.52	28.83	27.99
1380	74.65	64.96	29.02	28.17
1440	75.38	65.69	29.35	28.48
1500	75.1	65.41	29.23	28.36
1560	75.83	66.14	29.55	28.67
1620	76.2	66.51	29.72	28.82
1680	76.64	66.95	29.91	29.01
1740	76.66	66.97	29.92	29.02
1800	76.94	67.25	30.05	29.13
1860	77.57	67.88	30.33	29.40
1920	78.18	68.49	30.60	29.65
1980	78.46	68.77	30.73	29.77
2040	78.63	68.94	30.80	29.84
2100	79.03	69.34	30.98	30.01
2160	79.31	69.62	31.11	30.13
2220	80.53	70.84	31.65	30.64
2280	80.83	71.14	31.79	30.76
2340	81.23	71.54	31.96	30.93
2400	81.75	72.06	32.20	31.15
2460	82.2	72.51	32.40	31.34
2520	82.44	72.75	32.50	31.44
2580	82.71	73.02	32.63	31.55
2640	83.23	73.54	32.86	31.77
2700	83.54	73.85	33.00	31.89
2760	83.06	73.37	32.78	31.69
2820	83.22	73.53	32.85	31.76
2880	83.49	73.8	32.97	31.87
2940	83.6	73.91	33.02	31.92
3000	83.61	73.92	33.03	31.92
3060	83.61	73.92	33.03	31.92

3120	84.02	74.33	33.21	32.09
3180	84.25	74.56	33.31	32.19
3240	84.73	75.04	33.53	32.39
3300	85.04	75.35	33.67	32.52
3360	85.48	75.79	33.86	32.70
3420	85.46	75.77	33.85	32.69
3480	85.48	75.79	33.86	32.70
3540	85.94	76.25	34.07	32.89
3600	86.93	77.24	34.51	33.31
3660	87.12	77.43	34.60	33.38
3720	87.4	77.71	34.72	33.50
3780	87.76	78.07	34.88	33.65
3840	88.16	78.47	35.06	33.82
3900	88.45	78.76	35.19	33.94
3960	88.82	79.13	35.36	34.09
4020	88.9	79.21	35.39	34.12
4080	89.45	79.76	35.64	34.35
4140	89.52	79.83	35.67	34.38
4200	88.83	79.14	35.36	34.09
4260	88.58	78.89	35.25	33.99
4320	88.58	78.89	35.25	33.99
4380	88.48	78.79	35.20	33.95
4440	88.4	78.71	35.17	33.92
4500	88.17	78.48	35.07	33.82
4560	88.08	78.39	35.02	33.78
4620	88.18	78.49	35.07	33.82
4680	88.66	78.97	35.28	34.02
4740	88.99	79.3	35.43	34.16
4800	89.03	79.34	35.45	34.18
4860	88.37	78.68	35.15	33.90
4860	88.37	78.68	35.15	33.90
4861	77.98	68.29	30.51	29.57
4862	66.28	56.59	25.28	24.64
4863	54.6	44.91	20.07	19.66
4864	46.63	36.94	16.50	16.23
4865	40.81	31.12	13.90	13.71
4866	36.21	26.52	11.85	11.71
4867	32.47	22.78	10.18	10.07
4868	29.42	19.73	8.82	8.74
4869	27.08	17.39	7.77	7.71
4870	25.41	15.72	7.02	6.97
4872	23.32	13.63	6.09	6.05

4874	22.41	12.72	5.68	5.65
4876	21.76	12.07	5.39	5.36
4878	21.56	11.87	5.30	5.28
4880	21.38	11.69	5.22	5.20
4885	21.24	11.55	5.16	5.13
4890	21.1	11.41	5.10	5.07
4895	21.07	11.38	5.08	5.06
4900	20.93	11.24	5.02	5.00
4905	20.85	11.16	4.99	4.96
4910	20.78	11.09	4.96	4.93
4920	20.73	11.04	4.93	4.91
4930	20.62	10.93	4.88	4.86
4940	20.51	10.82	4.83	4.81
4950	20.42	10.73	4.79	4.77
4960	20.31	10.62	4.75	4.72
4980	20.23	10.54	4.71	4.69
5000	20.1	10.41	4.65	4.63
5020	19.97	10.28	4.59	4.57
5040	19.7	10.01	4.47	4.45
5070	19.53	9.84	4.40	4.38
5100	19.36	9.67	4.32	4.30
5130	19.21	9.52	4.25	4.24
5160	19.08	9.39	4.20	4.18
5190	18.92	9.23	4.12	4.11
5220	18.82	9.13	4.08	4.06
5280	18.44	8.75	3.91	3.89
5340	18.26	8.57	3.83	3.81
5400	17.95	8.26	3.69	3.68
5460	17.72	8.03	3.59	3.57
5520	17.46	7.77	3.47	3.46
5580	17.28	7.59	3.39	3.38
5640	17.08	7.39	3.30	3.29
5700	16.87	7.18	3.21	3.20
5760	16.7	7.01	3.13	3.12
5820	16.53	6.84	3.06	3.05
5880	16.27	6.58	2.94	2.93
5940	16.03	6.34	2.83	2.82
6000	15.9	6.21	2.77	2.77
6060	15.6	5.91	2.64	2.63

Table A- 32.Constant pumping test for LLA-3.

Time, min	Water Level	Drawdown, m	Drawdown Corrected for Partial Penetration	Correction for unconfind Aquifer(Sc)
0	13	0	0.00	0.00
1	23.4	10.4	8.26	8.20
2	24.6	11.6	9.21	9.14
3	25.2	12.2	9.69	9.61
4	25.43	12.43	9.87	9.79
5	25.68	12.68	10.07	9.98
6	25.83	12.83	10.19	10.10
7	25.94	12.94	10.28	10.18
8	26.03	13.03	10.35	10.25
9	26.08	13.08	10.39	10.29
10	26.09	13.09	10.40	10.30
12	25.95	12.95	10.28	10.19
14	25.86	12.86	10.21	10.12
16	25.87	12.87	10.22	10.13
18	25.89	12.89	10.24	10.15
20	25.93	12.93	10.27	10.18
25	26.02	13.02	10.34	10.25
30	26.09	13.09	10.40	10.30
35	26.1	13.1	10.40	10.31
40	26.13	13.13	10.43	10.33
45	26.18	13.18	10.47	10.37
50	26.3	13.3	10.56	10.47
60	26.33	13.33	10.59	10.49
70	26.38	13.38	10.63	10.53
80	26.36	13.36	10.61	10.51
90	26.25	13.25	10.52	10.43
100	26.22	13.22	10.50	10.40
120	26.34	13.34	10.59	10.50
160	26.32	13.32	10.58	10.48
180	26.3	13.3	10.56	10.47
210	26.36	13.36	10.61	10.51
240	26.38	13.38	10.63	10.53
270	26.4	13.4	10.64	10.54
300	26.5	13.5	10.72	10.62
360	26.56	13.56	10.77	10.67
420	26.68	13.68	10.86	10.76
480	26.74	13.74	10.91	10.81

540	26.72	13.72	10.90	10.79
600	26.74	13.74	10.91	10.81
660	26.68	13.68	10.86	10.76
720	26.75	13.75	10.92	10.82
780	26.68	13.68	10.86	10.76
840	26.74	13.74	10.91	10.81
900	26.84	13.84	10.99	10.89
960	26.89	13.89	11.03	10.93
1020	27.06	14.06	11.17	11.06
1080	27.03	14.03	11.14	11.03
1140	27.02	14.02	11.13	11.03
1200	26.98	13.98	11.10	11.00
1260	27.04	14.04	11.15	11.04
1320	27.11	14.11	11.21	11.10
1380	27.06	14.06	11.17	11.06
1440	27	14	11.12	11.01
1500	27	14	11.12	11.01
1560	26.8	13.8	10.96	10.86
1620	26.62	13.62	10.82	10.71
1680	26.54	13.54	10.75	10.65
1740	26.5	13.5	10.72	10.62
1800	26.5	13.5	10.72	10.62
1860	26.48	13.48	10.71	10.61
1920	26.54	13.54	10.75	10.65
1980	26.6	13.6	10.80	10.70
2040	26.69	13.69	10.87	10.77
2100	26.72	13.72	10.90	10.79
2160	26.9	13.9	11.04	10.93
2220	26.95	13.95	11.08	10.97
2280	26.72	13.72	10.90	10.79
2340	26.7	13.7	10.88	10.78
2400	26.76	13.76	10.93	10.82
2520	26.67	13.67	10.86	10.75
2580	26.72	13.72	10.90	10.79
2640	26.8	13.8	10.96	10.86
2700	26.82	13.82	10.98	10.87
2760	26.86	13.86	11.01	10.90
2820	26.88	13.88	11.02	10.92
2880	26.83	13.83	10.98	10.88
2940	26.81	13.81	10.97	10.86
3000	26.7	13.7	10.88	10.78
3060	26.64	13.64	10.83	10.73
3120	26.66	13.66	10.85	10.75

3180	26.69	13.69	10.87	10.77
3240	26.73	13.73	10.90	10.80
3300	26.76	13.76	10.93	10.82
3360	26.78	13.78	10.94	10.84
3420	26.51	13.51	10.73	10.63
3480	26.82	13.82	10.98	10.87
3540	26.88	13.88	11.02	10.92
3600	26.86	13.86	11.01	10.90
3660	26.9	13.9	11.04	10.93
3720	26.96	13.96	11.09	10.98
3780	26.94	13.94	11.07	10.96
3840	26.96	13.96	11.09	10.98
3900	26.99	13.99	11.11	11.00
3960	27.05	14.05	11.16	11.05
4020	27.13	14.13	11.22	11.11
4080	27.24	14.24	11.31	11.20
4140	27.24	14.24	11.31	11.20
4200	27.28	14.28	11.34	11.23
4260	27.31	14.31	11.36	11.25
4320	27.33	14.33	11.38	11.27

Table A- 33.Constant pumping test and recovery test for LLA-5.

Time, min	Water Level	Drawdown, m	Drawdown Corrected for Partial Penetration	Correction for unconfind Aquifer(Sc)
0	27.1	0	0.00	0.00
1	31.6	4.5	1.68	1.67
2	31.67	4.57	1.71	1.70
3	31.69	4.59	1.72	1.71
4	31.7	4.6	1.72	1.71
5	31.74	4.64	1.74	1.73
6	31.76	4.66	1.74	1.73
7	31.78	4.68	1.75	1.74
8	31.78	4.68	1.75	1.74
9	31.79	4.69	1.76	1.75
10	31.8	4.7	1.76	1.75
12	31.86	4.76	1.78	1.77
14	31.9	4.8	1.80	1.79
16	31.98	4.88	1.83	1.82
18	32.02	4.92	1.84	1.83
20	32.1	5	1.87	1.86
25	32.16	5.06	1.89	1.88
30	32.21	5.11	1.91	1.90
35	32.24	5.14	1.92	1.91
40	32.3	5.2	1.95	1.93
45	32.4	5.3	1.98	1.97
50	32.61	5.51	2.06	2.05
60	33.1	6	2.25	2.23
70	33.15	6.05	2.26	2.25
80	33.21	6.11	2.29	2.27
90	33.27	6.17	2.31	2.29
100	33.5	6.4	2.40	2.38
120	33.26	6.16	2.31	2.29
140	33.6	6.5	2.43	2.41
160	33.8	6.7	2.51	2.49
180	33.88	6.78	2.54	2.52
210	34.1	7	2.62	2.60
240	34.1	7	2.62	2.60
270	34.16	7.06	2.64	2.62
300	34.2	7.1	2.66	2.63
360	34.22	7.12	2.66	2.64
420	34.25	7.15	2.68	2.65

480	34.4	7.3	2.73	2.71
540	34.62	7.52	2.81	2.79
600	34.81	7.71	2.89	2.86
660	34.84	7.74	2.90	2.87
720	34.9	7.8	2.92	2.89
780	35.01	7.91	2.96	2.93
840	35.37	8.27	3.10	3.06
900	35.4	8.3	3.11	3.07
960	35.44	8.34	3.12	3.09
1020	35.55	8.45	3.16	3.13
1080	35.59	8.49	3.18	3.14
1140	35.65	8.55	3.20	3.17
1200	35.65	8.55	3.20	3.17
1260	35.65	8.55	3.20	3.17
1320	35.65	8.55	3.20	3.17
1380	35.65	8.55	3.20	3.17
1440	35.68	8.58	3.21	3.18
1500	35.72	8.62	3.23	3.19
1560	35.82	8.72	3.26	3.23
1620	35.98	8.88	3.32	3.29
1680	36.06	8.96	3.35	3.32
1740	36.08	8.98	3.36	3.32
1800	36.17	9.07	3.39	3.36
1860	36.28	9.18	3.44	3.40
1920	36.3	9.2	3.44	3.40
1980	36.32	9.22	3.45	3.41
2040	36.4	9.3	3.48	3.44
2100	36.43	9.33	3.49	3.45
2160	36.44	9.34	3.50	3.46
2220	36.44	9.34	3.50	3.46
2280	36.44	9.34	3.50	3.46
2340	36.44	9.34	3.50	3.46
2400	36.45	9.35	3.50	3.46
2460	36.48	9.38	3.51	3.47
2520	36.5	9.4	3.52	3.48
2580	36.51	9.41	3.52	3.48
2640	36.53	9.43	3.53	3.49
2700	36.54	9.44	3.53	3.49
2760	36.57	9.47	3.54	3.50
2820	36.57	9.47	3.54	3.50
2880	36.57	9.47	3.54	3.50
2940	36.59	9.49	3.55	3.51
3000	36.62	9.52	3.56	3.52

3060	36.62	9.52	3.56	3.52
3120	36.68	9.58	3.59	3.54
3180	36.72	9.62	3.60	3.56
3240	36.73	9.63	3.60	3.56
3300	36.75	9.65	3.61	3.57
3360	36.75	9.65	3.61	3.57
3420	36.77	9.67	3.62	3.58
3480	36.78	9.68	3.62	3.58
3540	36.8	9.7	3.63	3.59
3600	36.83	9.73	3.64	3.60
3660	36.85	9.75	3.65	3.61
3720	36.86	9.76	3.65	3.61
3780	36.87	9.77	3.66	3.61
3840	36.87	9.77	3.66	3.61
3900	36.88	9.78	3.66	3.62
3960	36.89	9.79	3.66	3.62
4020	37.05	9.95	3.72	3.68
4080	37.1	10	3.74	3.70
4140	37.14	10.04	3.76	3.71
4200	37.19	10.09	3.78	3.73
4260	37.2	10.1	3.78	3.73
4320	37.25	10.15	3.80	3.75
4320	37.25	10.15	3.80	3.75
4321	27.5	0.4	0.15	0.15
4322	27.4	0.3	0.11	0.11
4323	27.32	0.22	0.08	0.08
4324	27.25	0.15	0.06	0.06
4325	27.2	0.1	0.04	0.04
4326	27.18	0.08	0.03	0.03
4327	27.16	0.06	0.02	0.02
4328	27.15	0.05	0.02	0.02

Table A- 34.Constant pumping test and recovery test for LLA-PW3.

Time, min	Water Level	Draw down, m	Drawdown Corrected for Partial Penetration	Correction for unconfind Aquifer(Sc)
0	29.36	0	0.00	0.00
1	31.02	1.66	1.19	1.19
2	31.17	1.81	1.30	1.30
3	31.26	1.9	1.37	1.36
4	31.35	1.99	1.43	1.43
5	31.4	2.04	1.47	1.46
6	31.43	2.07	1.49	1.49
7	31.46	2.1	1.51	1.51
8	31.48	2.12	1.53	1.52
9	31.48	2.12	1.53	1.52
10	31.49	2.13	1.53	1.53
12	31.51	2.15	1.55	1.54
14	31.54	2.18	1.57	1.57
16	31.56	2.2	1.58	1.58
18	31.57	2.21	1.59	1.59
20	31.58	2.22	1.60	1.59
25	31.59	2.23	1.60	1.60
30	31.6	2.24	1.61	1.61
35	31.62	2.26	1.63	1.62
40	31.63	2.27	1.63	1.63
45	31.63	2.27	1.63	1.63
50	31.63	2.27	1.63	1.63
60	31.65	2.29	1.65	1.64
70	31.67	2.31	1.66	1.66
80	31.69	2.33	1.68	1.67
90	31.71	2.35	1.69	1.69
100	31.72	2.36	1.70	1.69
120	31.74	2.38	1.71	1.71
140	31.76	2.4	1.73	1.72
160	31.78	2.42	1.74	1.74
180	31.8	2.44	1.76	1.75
210	31.81	2.45	1.76	1.76
240	31.82	2.46	1.77	1.77
270	31.83	2.47	1.78	1.77
300	31.85	2.49	1.79	1.79
330	31.88	2.52	1.81	1.81

360	31.91	2.55	1.83	1.83
420	31.99	2.63	1.89	1.89
480	32.07	2.71	1.95	1.94
540	32.12	2.76	1.99	1.98
600	32.17	2.81	2.02	2.02
660	32.2	2.84	2.04	2.04
720	32.22	2.86	2.06	2.05
780	32.24	2.88	2.07	2.07
840	32.25	2.89	2.08	2.07
900	32.26	2.9	2.09	2.08
960	32.27	2.91	2.09	2.09
1020	32.29	2.93	2.11	2.10
1080	32.31	2.95	2.12	2.12
1140	32.33	2.97	2.14	2.13
1200	32.35	2.99	2.15	2.14
1260	32.36	3	2.16	2.15
1320	32.38	3.02	2.17	2.17
1380	32.4	3.04	2.19	2.18
1440	32.41	3.05	2.19	2.19
1500	32.41	3.05	2.19	2.19
1560	32.42	3.06	2.20	2.19
1620	32.43	3.07	2.21	2.20
1680	32.44	3.08	2.22	2.21
1740	32.45	3.09	2.22	2.22
1800	32.46	3.1	2.23	2.22
1860	32.47	3.11	2.24	2.23
1920	32.48	3.12	2.25	2.24
1980	32.5	3.14	2.26	2.25
2040	32.51	3.15	2.27	2.26
2100	32.52	3.16	2.27	2.27
2160	32.53	3.17	2.28	2.27
2220	32.54	3.18	2.29	2.28
2280	32.55	3.19	2.30	2.29
2340	32.55	3.19	2.30	2.29
2400	32.55	3.19	2.30	2.29
2460	32.56	3.2	2.30	2.29
2520	32.57	3.21	2.31	2.30
2580	32.58	3.22	2.32	2.31
2640	32.59	3.23	2.32	2.32
2700	32.6	3.24	2.33	2.32
2760	32.61	3.25	2.34	2.33

2820	32.62	3.26	2.35	2.34
2880	32.63	3.27	2.35	2.35
2940	32.64	3.28	2.36	2.35
3000	32.65	3.29	2.37	2.36
3060	32.66	3.3	2.37	2.37
3120	32.66	3.3	2.37	2.37
3180	32.67	3.31	2.38	2.37
3240	32.67	3.31	2.38	2.37
3300	32.68	3.32	2.39	2.38
3360	32.69	3.33	2.40	2.39
3420	32.7	3.34	2.40	2.40
3480	32.71	3.35	2.41	2.40
3540	32.71	3.35	2.41	2.40
3600	32.72	3.36	2.42	2.41
3660	32.73	3.37	2.43	2.42
3720	32.73	3.37	2.43	2.42
3780	32.73	3.37	2.43	2.42
3840	32.73	3.37	2.43	2.42
3900	32.74	3.38	2.43	2.42
3960	32.74	3.38	2.43	2.42
4020	32.75	3.39	2.44	2.43
4080	32.75	3.39	2.44	2.43
4140	32.76	3.4	2.45	2.44
4200	32.77	3.41	2.45	2.45
4260	32.78	3.42	2.46	2.45
4320	32.79	3.43	2.47	2.46
4320	32.79	3.43	2.47	2.46
4321	31.1	1.74	1.25	1.25
4322	31	1.64	1.18	1.18
4323	30.91	1.55	1.12	1.11
4324	30.85	1.49	1.07	1.07
4325	30.81	1.45	1.04	1.04
4326	30.78	1.42	1.02	1.02
4327	30.75	1.39	1.00	1.00
4328	30.72	1.36	0.98	0.98
4329	30.7	1.34	0.96	0.96
4330	30.68	1.32	0.95	0.95
4332	30.67	1.31	0.94	0.94
4334	30.65	1.29	0.93	0.93
4336	30.63	1.27	0.91	0.91
4338	30.62	1.26	0.91	0.91

4340	30.61	1.25	0.90	0.90
4345	30.6	1.24	0.89	0.89
4350	30.59	1.23	0.89	0.88
4355	30.58	1.22	0.88	0.88
4360	30.57	1.21	0.87	0.87
4365	30.56	1.2	0.86	0.86
4370	30.55	1.19	0.86	0.86
4380	30.52	1.16	0.83	0.83
4390	30.5	1.14	0.82	0.82
4400	30.49	1.13	0.81	0.81
4410	30.48	1.12	0.81	0.81
4420	30.47	1.11	0.80	0.80
4440	30.44	1.08	0.78	0.78
4460	30.42	1.06	0.76	0.76
4480	30.4	1.04	0.75	0.75
4500	30.38	1.02	0.73	0.73
4530	30.35	0.99	0.71	0.71
4560	30.32	0.96	0.69	0.69
4590	30.29	0.93	0.67	0.67
4620	30.25	0.89	0.64	0.64
4650	30.23	0.87	0.63	0.63
4680	30.21	0.85	0.61	0.61
4740	30.2	0.84	0.60	0.60
4800	30.19	0.83	0.60	0.60
4860	30.18	0.82	0.59	0.59
4920	30.17	0.81	0.58	0.58
4980	30.16	0.8	0.58	0.58
5040	30.15	0.79	0.57	0.57
5100	30.14	0.78	0.56	0.56
5160	30.13	0.77	0.55	0.55
5220	30.12	0.76	0.55	0.55
5280	30.11	0.75	0.54	0.54
5340	30.1	0.74	0.53	0.53
5400	30.09	0.73	0.53	0.52
5460	30.08	0.72	0.52	0.52
5520	30.06	0.7	0.50	0.50
5580	30.04	0.68	0.49	0.49
5640	30.03	0.67	0.48	0.48
5700	30.02	0.66	0.47	0.47
5760	30	0.64	0.46	0.46
5820	29.98	0.62	0.45	0.45

5880	29.97	0.61	0.44	0.44
5940	29.95	0.59	0.42	0.42
6000	29.94	0.58	0.42	0.42
6060	29.93	0.57	0.41	0.41
6120	29.91	0.55	0.40	0.40
6180	29.89	0.53	0.38	0.38
6240	29.87	0.51	0.37	0.37
6300	29.86	0.5	0.36	0.36
6360	29.85	0.49	0.35	0.35
6420	29.84	0.48	0.35	0.35
6480	29.83	0.47	0.34	0.34

Table A- 35.Constant pumping test and recovery test for LLA-PW4.

Time, min	Water Level	Dra down, m	Drawdown Corrected for Partial Penetration	Correction for unconfind Aquifer(Sc)
0	19.8	0	0.00	0.00
1	24.55	4.75	3.23	3.22
2	24.79	4.99	3.39	3.38
3	24.9	5.1	3.47	3.46
4	24.93	5.13	3.49	3.48
5	24.94	5.14	3.50	3.48
6	24.95	5.15	3.50	3.49
7	24.96	5.16	3.51	3.50
8	24.98	5.18	3.52	3.51
9	24.99	5.19	3.53	3.52
10	25	5.2	3.54	3.52
12	25.02	5.22	3.55	3.54
14	25.03	5.23	3.56	3.54
16	25.05	5.25	3.57	3.56
18	25.06	5.26	3.58	3.56
20	25.08	5.28	3.59	3.58
25	25.1	5.3	3.60	3.59
30	25.14	5.34	3.63	3.62
35	25.16	5.36	3.65	3.63
40	25.19	5.39	3.67	3.65
45	25.21	5.41	3.68	3.67
50	25.22	5.42	3.69	3.67
60	25.26	5.46	3.71	3.70
70	25.3	5.5	3.74	3.73
80	25.34	5.54	3.77	3.75
90	25.35	5.55	3.77	3.76
100	25.37	5.57	3.79	3.77
120	25.4	5.6	3.81	3.79
140	25.41	5.61	3.82	3.80
160	25.44	5.64	3.84	3.82
180	25.46	5.66	3.85	3.83
210	25.49	5.69	3.87	3.85
240	25.52	5.72	3.89	3.87
270	25.53	5.73	3.90	3.88
300	25.55	5.75	3.91	3.89
330	25.58	5.78	3.93	3.91
360	25.6	5.8	3.94	3.93
420	25.61	5.81	3.95	3.94

480	25.63	5.83	3.96	3.95
540	25.65	5.85	3.98	3.96
600	25.68	5.88	4.00	3.98
660	25.7	5.9	4.01	4.00
720	25.71	5.91	4.02	4.00
780	25.72	5.92	4.03	4.01
840	25.73	5.93	4.03	4.02
900	25.74	5.94	4.04	4.02
960	25.75	5.95	4.05	4.03
1020	25.76	5.96	4.05	4.04
1080	25.77	5.97	4.06	4.04
1140	25.78	5.98	4.07	4.05
1200	25.79	5.99	4.07	4.06
1260	25.8	6	4.08	4.06
1320	25.81	6.01	4.09	4.07
1380	25.83	6.03	4.10	4.08
1440	25.87	6.07	4.13	4.11
1500	25.7	6.1	4.15	4.13
1560	25.91	6.11	4.16	4.14
1620	25.91	6.11	4.16	4.14
1680	25.91	6.11	4.16	4.14
1740	25.92	6.12	4.16	4.14
1800	25.93	6.13	4.17	4.15
1860	25.94	6.14	4.18	4.16
1920	25.95	6.15	4.18	4.16
1980	25.96	6.16	4.19	4.17
2040	25.97	6.17	4.20	4.18
2100	25.98	6.18	4.20	4.18
2160	25.99	6.19	4.21	4.19
2220	26	6.2	4.22	4.20
2280	26.01	6.21	4.22	4.20
2340	26.02	6.22	4.23	4.21
2400	26.03	6.23	4.24	4.22
2460	26.05	6.25	4.25	4.23
2520	26.07	6.27	4.26	4.25
2580	26.09	6.29	4.28	4.26
2640	26.13	6.33	4.30	4.29
2700	26.15	6.35	4.32	4.30
2760	26.16	6.36	4.33	4.31
2820	26.16	6.36	4.33	4.31
2880	26.16	6.36	4.33	4.31
2940	26.16	6.36	4.33	4.31
3000	26.16	6.36	4.33	4.31

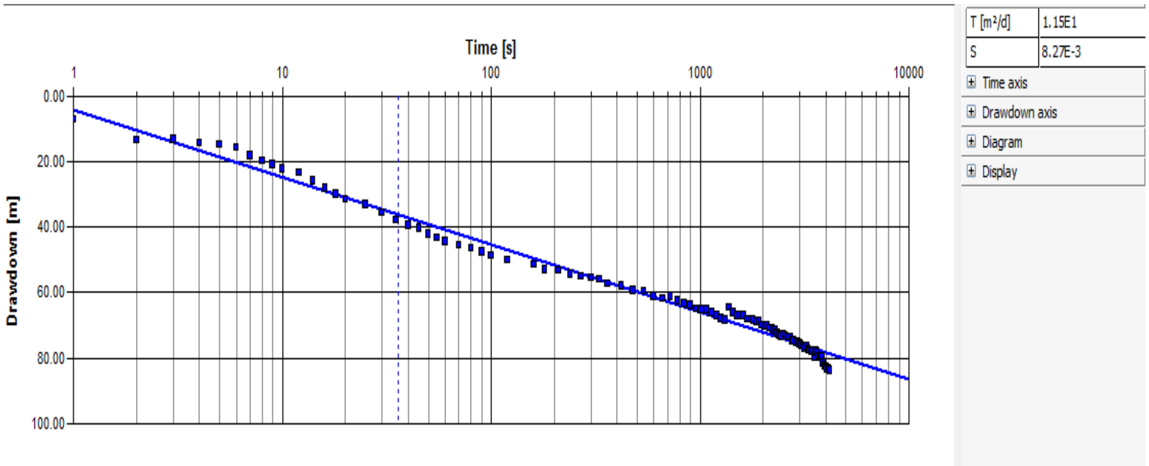
3060	26.16	6.36	4.33	4.31
3120	26.16	6.36	4.33	4.31
3180	26.16	6.36	4.33	4.31
3240	26.16	6.36	4.33	4.31
3300	26.17	6.37	4.33	4.31
3360	26.18	6.38	4.34	4.32
3420	26.19	6.39	4.35	4.33
3480	26.2	6.4	4.35	4.33
3540	26.21	6.41	4.36	4.34
3600	26.23	6.43	4.37	4.35
3660	26.24	6.44	4.38	4.36
3720	26.25	6.45	4.39	4.37
3780	26.26	6.46	4.39	4.37
3840	26.26	6.46	4.39	4.37
3900	26.26	6.46	4.39	4.37
3960	26.26	6.46	4.39	4.37
4020	26.29	6.49	4.41	4.39
4080	26.32	6.52	4.43	4.41
4140	26.35	6.55	4.45	4.43
4200	26.36	6.56	4.46	4.44
4260	26.37	6.57	4.47	4.45
4320	26.38	6.58	4.47	4.45
4320	26.38	6.58	4.47	4.45
4321	21.36	1.56	1.06	1.06
4322	21.33	1.53	1.04	1.04
4323	21.31	1.51	1.03	1.03
4324	21.29	1.49	1.01	1.01
4325	21.27	1.47	1.00	1.00
4326	21.26	1.46	0.99	0.99
4327	21.25	1.45	0.99	0.99
4328	21.23	1.43	0.97	0.97
4329	21.22	1.42	0.97	0.96
4330	21.21	1.41	0.96	0.96
4332	21.19	1.39	0.95	0.94
4334	21.17	1.37	0.93	0.93
4336	21.15	1.35	0.92	0.92
4338	21.13	1.33	0.90	0.90
4340	21.11	1.31	0.89	0.89
4345	21.08	1.28	0.87	0.87
4350	21.04	1.24	0.84	0.84
4355	21.01	1.21	0.82	0.82

4360	20.97	1.17	0.80	0.80
4365	20.94	1.14	0.78	0.77
4370	20.91	1.11	0.75	0.75
4380	20.88	1.08	0.73	0.73
4390	20.83	1.03	0.70	0.70
4400	20.81	1.01	0.69	0.69
4410	20.79	0.99	0.67	0.67
4420	20.75	0.95	0.65	0.65
4440	20.71	0.91	0.62	0.62
4460	20.67	0.87	0.59	0.59
4480	20.64	0.84	0.57	0.57
4500	20.62	0.82	0.56	0.56
4530	20.56	0.76	0.52	0.52
4560	20.56	0.76	0.52	0.52
4590	20.55	0.75	0.51	0.51
4620	20.54	0.74	0.50	0.50
4650	20.53	0.73	0.50	0.50
4680	20.52	0.72	0.49	0.49
4740	20.5	0.7	0.48	0.48
4800	20.5	0.7	0.48	0.48
4860	20.49	0.69	0.47	0.47
4920	20.49	0.69	0.47	0.47
4980	20.49	0.69	0.47	0.47
5040	20.48	0.68	0.46	0.46
5100	20.48	0.68	0.46	0.46
5160	20.48	0.68	0.46	0.46
5220	20.48	0.68	0.46	0.46
5280	20.48	0.68	0.46	0.46
5340	20.48	0.68	0.46	0.46
5400	20.48	0.68	0.46	0.46
5460	20.48	0.68	0.46	0.46
5520	20.48	0.68	0.46	0.46
5580	20.48	0.68	0.46	0.46
5640	20.48	0.68	0.46	0.46
5700	20.47	0.67	0.46	0.46
5760	20.46	0.66	0.45	0.45

Appendix-8 Analysis for Wells of Legedadi Deep Wells Using Aquifer Test Pro Software.

i).Cooper-Jacob Method

(a) With observed drawdown.



(b) With corrected drawdown

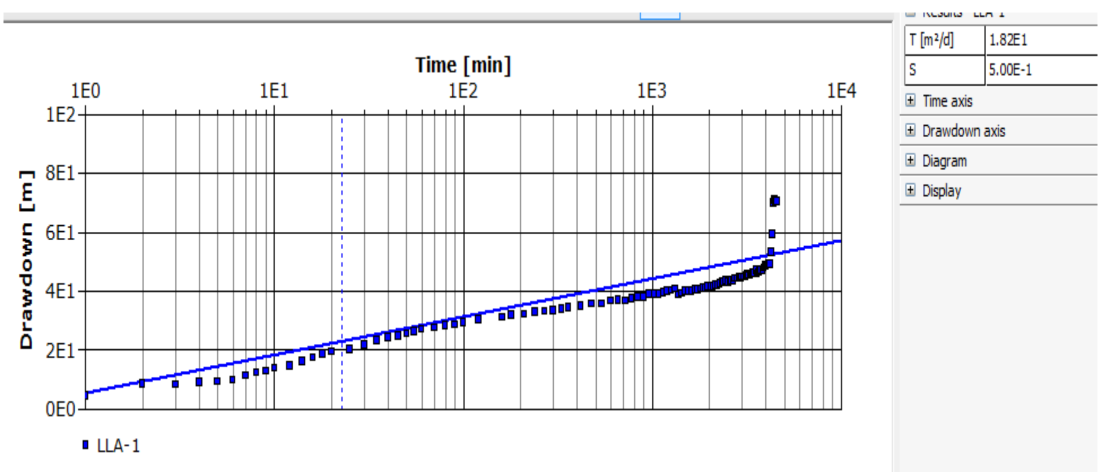
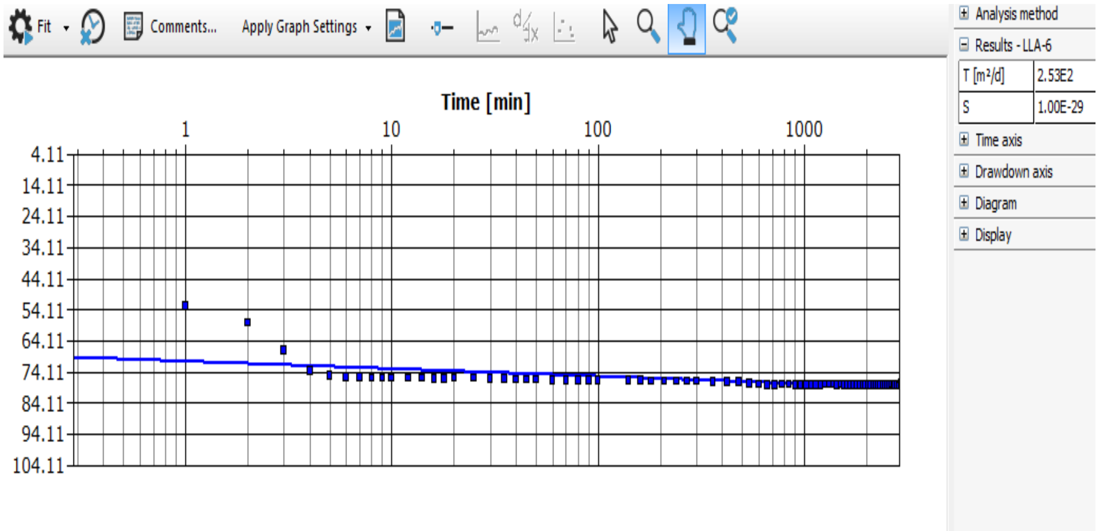


Figure A- 48 Cooper-Jacob result for LLA-1 (a & b)

(c) With observed drawdown



(b) With corrected drawdown

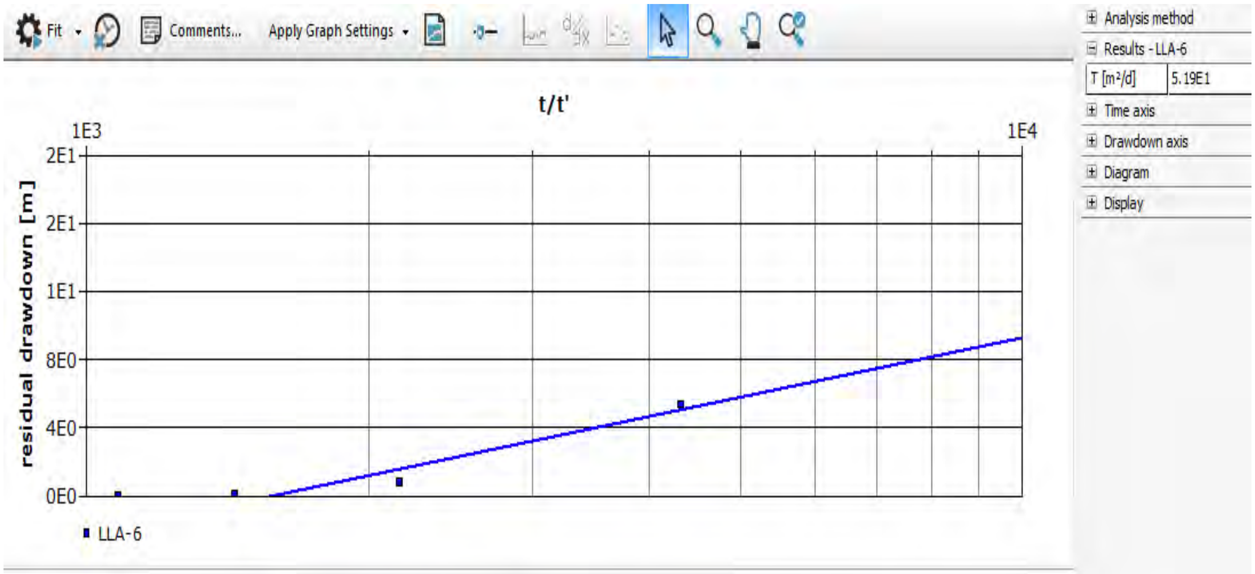
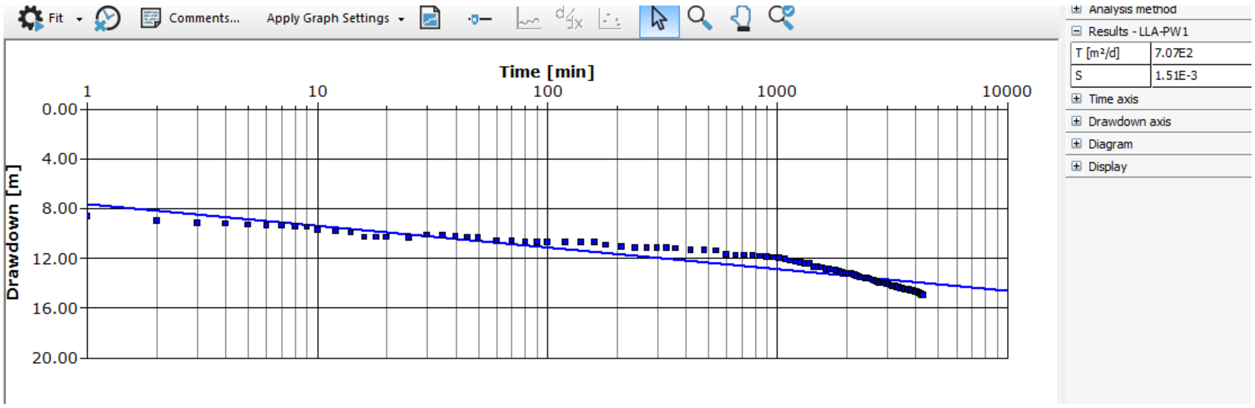


Figure A- 49.Cooper-Jacob result for LLA-6 (c & d)

(e) With observed drawdown



(f) With corrected drawdown

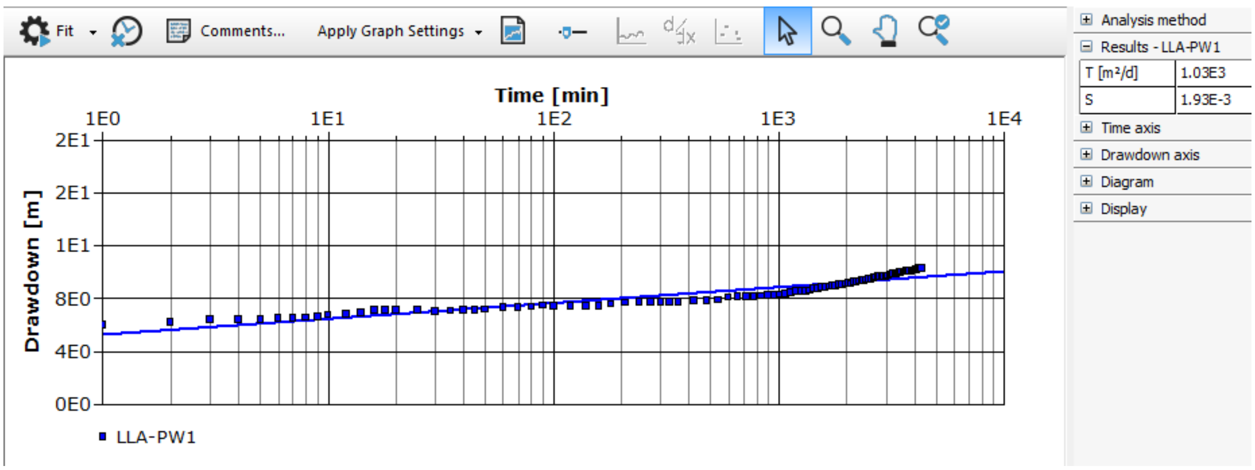
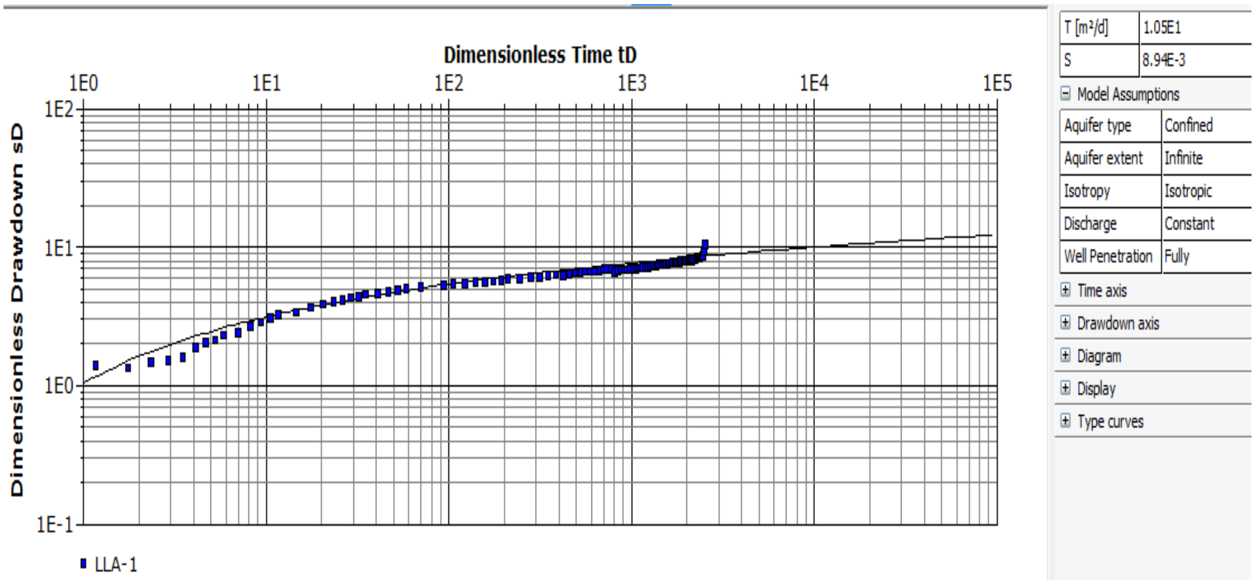


Figure A- 50 Cooper-Jacob result for LLA-PW1 (e & f).

ii).Theis Method Result

(a).With observed drawdown.



(b) With corrected drawdown

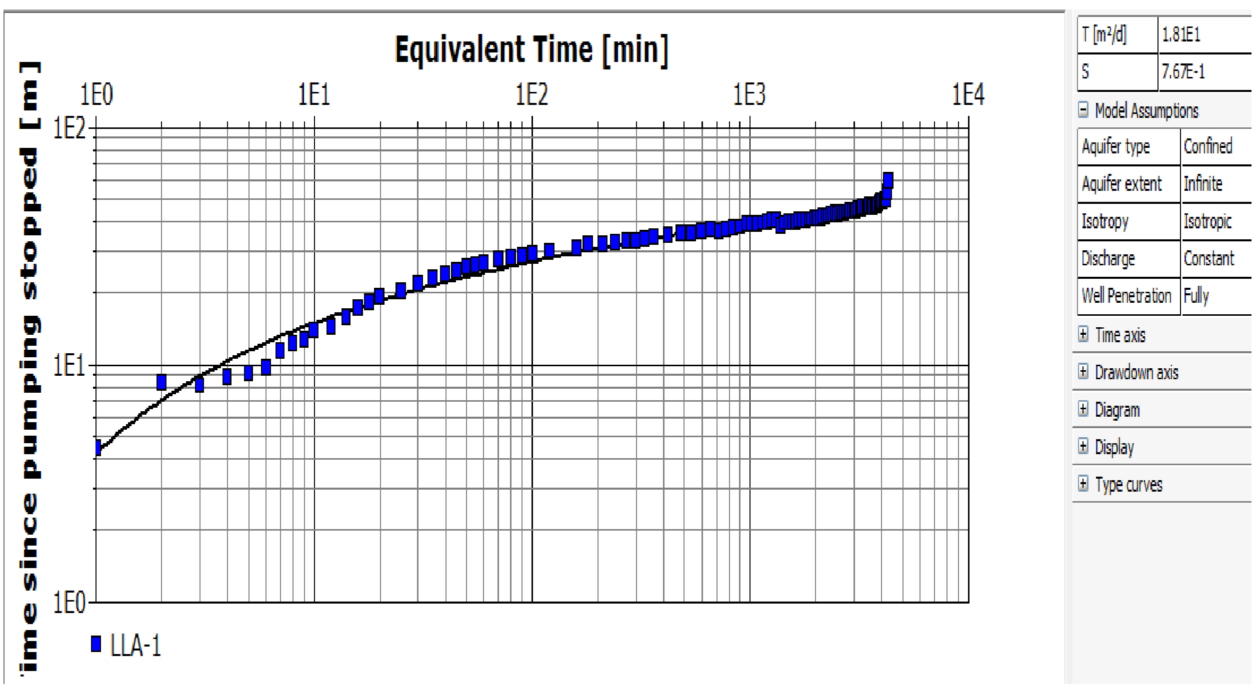
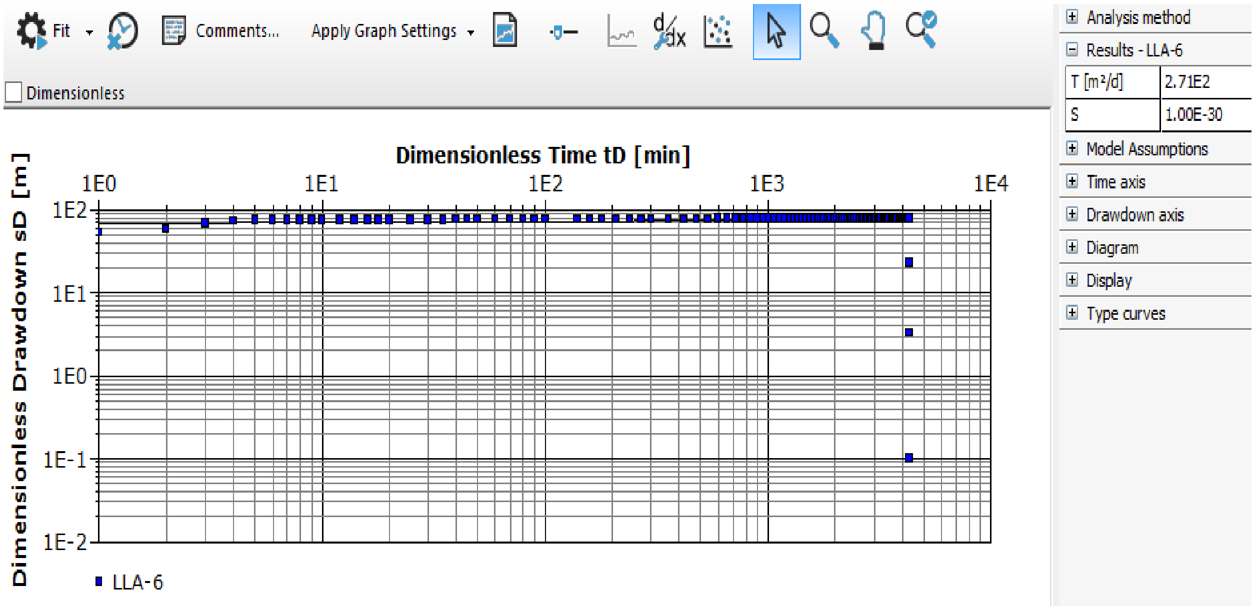


Figure A- 51.Theis result for LLA-1 (a &b)

(c).With observed drawdown.



(d).With corrected drawdown

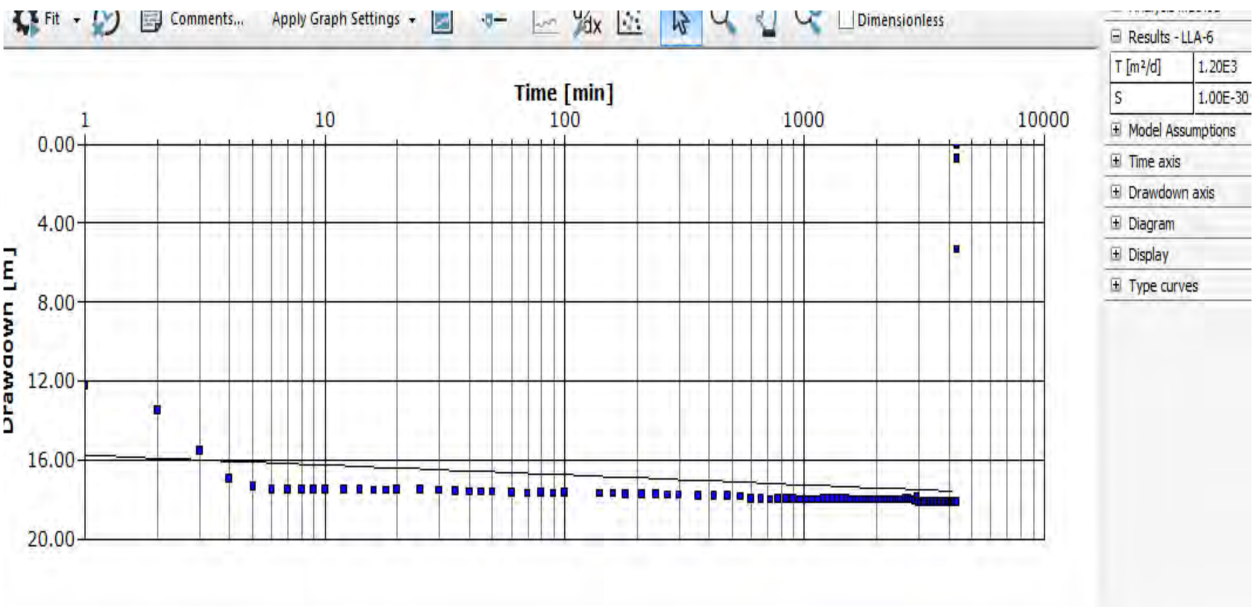
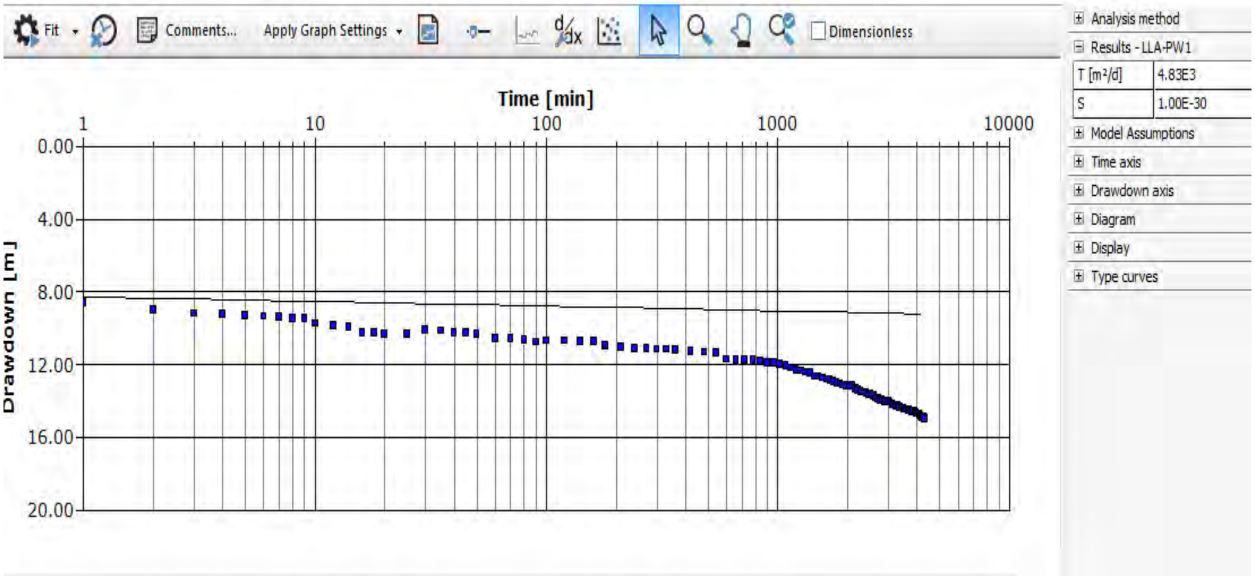


Figure A- 52.Theis result for LLA-6(c &d)

(e) With observed drawdown



(f) With corrected drawdown

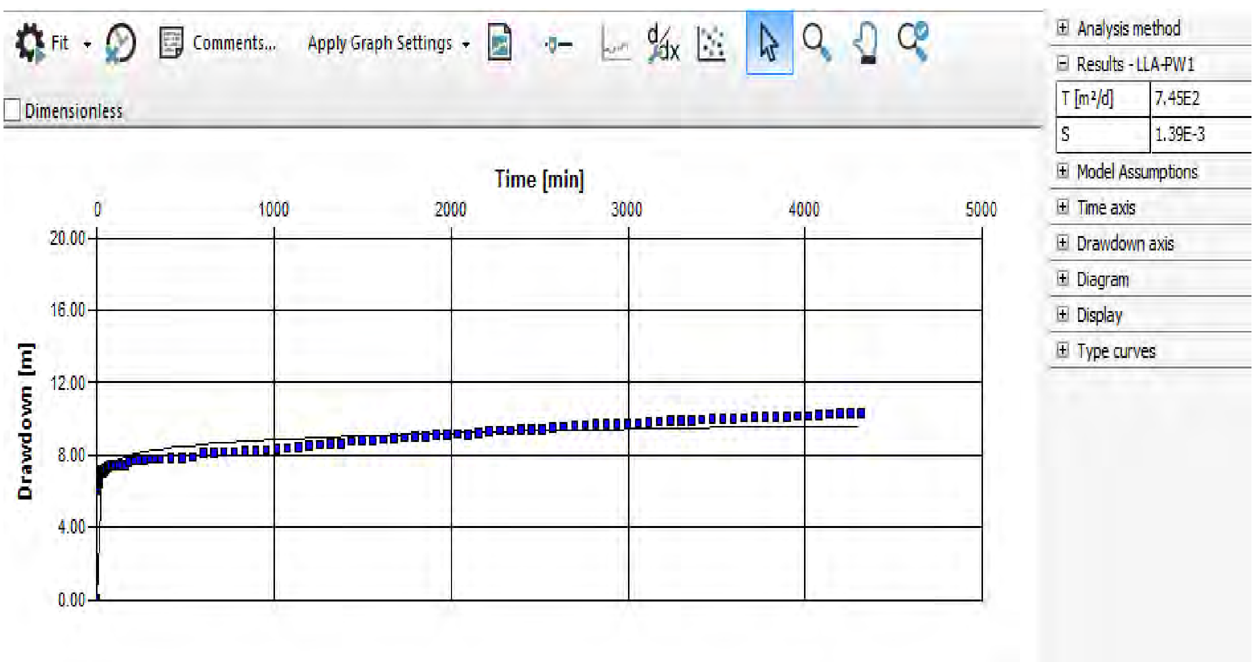


Figure A- 53Theis result for LLA-PW1 (e & f).