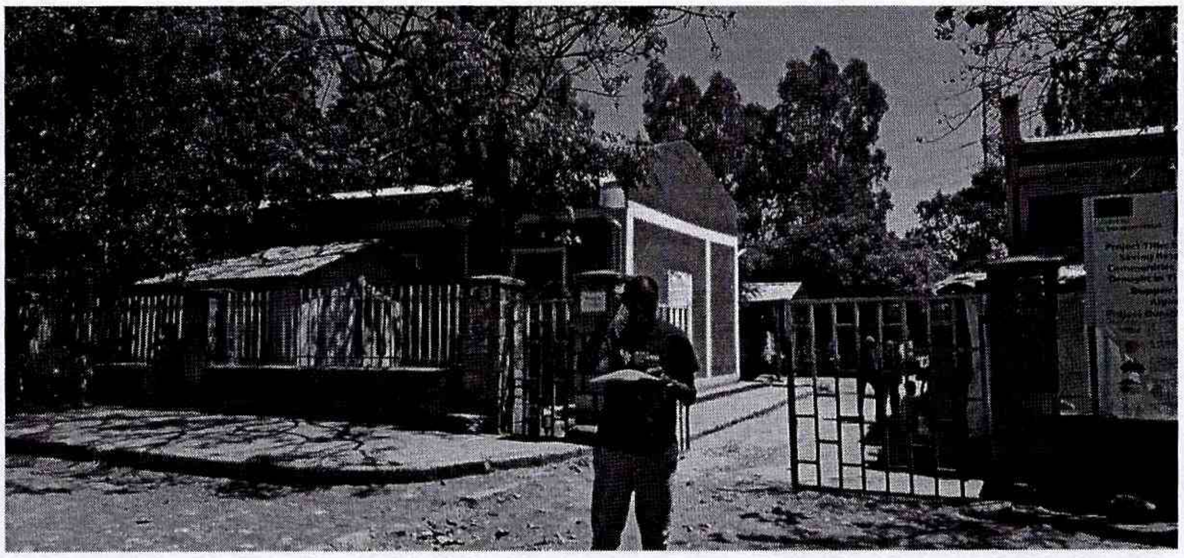
TIGRAY WATER AND ENERGY BUREAU

WATER SUPPLY DIRECTORATE

STUDY, DESIGN AND REVIEW TEAM



GROUNDWATER RESOURCE ASSESSMENT AND BOREHOLE SITING

FOR

THE PURPOSE OF ALGANESH HEALTH CENTER WATER SUPPLY

(SHIRE TOWN, KEBELE 03)

BY: G/MICHAEL G/KIRSTOS

MARCH, 2025

MEKELLE, ETHIOPIA

ክልል ትግራይ ግዝያዊ ምምሕዳር ቢሮ ማይን ኢነርጂን
Tigray Regional State
Interim Administration
Bureau of Water & Energy

Table of contents

List of figures

List of tables

1. Introduction

Communities of Tigray Institutes like Health and schools, found in most parts of Tigray are suffering due to shortage of water supply for different activities undertaken within their institutions. One of the Health centers found in Shire town with shortage of water supply for target communities and staffs is Alganesh Health Center, which makes difficult to undertake activities within its compound. The Health Center is responsible for all the medication process consisting communities and staffs, actively working to achieve all the aforementioned activities of the Health process, which are considered to be the beneficiary of the target groundwater drilling site. For this to be achieved availability of water supply for different activities including the aforementioned beneficiary is mandatory.

With these all water supply problems, helping such Health center to have sufficient water supply can play a major role solving the interruption of medication problem due to lack of clean water supply.

Considering the present water supply problem and need for additional water source (groundwater) which will be used as water supply sources for the different activities undertaking in the building compound, Doctors with Africa Management asks Tigray water and Energy Bureau to conduct Groundwater investigation for assessment of additional source of water supply. Accordingly, the Bureau has sent a hydrogeologist to conduct the investigation and develop study document for deep borehole drilling and construction.

The main focuses of this study was review and conducting hydrogeological and geophysical survey inside or outside the compound and then propose borehole sites for drilling which could yield sufficient water for the desired purpose (different activities undertaking inside the compound).

The procedures followed to achieve the objective is to investigate the hydrogeological characteristics of the wells around the study area and conduct detailed surveys in a systematic manner at selected points to identify the water bearing zones and deduce their thickness and depth. Based on the hydro-geophysical investigations, the different water bearing zones and their relative thickness and depths have been deduced. The details of this investigation and the findings are shown in this report.

This report mainly presents the detailed investigation surveys, discussion of the investigation results, conclusions and recommendations, and finally specification and bill of quantities of the proposed borehole inside the compound. Accordingly one borehole site is proposed.

Due to the limitation of the area of assessment, only considered the area within the compound of the building.

1.1. Location and accessibility

Shire town, the capital city of Northwestern zone and center for trading activities, is situated on the Northeastern part of the central plateau west of the rift valley of Ethiopia. The selected site for drilling and production of groundwater is found in Shire town, Kebele 03 and ketena 03 to the left of the main Asphalt road from Shire to Axum. It is located at UTM location of 423451mE and 1558914mN and Elevation of 1901m in the global grid system and near to the Airport found in the town Shire. The datum used is ADINDAN UTM ZONE 37N and the selected site is accessible through the asphalt and dry road.

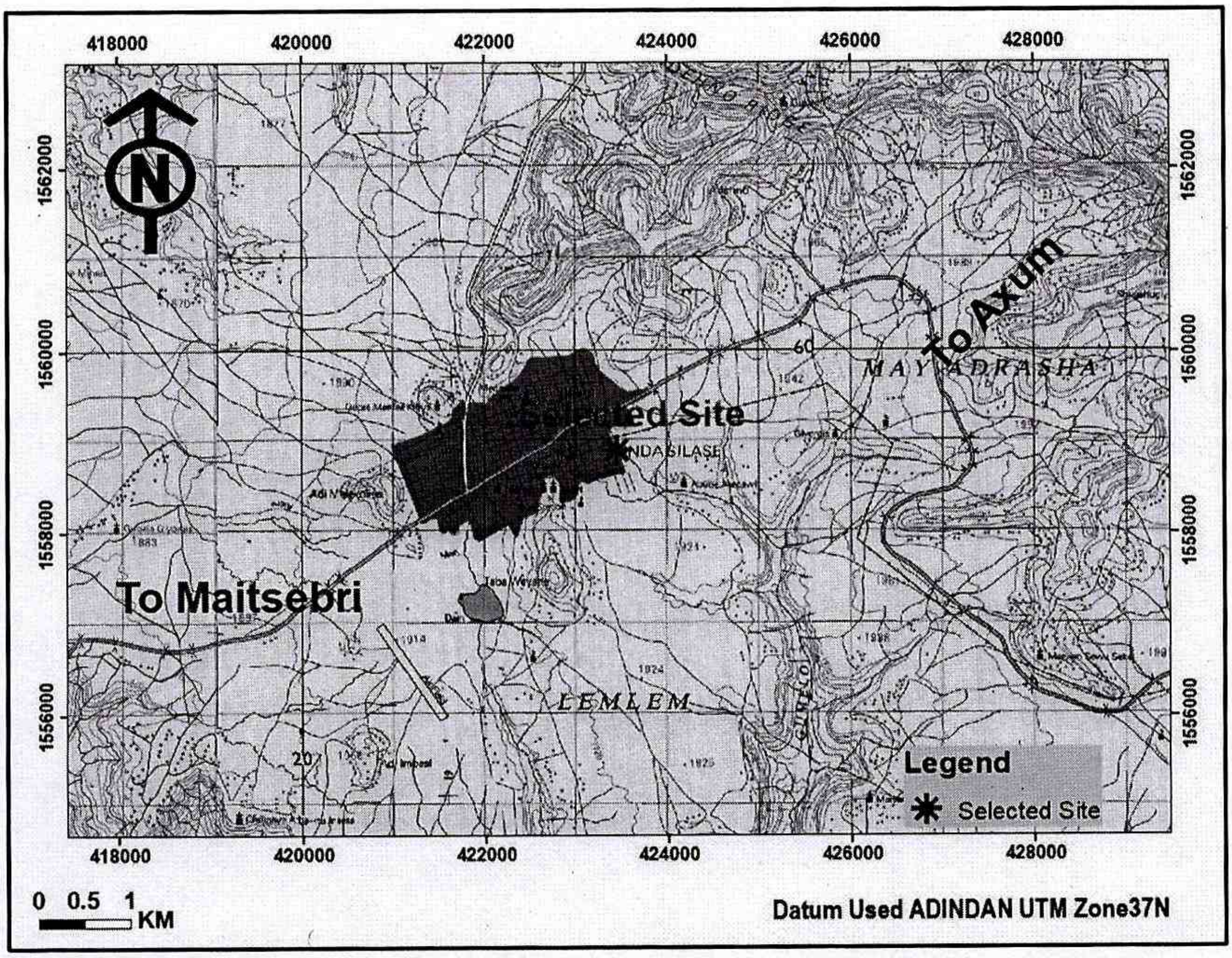


Figure 1 Location map of the area and Selected sites

1.2. Objective of the study

The main objective of the present study is to select borehole site mainly for the water supply purpose of different activities undertaking within the compound of Alganesh Health Center.

- To conduct hydrogeological investigation and overall analysis.
- Identify and locate borehole site with good discharge for the water supply purpose.
- To prepare bill of quantity and technical specification for the drilling and construction of the borehole, and then give further recommendations.

1.3. Methods and materials used

The method employed for the well site selection includes office work and field investigation and finally result compilation. The office work starts by collecting all relevant information and data from concerned bodies. Major information collected from these offices include existing water points, drilling reports, geological logs, satellite imagery, topographic map, other different relevant data. The collected information was processed in the office using different GIS software and important information was extracted from the analysis. After that a field work was conducted and potential sites for further investigation were selected. Hydrogeological field investigation was concentrated more on differentiating the rock units of groundwater significance (such as the degree of fracturing of the rock units, the extent of weathering, the thickness of the formations, the grain size, shape and sorting, and the clay proportion) and in collecting hydrogeological information. Those areas identified for further investigation were closely examined and detail correlation of existing source with the selected site area was applied to investigate the subsurface geology of the study areas.

The materials and software used during the investigation include:

- Satellite images
- Topographic map at a scale of 1:50000,
- GPS, measuring tapes
- Software like IPI2win, Arc GIS, surfer, Global Mapper.

1.4. Climate and Physiography

According to the altitude based Climate Classification of Ethiopia, the study area is within semi-arid climate ("Weinadega"). This area is intermediate between the hot arid and humid climate. In this area, the mean annual temperature is between 18°C to 27°C and the mean annual rainfall is between 410 and 820mm. The amount and distribution of rainfall is highly variable from season to season such that 40 to 60% of the rains fall prevails in the summer months. This shows, most of the annual rainfall is received during the summer; especially in the months July and August of the year. And very little rain occurs from March to May.

Topographically, the target area is characterized by relatively gently sloping land surrounded by a rugged chain of ridges and mountains. The area is characterized by dense dendritic type drainage. As the area is found within part of the Adwa mountain chain, peak ridges and plugs of trachyte were observed during the field visit.

2. Geology and hydro geology

2.1 Regional Geology

The geological units of Ethiopia fall into one of the following three major categories; the Precambrian basement rocks, the sedimentary strata which comprise the Paleozoic, Mesozoic sedimentary rocks; and Cenozoic basalt and trachyte rocks and associated alluvial sediments.

Precambrian metamorphic rocks

The Precambrian rocks of Ethiopia are the oldest rock in the country. They are exposed in areas not intensively affected by Paleozoic and Mesozoic sedimentary rocks, Cenozoic volcanism, rifting and alluvial sediments and the younger cover rocks have been eroded away.

At regional scale there are four major regions were this Precambrian rocks outcrop in the country. Tigray is one of the four major regions around the plateau margins in the northern Ethiopia were the Precambrian rocks outcropped. The Precambrian rock contains a wide variety of sedimentary, volcanic and intrusive rocks, which have been metamorphosed to varying degrees. Due to contrasts, in metamorphic grade, Age & structural style, the Precambrian rocks in Ethiopia were classified into lower, middle & upper Complexes (Kazmin, 1973; 1972; 1971). These were assigned as Archean, middle & upper Proterozoic ages, respectively.

The Precambrian rocks in Tigray, the northern part of Ethiopia, is categorized in the upper complex which consisting of low grade rock successions of ophiolictic rocks, andesitic Meta volcanic, and associated Metasediment, clastic and to lesser extent carbonate sediments (Kazmin, 1978). These low grade Precambrian rocks of the upper complex have tentatively been divided from the oldest to the youngest is Tsaliet Group, Tembien Group, Didikama Formation and Shiraro Formation (Kazmin, 1975, Garland,1980).

Precambrian and Phanerozoic Intrusive

Several generations of Precambrian to early Paleozoic intrusive are widespread in the northern, southern, western parts of Ethiopia. The intrusive bodies are pre to post orogenic, with well-preserved primary igneous textures and form large masses of granites, granodiorites, tonalities, diorites, hornblendites, gabbros and ultramafics which intruded into both the high-grade gneissic basement and the low-grade volcano-sedimentary succession. Most of these intrusive are related to the tectonic development of the late Proterozoic volcano-sedimentary successions (Mengesha Tefera, Tadiwos Chernet and Workneh Haro, 1996).

Paleozoic sedimentary strata

Following the Proterozoic to early Paleozoic tectonic and magmatic activity, peneplanation of the metamorphic basement took place until carboniferous and Permian (Kazmin1972). Late Paleozoic to early Mesozoic sedimentary rocks such as Enticho sandstone and Edaga-arbi glacial in northern Ethiopia (Dow et al., 1971) accumulated in shallow basins and narrow channels cut into the Precambrian basement rocks. In a regional stratigraphy the Enticho sandstone overlies unconformable on the Precambrian basement rocks and the Edaga Arbi glacial overlies unconformable on the Enticho sandstone, however at several local places both the Enticho sandstone and Edaga-arbi glacial overlies unconformable on the Precambrian basement rocks and the Edaga-arbi glacial is found inter fingering with the upper parts of the Enticho sandstone.

Mesozoic sedimentary rocks

Two major transgression-regression cycles took place during the Mesozoic era (Kazmin 1972). The first transgression started in the Early Jurassic or Late Triassic from Southeast towards northwest direction. During this time Adigrat Formation consisting mainly of sandstone and minor lenses of siltstone formed. Antalo formation consisting mainly of fossilferous limestone was also deposited in northern Ethiopia. The regression of the sea started towards the end of Jurassic depositing lagoonal facies of the Agula formation which consists of black shale, marl and clay stone with beds of limestone, gypsum and dolomite in the Mekelle outlier. In the Late Cretaceous the second regression event took place depositing continental sediments predominantly composed of interbedded shale, siltstone and sandstone of the Amaba Aradom frormation in the region.

The Adigrat formation which was originally named as Adigrat sandstone after Adigrat town in Tigray (Blanford, 1870) includes the whole succession of clastic rocks resting unconformably on the Precambrian basement and overlain unconformably by the Antalo formation; (Dow et al, 1971; Garland, 1980). But in some parts of northern Ethiopia rests with a slight disconformity on the Late Paleozoic to early Mesozoic sedimentary rocks of Enticho sandstone and Edaga-arbi glacial. The Antalo formation was first named by Blanford (1870) from local name Antalo and named Antalo limestone and later described in detail by Mohr (1963), Beyth (1971), Kazmin.(1972 & 1975) and Merla (1973 & 1979). In Mekelle area, it conformably overlies the Adigrat formation and grades upward into Agula formation (Garland, 1980). Stratigraphically the Antalo limestone overlies conformably by the Agula formation.

The Amba Aradom formation, known as the upper sandstone (Mehade, 1968; Beyth, 1971; Arkin et al. 1971; Kazmin, 1972 & 1975) in Mekelle area and lies unconformably on the Jurassic sediment, namely, Agula formation.

Tertiary volcanic rocks

Following the Late Mesozoic-Early Tertiary transgression of the sea from the south-east an epierogenic uplift of Afro-Arabia (East Africa together with Arabian Peninsula and the intervening regions now occupied by the Red sea and Gulf of Aden) occurred on an immense scale. The cause of the major uplift is related to a mantle plume, whose decompression melting generated enormous quantities of basaltic magma in the lithosphere and resulted in the formation of a classic continental flood basalt province. The upraised and up arched crust fissuring under tension permitted the ascension of voluminous basaltic magma (estimated as 300,000 km3, Mohr, 1983) to form the Trap Series of Ethiopia. As a result of this geological phenomenon the Hashenge basalt, Aiba basalt, Alajae formation and Adwa formation are formed.

Traditionally, the Ethiopian Flood basalt province is divided in to four stratigraphic units (Mohr and Zanettin, 1988), which are from bottom to top the Ashange, Aiba, Alage, and Termaber formations.

Trachytes Plugs

Stratigraphyically above the Trap volcanic are pale colored fine grained lavas and plugs composed of alkaline trachytic rocks (Blanford 1869). In places where the magma was still less fluid it piled up into the familiar domes, which rest on sloping pedestal of blocky lava. The latest event in this sequence was slow intrusion of homogeneous massive trachyte through the original feeder vent, rising sheer-sided plugs above earlier material. These plugs are quite unmistakable and form the mountains of the area.

2.2 Local Geology

Based on previous studies regional geology and field observations, the geological formations identified are mainly volcanic rock, sandstone, basement and alluvial deposit /Quaternary sediments. As it is observed at gully cuts and road cuts, the geological makeup of the study area is characterized by top fractured to massive volcanic rock and also fractured thin beds of sandstone underlying by fractured to massive granite rock and in the low land is covered by alluvial deposit. Most of the mountains and flat top hills of the area is either devoid of any or locally covered by thin quaternary sediments.

The alluvial sediment in the study area includes, silt, clay, sand and gravel layered pebbles and boulders are mainly outcropped around the main rivers of the catchment. The alluvial formation normally the deposition from the upper ridge of the catchment, varies in thickness across the area.

The volcanic rock is the main aquifer in the study area mainly near to the foot of the surrounding volcanic ridges of the area and also the recharging means in the lower and flat area of the catchments. The unit is strongly affected by various weathering processes including spheroidal weathering systems. In addition vertical and horizontal fractures (micro fractures) and joints are common throughout the catchment area.

The sandstone normally part of the Adigrat sandstone formation, is exposed at the lower most margin of the catchments. According the field study (previous VES results), the thickness of the sandstone locally varies from 4 to 45meters.

The Precambrian basement rock unit called basement rock or hard rocks may comprise both the metamorphic and granite rocks in the area. The granite porphyry (Feldspar granite) otherwise the Shire granite and granodiorite outcrops in the downstream of the catchments river where part of the sandstone is eroded away and deep gorge is formed.

2.2.1. Alluvial sediments (Unconsolidated sediments)

The alluvial sediments are extensively observed in the study area, along flood plains, riverbanks and depressions. They are composed of sand, gravel, silt and clay. In addition to these pebble and cobble size, sediments are observed in those riverbanks.

The thickness of the alluvial sediments ranges from 0.5m up to 10m in river banks that drain from the surrounding ridges and elsewhere. They are grouped as recent fluvial- eluvia deposits and hence are the youngest of all the rock units exposed in the study area. They are observed forming flat and low-lying valleys.

2.2.2. Basalt

This unit unconformably overlies the Adigrat sandstone. It outcrops in the western part of the study area forming very steep-to-steep cliffs. Its thickness varies from place to place. It is thicker towards north and thins southwards. Thin layers of paleosol are present indicating time gap probably showing different episodes of magmatic eruptions of the basaltic unit.

The basalt is dark in color fine grained (aphanitic) and at places vesicular filled by amygdales. In most areas, it is moderately weathered to pinkish and brownish color. The contact between the basalt and Adigrat sandstone is clearly seen throughout the study area. This basalt at the top of the ridges is affected by vertical to sub vertical joints in the direction of E-W and at places show spheroidal weathering.

2.2.3. The basement rocks

The basement rocks comprise patches of Meta volcanic which is part of the green schist facies, and dolomitic rocks. They are foliated striking NE. They are also traversed with granitic dykes having the same trend as the foliation. This Meta volcanic also displays two sets of joints trending NE and NW.

3. Hydrogeology of the Area

The two basic factors that generally determine the groundwater potential of any region or area are geo-structural conditions and hydrometeorology. The geo-structural factors determine the capacity of rocks and soils (aquifers) to store water. The geo-structural factors are composed of lithological units (rock type and mineral composition), structural units (faults, fractures, fissures, porosity) and geomorphologic features.

Hydro-meteorological factors are treated all components of hydrologic cycle with special emphasis to sources of groundwater replenishment.

Volcanic rocks of the target site were considered as potential sites, which have an excellent water holding and transmitting properties if an appreciable thickness of the formation with a higher degree of fracturing is penetrated.

Although Sandstones have intergranular permeability most of the recharge is believed to come through structural discontinuities. Hence, ground water occurs in the pore spaces of the grains and some fracture zones which can transmit and store water.

The basement rocks are generally considered as aquicludes /aquifuges; however, the fractured zones, the weathered mantle and the foliation planes are important places of ground water occurrences. The fractures favor infiltration of water from precipitation and increase the storage and ease of flow of ground water, especially where they are crossed by a recharging stream.

3.1 Alluvial Aquifers: (moderate to high productivity)

As it has been indicated elsewhere, alluvial deposits which are mainly derived from weathering and erosion of the surrounding volcanic, sedimentary and basement rocks are variable in material type and thickness. This deposit mainly consists of intercalated layers of gravel, gravely sands, Silty sands, clay and silty clay as evidenced by the lithological logs and geophysical exploration. In general the alluvial materials can be grouped as Colluvial and alluvial materials. The colluvial deposits mainly found at the foot of the mountains. This deposit is mainly derived from down slope movements, fall and flow of fragments derived from weathering and erosion owing to the gravitational attraction. This deposit has a characteristic of coarse grained, poorly sorted and angular sediments. They are good aquifers when they are thick. In general the alluvial deposit of the area is considered as shallow potential area for groundwater development.

3.2 Volcanic Aquifers: (Moderate to high productivity)

From hydrogeological point of view volcanic rocks affected by secondary structures are the most important formations in the study area. The basalt formation in the area is slightly weathered and highly fractured. Therefore, the main aquifer unit considered in the area are fractured basalt rocks. This rock covers relatively large part of the study area. The high degree of fracturing and weathering and its topographic and geographic location makes this rock to be a good recharge zone and potential for groundwater development.

3.3 Sedimentary Aquifers: (Moderate to high productivity)

From hydrogeological point of view sandstone rocks affected by secondary structures are the most important formations in the study area. The sandstone formation in the area is slightly weathered and highly fractured. Therefore, in addition to the basaltic rock, the main aquifer unit considered in the area are sandstone rocks. This rock covers relatively large part of the study area. The high degree of fracturing and weathering and its topographic and geographic location makes this rock to be a good recharge zone and potential for groundwater development.

3.4 Groundwater Condition and its movement

Groundwater occurrence is greatly influenced by the geology, topography and climatic factors that prevailed in a given area. Hence the groundwater occurrence, availability and movement condition of the study area is directly related to the presence of water bearing geological formations.

Groundwater in the area is generally expected to occur in unconfined and confined conditions. Water table (unconfined) condition occurs in the upper layers of the weathered and fractured basalt/trachyte. The shallow wells and hand dug wells found far from the target area serving the community are tapping the groundwater of the unconfined aquifer. This aquifer is directly linked to the immediate hydrologic cycle of the area. On the other hand, confined aquifers of the area are expected at deeper levels especially, in the underlying basalt aquifer unit and also greater chances for interconnections of groundwater bodies are predicted at structures zones where shattered basalt rock/trachyte attains their relatively high permeability. The general groundwater movement direction is assumed to follow that of the general topographic trend. However, exceptions to this could occur due to the structural conditions though this has not been supported with evidence. As the area is found on flat to gently sloping terrain, there is a possibility of good recharging condition from the slow runoff created after every precipitation time.

4. Geophysical investigation data Interpretation

4.1 Objectives of the Interpretation

To supplement the hydrogeological investigation, data obtained from geophysical survey mainly vertical electrical sounding conducted previously at different sites with similar geological setup to the selected sites are used to assess or investigate the possible geological succession with depth.

Generally, the aim of the previous VES survey data interpretation was mainly:

- To identify the nature and thickness of the different layers
- To estimating the depth to the massive bed rock
- To estimate the depth and the thickness of the water bearing zone
- To estimate the thickness of Basalt and or Sandstone rocks, expected as the main aquifer of the site and to detect any weak zone thickness of the dolerite dyke/sill of the area.

Accordingly, the previous data (VES result) analysis result used as input for the selection of the well site within the compound of the Health Center, shows fractured basalt and Sandstone rock affected by weathering and fracturing processing is considered as good groundwater potential or aquifer.

5. Selected well site and its description

5.1 Well site selection

Before the appropriate well sites are selected a detailed investigation of digital elevation model, satellite image analysis, existing geological maps and wells has been analysed. In addition, previous Geophysical investigation of Vertical electrical sounding (VES) were used a major input for the well selection. After analysing the result obtained from the VES point of different sites, the target site was found to be good potential for groundwater development. Therefore, considering the geological condition of the compound and the surrounding area where the previous geophysical investigation was done, a deep borehole site was located with a geographic location presented below.

Table 1 Selected site for groundwater development

UTME(m)	*UTMN(m)*	*Z(m)*	*Kebele*	*Site name*	*Depth (m)*	*Drilling method*
423451	1558914	1901	03	Alganesh Health Center	100	DTH

5.2 Well Design

Screen length and blind casing length is mainly proposed based on the presumable permeable and impermeable material. All assumed saturated permeable materials might be screened which is of course may not be economical. Therefore it is suggested that in most cases the screen length to be 40 % of the total depth. Moreover the casing material is suggested to be PVC but one can think of using stainless steel casings in the case of higher depth wells. Based on site condition the surface casing could also be wider and made of steel. In some cases the top five to eight meters are averaged in VES interpretation as commonly these portions has little impact in well design. Considering the saturated aquifer thickness and the aquifer material the selected well is expected to yield 2 to 3 litter per second.

This part of the report is planned to serve as primary information for drilling. Therefore each site is treated as a separate entity and detailed description is given for potential well site. The drilling diameter might be wider than the proposed figures; for the top 10 meters of the wells based on site condition. Moreover the diameters of casing and screen are suggested based on standard books and also experiences in the study area. It is possible to adjust this information based on site condition during drilling in that particular area.

5.2.1 Recommended site for drilling

Based on the different data interpretation result, the main aquifer of the site is assumed as fractured and saturated Basalt and Sandstone rock. The following recommendation should be followed during drilling and construction of the site:

- The recommended depth of drilling is **100** meters but the actual depth of drilling should be determined during supervision based on the actual geological findings.
- The drilling diameter in the upper soft formation is **$14^{3/4}$** inch and the rest should be **10** inch.
- The gravel pack shall consist of clean, well-rounded, erosion resistant, washed river gravel, with grain size of 2-4mm. The gravel should be hard, rounded, and free of calcareous materials. Generally, the gravel pack must be free of any interaction during contact with water.
- The well should be cased with **6 inch** internal diameter **PVC** slotted and blind casings. The actual screen length and position of the screen shall be determined from the geological formation encountered during drilling. The quality and standard of the casing and screens should fulfill the standards set by the internationally recognized institutions like American Petroleum Institute (API) and American Soil Testing and Materials (ASTM).
- A ¾ inch galvanized steel pipe (observation pipe) should be installed to a depth of below maximum anticipate draw down in the annular space of the borehole that help to monitor the water level.
- The well should be well developed and the process should continue until the water of well becomes clean and free of suspended loads.
- Other recommendation are in the technical specification part

6. Environmental and social impact Assessment Report

The deep well which is selected for groundwater pumping found within the target building area will pump groundwater for the water supply of different activities undertaking within the Health Center compound and the environmental and social issues should be considered. Most of the expected minor impacts are from the types of impacts which can be readily managed by the resources and expertise available.

Environmental Impacts: Considering the possible Environmental impact of the proposed drilling site, no impacts considered as adverse is expected from the target project. Some of the observations to be considered:

- The selected site is located within the compound of the Health Center building, which is legally granted to the Health center community.
- No water courses, streams, rivers, lakes, wetlands, swamps and other biodiversity are relevant in the area and its surrounding.
- The proposed project has no adverse effect on wildlife, wild habitat, and other aquatic ecology as well as on the overall terrestrial environment.
- There is no displacement of people or resettling due to this project.
- No cultural, religious and archeological resources will be affected as a result of this project.
- No chemicals or fuel will be used during the pumping of the well, because there is a grid line power, which will be connected to the borehole.
- Considering the status of sanitation of the site, no sewerage canal or system passes through the selected drilling site.
- The expected temporary sound and dust pollution during the drilling process will be minimized, especially the dust by using water from external sources until the first water strike of the well.

Social Impacts: Communities around the area are expected to be ambitious that their additional water demand will be complemented by construction of such water supply projects not only by the government but also by different bodies participating in providing water supply activities. Hence implementation of the water supply project by itself has a multiple of benefits than impacts considered as adverse impacts that the local people and service providing institutions could enjoy it preferably when the municipal water utility interrupts the provision of water for different reasons. Therefore, the implementation of the water supply project will not have social conflict of interest, rather it will play a major role in solving the shortage of water supply especially in times of critical water crises as there is scarcity of water supply in the town.

The expected positive impact of this project:

- Creating job opportunity to the local community and also other technical personals of the region as well as the country as a whole.
- Play a major role in providing water for different activities of the building so as to solve any shortage of water supply. This minimizes using of water provided by the town water utility office.

- Play major role in improving the sanitary condition and also day to day activities of the Health Center. In addition, this can improve the level and type of medication process to be undertaken at the target Health center.
- Excess water from the well can be used as source of water supply for the nearby local people.
- In addition to the fulfillments of the domestic water supply, the project can help in maximizing the sanitary condition of the Building as a whole and its vicinities. This will be one of the methodologies or means of disease prevention mechanism.

Mitigation measures for possible environmental and social impact of this project:

- The expected temporary sound and dust pollution during the drilling process will be minimized, especially the dust by using water from external sources until the first water strike of the well.
- The water to be pumped out during drilling and pumping test activities should be conveyed to the drainage canal found downstream of the drilling site without disturbing the local people and infrastructure of the area.
- No chemicals that can have adverse impacts on the health of local communities and downstream area will be used during drilling of the target site.
- Materials which are not free of any contamination with chemicals that can have a potential to contaminate or pollute the groundwater should be avoided during installation of the drilling and system installation of the site.
- Complete grouting of the upper formation of the well with cement up to the depths indicated in the BOQ of the investigation document is mandatory to avoid any contamination of the well and groundwater as a whole by any underground contaminants.
- Construction of standard well head, indicated in the BOQ of this investigation document, is mandatory to avoid any infiltration of effluents that can pollute the groundwater of the area.
- All the above recommendation and consideration should be addressed properly before proceeding to the next step during drilling and system installation activities of the target water supply project.

7. Conclusion and Recommendations

7.1 Conclusions

As the field survey on geology and hydrogeology indicates, the groundwater occurrence and movement in the surrounding area is highly governed by the geology, Topography and geological structures prevailed in the area. To locate borehole site for groundwater development, it is vital to carry out a site specific study. Accordingly a study focused on the description of geology, geomorphology and recharge condition was conducted in the production site and its surroundings. Based on actual field observation and previously collected geophysical investigation and interpretation, one borehole site is identified and located for groundwater developments. The well selected site is going to be drilled for the different activities undertaking in the Health Center. After analyzing the pumping test results to be obtained from this well, if any excess lowering of groundwater within the selected site is encountered, monitoring of the amount of water to be used is possible.

7.2 Recommendation

After undertaking all required investigations the following recommendations are forwarded.\

- Groundwater systems are dynamic and adjust continually to short term and long term changes in climate, groundwater withdrawal, and land use. Water level measurements from observation wells are the principal sources of information about the hydro geological stresses acting up on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Hence it is important to establish a long term systematic measurements of water level of the target well, which can provide essential data needed to evaluate changes in the existing resource over time. This can also help for further locating of additional wells and expected impact of the additional proposed wells to be drilled on the existing wells and the well field as a whole.
- The selected site is mainly based on available information including data obtained from previous investigation of geophysical exploration so one should closely follow on the drilling activity to make onsite adjustment about the suggested information and identify the major water bearing.
- The recommended depth of the drilling site is given above but the actual depth should be decided during the drilling supervision, therefore, all drilling activities should be conducted under the supervision of hydrogeologist to give required decisions on the basis of actual observations.

- As it was described in the different geological layers of the previous geophysical (VES) interpretation of different sites, the geology of the site consist of mostly saturated and fractured Basalt and Sandstone rock is assumed to be water bearing. Thus proper screen casing of the water bearing layers is vital for which close supervision is needed.
- Groundwater level of the site to be drilled should be controlled during using of water for the different activities, which helps in avoiding further lowering of groundwater level. This can also be used as an input to adjust the amount of water to be extracted from the well and avoid over pumping. Generally, the water level should be monitored according to the pump test result from the well.
- As it was described in the local geology of the target site, the geology of the sites consist of mostly saturated and fracture basalt and Sandstone with some thickness of fractured granite rock is assumed to be water bearing. Thus proper screen casing of the water bearing layers is vital for which close supervision is needed.

For the sites to be drilled the following recommendations are forwarded:

- The recommended depth to be drilled is 100m
- The recommended method of drilling is DTH.
- The drilling diameter should be $14^{1/2}$" bit for the top or soft formation (10m) and the remaining 100m has to be drilled by $10^{3/4}$" drilling bit.
- The recommended temporary and permanent surface casing is 12" Steel.
- The production casing recommended is Ø 6" internal diameter. The type of casing should be PVC.
- The well should be packed with appropriately sieved, well rounded and sorted river gravel (6 - 9 mm)
- The well should be developed until it becomes clear and free of any fine particles
- The depth of drilling should be up to the recommended depth, but the actual depth of drilling should be determined during supervision based on the actual geological findings.
- A Ø 3/4" galvanized steel observation pipe shall be installed to a depth of maximum anticipated drawdown in the annular space of the borehole that helps to monitor the water level.

As the area where the site is located is found within the town, care must be taken during drilling of the well to avoid any contamination of the well and the well should be grouted to the maximum depth indicated in the BOQ and/or more based on the findings during drilling of the target well.

The drilling process should be strictly supervised by a qualified and well experienced hydrogeologist.

8. TECHNICAL SPECIFICATION

Scope

This specification gives information about the drilling and/or construction methods, materials, equipment need and the work condition required to complete water well successfully in accordance to the general specifications given in the bill of quantity.

Personnel and Drilling Equipment

The CONTRACTOR shall supply capable and experienced personnel including hydro geologists, chief drillers and deploy a modern and good capacity hydraulic MUD/DTH and /or direct circulation rotary drill rig.

Mobilization/ Demobilization

Mobilization and demobilization include transportation of the materials, equipment, accessories, crew members necessary for constructing and developing the well to and from the site to the CONTRACTOR'S main store.

Groundwater Investigation

(Not applicable)

Well Drilling

A. Drilling shall proceed with **$14^{1/2}$** inch external bit diameter up to the final depth of unconsolidated sediments. Applying surface casing (temporary/permanent) is necessary to prevent the unconsolidated sediments from being collapsed. In addition, the upper loose unconsolidated sediment should be grouted to prevent collapsing and contamination of the well. DTH/MUD type of drilling will be used depending on the geological condition of the site.

B. The borehole should be drilled to the desired depth with **$10^{3/4}$** inch bit diameter so as let in **6** inch blind and screen casings so as to have thicker gravel pack at the annular space.

C. The CONTRACTOR shall employ qualified Hydro geologist who will be responsible for the accomplishment of the works according to the design, to supervise the drilling rate and describe the cutting for the preparation of lithological log.

D. The rock cutting sample will be collected every 2m depending on the geological condition and describe properly together with drilling rate. These data will be documented for supervision and will be presented in the final formal technical report.

E. The geophysical well logging should be conducted prior to well casing to determine the hydrogeological characteristics of the boreholes including aquifer disposition and water quality. The drilling contractor will carry out the well logging under the advice of the supervisor and should provide all logging charts along with its interpretation to the client ***(optional).***

Material Supply

Screen, Blind Casing and Observation Pipes

The well screen should be continuous slot type, designed to provide maximum inlet of water and minimize the entry of sand, silt and clay particles. The CONTRACTOR shall supply **6** inch internal diameter PVC slotted and blind casings. The actual screen length and position of the screen shall be determined from the geological formation encountered during drilling.

A ¾'' galvanized steel pipe (observation pipe) should be installed to a depth of below maximum anticipate draw down in the annular space of the borehole that help to monitor the water level.

The quality and standard of the casing and screens should fulfill the standards set by the internationally recognized institutions like American Petroleum Institute (API) and American Soil Testing and Materials (ASTM).

Slots which are prepared by hacksaw, welding or oxy-acetylene are not allowed and damaged and deformed casings due to mishandling will not be accepted for installation.

Gravel Pack

The gravel pack shall consist of clean, well graded and same size with grain size of 2-4mm. The gravel should be free of calcareous materials, hard, rounded. The filling of gravel pack should be done carefully and slowly by hand using shovel or water bucket to avoid bridging.

The annular space between the borehole wall and casing over the gravel pack will be grouted with cement to depth not less than 10 meters to protect the well from contamination.

Source of gravel should be from areas with quartz sources others like volcanic source are not accepted.

Before placing of gravel, the assigned supervisor should approve the quality and need for gravel packing and samples to be used for packing.

Well Flushing and Development

Well development is very important to remove the silt, clay, mud cake and other residues from the aquifer, gravel pack and bottom of the well to assure the purity and maximum yield of water. The well development process should be continued until the water of well becomes clean and free of suspended loads, and shall be developed using air compressor for about **5** hours.

Well Head Construction

For due protection of the well from any/ against the entrance of water or any pollutants the annular space between the wall of the borehole and the casing will be secured by filling the upper part by mass concrete on top and in connection with grouted portion of the well. A rectangular or circular or trapezoidal well head should be constructed with about 0.8 heights above the ground level and submerged about ½ m below the ground surface.

Upon the completion (installation) of the well, the contractor shall install a suitable welded cap to prevent entrance of foreign materials.

Well Testing (Pumping Test)

Pumping test is conducted to know the performance of the well and aquifer parameters, determine the pump capacity etc.

The contractor should assign qualified and experienced personnel and should use reliable and accurate equipment to conduct the pumping test. The test includes:

- Pre test
- Step-draw dawn test
- Constant discharge test
- Recovery test

Step draw-down Test

The step test should cover at least four successive steps each having 2 hours duration. During the successive steps, the discharge should increase when the draw down starts to stabilize until the Q-maximum is attained. The Q-maximum can be estimated from the development stage (compressor yield).

The four steps should be performed at the following yields:

- Step 1: 1/3 of the expected yield
- Step 2: 2/3 of the expected yield
- Step 3: equal to the expected yield
- Step 4: 125% or 150% of the expected yield

Water levels shall be recorded during this time at intervals as follows for each of the steps

Every	1 minute	From 1-10 minutes of pumping
Every	2	From 10-20 minutes of pumping
Every	5	From 20-500 minutes of pumping
Every	10	From 50-100 minutes of pumping
Every	20	From 100-180 minutes of pumping
Every	30	From 180-360 minutes of pumping
Every	60	After more than 6 hours

Tigray Regional State Interim Administration Bureau of Water & Energy

- The well yield should be measured precisely by the suitable discharge /yield measuring device (mostly water meter or circular orifice).
- The duration of each step shall not be less than 2 hours, and if necessary longer.
- The water samples should be collected at end of every step and temperature of water should also be recorded.
- The water recovery should be measured in time after stopping the pump set, until the water level recovery equals or reaches near the natural water level >90%.
- The pumping test data record should be adequately interpreted to determine the well hydraulic performance in relation to aquifer potential, etc.

Constant Discharge Test

This type of test is done after the step test is accomplished successfully.

- Well yield/discharge capacity should be decided and should be constant during the continuous operation of the borehole for the period of testing. The well yield should not fluctuate beyond 3% of the average yield.
- The pumping duration for continuous pump operation should be up to **24** hours according to the hydraulic capacity of the productive aquifer potential.
- The depth of water should be measured in the production borehole at the static stage of the water well structures from the fixed point.
- From pumping period, the frequency of dynamic water level observations should be initially half minute interval up to 5 minutes, one minute interval up to 30 minutes, two minute interval up to 60 minutes, five minute interval up to 120 minute, ten minutes interval up to 360 minutes and then thirty minutes interval up to the end of the pumping duration.
- The well yield/discharge should be measured precisely from the starting pumping test and at suitable intervals so as to ensure the constant yield/discharge during the whole period of test.
- Four water samples should be collected from the start to the end of the test at equal intervals for field water quality analysis, and the temperature of water should also be recorded.
- The water recovery should be measured on stopping the pump set, until the water level recovery equals or reaches near the natural water level.

- The pumping test record should be adequately interpreted to determine the aquifer parameters such as transmissivity, hydraulic conductivity and the storage coefficient /specific yield, etc.

Recovery Test

At the end of the last step draw down test and the constant rate test, recovery measurements should be taken. Recovery test should not be omitted because it helps to verify the accuracy of the pumping data and assist to confirm the results of the aquifer parameters determined by the constant test.

Recovery measurement data are more reliable than the pumping data for the very reason that no pumping is involved during this test and hence no water level reading problem associated with the pumping action is encountered.

Even though, the recovery test duration once again depends upon the intended quality of the data. In this case, the duration could be decided based on the following approaches appointed person:

- Equal duration as the constant rate test
- At least five readings in succession are identical
- Until the water level fully recovers
- The water level recovers to less than 5% of the total draw down

The recovery water level measurements should be taken right after the pumping has been stopped with similar time intervals applied for the draw down and constant rate tests.

At the end of recovery test which is performed after the constant rate test, the pump has to be removed and the well must be properly secured until the permanent pump is installed.

Pumping Test Requirements

The pumping test requirements are as follows:

- Pumping set and power source: A strong pumping set along with a power source of adequate capacity, reliability and durability is required to enable uninterrupted pumping of the test borehole for the requisite period.
- It has to be ensured that the pumping set and power source must not fail during the pumping test and so the utmost care must be taken by the pump operation and maintenance unit, otherwise the sole responsibility will lie on the pump unit manager or his staff at site for the pumping test failure and consequences thereof.
- The competent observatory professional crews / persons on the pumping test should be appointed by the client.

Water Sampling and Quality Analysis

Field and laboratory water quality analysis shall be carried out. Sample should be properly recorded, stating date and time of sampling and other required parameters.

Some of the analysis to be carried out either in the laboratory and /or field includes:

- Electrical conductivity (EC)
- PH
- Total dissolved Solids
- Hardness
- Major cations
- Major anions
- SAR (Sodium Absorption Ratio) value

Specification of Water Point Tagging

- A plate made of stainless steel most preferably of grey color
- Dimension 5cmX5cmX1mm, and preferably with slight rounding at the corners to avoid detaching
- Labeled with the information as shown in the figures below – the labeling of texts should be done using laser print or similar technology so that the printed information would not be washed or scratched in any means
  - ✓ Main labels (Woreda name, Unique ID and Depth) written in Times New Roman 16 pts and paragraphs spacing – multiple
  - ✓ Metadata (text below Logos and barcode) written in Times New Roman 7pts and paragraph spacing – exactly
  - ✓ Logos of Tigray Water Resources Bureau in JEPG should be clearly printed
  - ✓ Barcode of unique ID with a size of 0.82 cm by 2.52 cm – the supplier has to generate barcode for each water point based on the information received officially from the woreda or Tigray water resources. The printed barcode must be readable using barcode scanner on mobile.
- The back side of the plate must be covered with glue that could be permanently fixed on metallic and concrete materials.

Figure 2: Design of tagging plate

Figure 3: Sample example of tagging plate

Preparation of the tagging information

- The constructing body delivers the well log or other information showing depth to the woreda water mines and energy office
- The water resources management expert in the woreda extracts the tagging information (properly spelled Woreda name , unique ID and depth of the structure)
- The constructing body prepares the tagging plates based on the official information received from the woreda office.
- Hand dug well, shallow well, spring, or deep well constructed by government or NGO or private body must be tagged after hand pump or spring construction. In deep well it could be done after construction or pumping test.
- The depth information should be empty in case of springs
- The water point tag need to be done for productive boreholes/wells only

Fixing the tagging plates

- In hand pumps, the tagging plate has to be placed vertically on the flat side of hand pump head.
- In springs, the tagging plate has to be placed on the concrete box on the source not on distribution points or collection n chambers.
- In deep wells, the tagging has to be placed on the well head facing to the access to the well site
- However, the plates could also be placed on any other position on the source wells if accepted by supervisor

Technical Report

After completing the drilling and pumping test woks, the contractor has to submit the final technical report, which is prepared in English language and incorporates all results of specific activities. The report should include but not limited to the following:

- Location of the site (relative and UTM)
- General geology and hydrogeology condition of the area
- Type of drilling rig
- Rate of drilling
- Description of logging results; present geological and hydro geological cross-section, identify the type and major aquifer types
- Drilling diameter, final total depth, depth of different aquifers,
- Static water levels
- Plotted pumping test graphs
- Proposed pump position, dynamic water level, recommended safe yield,
- Recommended pump and generator capacity, type. Recommend alternative energy sources (Optional).
- Description about the analytical methods and relevant calculations and the interpretation of pumping and Recovery test data.
- Water quality analysis and suitable of the water for drinking.

The final report has to accommodate remarks on special observations, difficulties encountered and findings that would be followed by interpretation of results.

Each compiled data and result will be supported by detail discussion and submitted to the client with the recommendation of pump type, capacity, permanent pump position and continuous pumping hours. Payment for the compiling of technical report will be according to the unit price given on the price quotation.

Abortive Boreholes

Any borehole, which on completion yields less water than in the opinion of the Engineer is necessary to render it of use, shall be considered as an abortive borehole. In this case the Contractor will be paid for drilling of the borehole at the appropriate rates in the Bill of Quantities. The abandoned borehole shall be sealed.

Failure to Complete a Borehole

Should the Contractor fail to comply with the requirements of this specification or should the Contractor fail to complete the borehole due to loss of tools or any other cause, and the borehole as a result thereof, has to be abandoned, then the Engineer shall have the right to instruct the Contractor to commence a new borehole as near as practicable to the abandoned one and no payment will be made for drilling the abandoned borehole, or any other work carried out in it, or for the casing or other materials used therein.

Sealing of Abandoned or Abortive Boreholes

Abandoned or abortive boreholes shall be sealed by filling with concrete, grout, neat cement, clay or clay and sand. In the event that the water bearing formation consists of coarse gravel and producing wells are nearby, care must be taken to select sealing materials that will not affect the producing wells. Concrete may be used if the producing wells can be shut down for a sufficient time to allow the concrete to set. Clean, disinfected sand or gravel may also be used as fill material opposite the water-bearing formation. The remainder of the well, especially the upper portion, shall be filled with clay, concrete, grout, or neat cement to exclude surface water. The latter method, using clay as the upper sealing materiel, is especially applicable.

Clean Up

After the borehole has been completely constructed, its environs shall be thoroughly cleaned of all foreign substances, including tools, timbers, ropes, debris of any kind, cement, oil grease, joint dope and scum.

Protection of Borehole

At all times during the progress of the work, the Contractor shall protect the borehole in such a manner as is effective to prevent either tampering with the borehole or the entry of foreign matter into it.

Precautions against Contamination

The Contractor shall take such precautions as are necessary at any time or as may be required permanently to prevent contaminated water having undesirable physical or chemical characteristics form entering the stratum from which the borehole is to draw its supply, through the opening made by the Contractor is drilling the borehole. He shall also take all necessary precautions during the construction period to prevent contaminated water, gasoline, or any other contaminant from entering the borehole either through the opening or by seepage through the ground surface. In the event that the borehole becomes contaminated or that water, having undesirable physical or chemical characteristics, enters the borehole because of negligence by the Contractor, he shall, at his own expense, perform such work or supply such casing, seals, sterilizing agents or other material as may be necessary to eliminate the contamination or shut off the undesirable water.

9. BOQ

Project: - Alganesh Health Center Water Supply
Site Location:- Shire town, Kebele 03, Ketena 03 and Target name Alganesh Health Center
Depth: 100m

No	Activity	Unit	Qty	Unit Price (Birr)	Total Price (Birr)
1. General					
1.1	Mobilization of Resources, man power	LS	1		
1.2	Demobilization	LS	1		
2	**Drilling**				
2.1	Drilling in All formation, DTH/MUD $14^{1/2}$" bit diameter	M	10		
2.2	Drilling in All formation, DTH $10^{3/4}$ " bit diameter	M	90		
3	**Well Logging**				
3.1	Lithological borehole logging	L.S	1		
4	**Supply and Installation of Casings**				
4.1	Supply and Installation of 12" steel temporary surface casing	M	10		
4.2	Supply and Installation of 12" steel permanent surface casing	M	10		
4.3	Supply and Installation of 6" ID PVC blind casing	M	60		
4.4	Supply and Installation of 6" ID PVC screen casing	M	40		
5	**Gravel Packing and Well construction**				
5.1	Supply and pack selected river gravel	M^3	8		
5.2	Grout with mass concrete to a depth not exceeding 10m and construct well head (0.8x0.5x0.4m) C-25 concrete	LS	1		
5.3	Well cleaning and development using appropriate method	Hrs	5		
5.4	Supply and installation of ¾" observation pipe (GI)	M	78		
5.5	Supply and weld on iron cover on top of borehole	L.S	1		
5.6	Well disinfection with hypochloride (150mg/l)	L.S	1		
6	**Pumping Test**				
6.1	Mobilization and demobilization of man power, pump test equipment	L.S	1		
6.2	Step test (Four steps of 2 hrs duration)	Hrs.	8		
6.3	Constant Test	Hrs.	24		
6.4	Recovery Test	Hrs.	12		
7	**Physical and Chemical test**	L.S	1		
8	**Supply and installation of tagging plate**	L.S	1		
9	**Report writing (3 copies) with soft copy**	L.S	1		
Total cost for one deep well with mobilization and demobilization					
VAT (15%)					
Grand total for one deep wells including VAT					