THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER

GUIDELINES FOR GROUNDWATER EXPLORATION AND WELL DRILLING

December, 2019

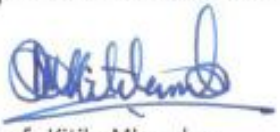
FOREWORD

Tanzania is one of the countries where the private sector is highly involved in the groundwater development industry. The National Water Policy (2002) highlights on the need to engage private sector in groundwater development by providing consultancy services in groundwater development and conducting water well drilling. This has in recent years led to mushrooming of private firms dealing with groundwater exploration services and drilling of water wells particularly in urban areas. Some of the firms engaged in providing exploration services and drilling of wells are unregistered.

To address this challenge, the Government developed Groundwater Regulations (Exploration and Drilling) Licensing of 2013 in order to enforce the Water Resources Management Act No 11 of 2009. This intervention enabled the Government, through the Basin Water Boards (BWBs), to monitor and control groundwater development activities in the country. However, it has been realized that most private firms are not following the best practices required for groundwater development, mainly due to lack of the professional norms and guidance. The Ministry has therefore prepared these guidelines, which cover both groundwater exploration and drilling activities largely to guide groundwater explorers, drillers, developers (clients), BWBs and other stakeholders engaged in the groundwater development industry.

The objective of these guidelines are to guide groundwater development activities in the country and ensure they are conducted by relevant experts with professional ethics. The guidelines are also a tool to enableeffective enforcement of the Water Resources Management Act, No 11 of 2009 and the Groundwater (Exploration and Drilling) Licensing Regulations, 2013. In this regard, preparation of these guidelines will fill the knowledge gap among stakeholders, and also enhance the ability of Basin Water Boards to monitor and control water well drilling activities in order to ensure sustainability of the groundwater resources.

The primary users of the guideline are the technical staff of the Ministry responsible for Water; Basin Water Boards; Local Government Authorities; other Regulatory Agencies; Drilling Agencies and Companies, Non-Governmental and International Organizations; Consultancy Firms; Monitoring groups and the General Public.



Prof. Kitila Mkumbo
PERMANENT SECRETARY

EXECUTIVE SUMMARY

Exploration and drilling activities in the country are mainly done by private firms, but in some cases government agencies also undertake them. It has been observed that, firms performing exploration and drilling activities in the country are not following the best practices required for groundwater development mainly due to lack of clear guide on how to undertake all ethical and technical procedures. Therefore, these guidelines have been prepared to fill the gap that existed.

The guidelines cover two major areas in groundwater development that are exploration and drilling. Before undertaking groundwater development, the client is advised to consult the respective Basin Water Board on suitability of the proposed area. In performing groundwater exploration for a specific area the guidelines explain the technical and ethical procedure that has to be followed. The procedure starts with literature review, hydrogeological survey, geophysical investigation and drilling of exploratory borehole which has to be tested in order to establish yield of the aquifer.

Groundwater drilling procedures as well as the technical capacity and requirements of a person conducting drilling activities have been explained in details. The guidelines outline the drilling procedures which comprise of general requirements, drilling operations, well development, pumping test, restoration of the environment and well commissioning for successful boreholes. Further, the guidelines explain on the well completion procedures and where to submit the completion reports.

In order to generate data and information, the guidelines provide forms to be filled by a driller at each stage of borehole development. The drillers are required to fill and submit to the BWBs/Ministry of Water. The forms include; well development and pumping test summary, water quality, lithological logging, step-draw down test, constant rate test form, recovery test and daily drillers log.

Dr. George Lugomela
Director of Water Resources

LIST OF ABBREVIATIONS

K	Hydraulic Conductivity
BWB	Basin Water Board
DEM	Digital Elevation Model
EC	Electrical Conductivity
NAWAPO	National Water Policy
NTU	Nephelometric Turbidity Unit
pH	A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline. The pH is equal to $-\log 10\ c$, where c is the hydrogen ion concentration in moles per litre.
Q [m^3/hr]	Abstraction rate per hour during pumping test
S	Storativity
s' =	Residual drawdown, obtained by subtracting the rest water level (measured before pumping started) from the measured water levels
Sy	Specific yield
t (min)	Time elapsed since the start of pumping test
T	Transmissivity
T (min)	Time in minutes during pumping test
TDS	**Total dissolved solids**, is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal sol) suspended form
t' (min)	Time in minutes since pumping stopped (recovery data)
UTM	Universal Transverse Mercator
VES	Vertical Electrical Sound

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DEFINITION OF TERMS

Aquifer – Is an underground saturated layer of water-bearing permeable rock, rock fractures or unconsolidated materials.

Borehole - is a narrow shaft bored in the ground for extraction of water

Draw down – the reduction in hydraulic head observed at a well in an aquifer, typically due to pumping a well as part of an aquifer test or well test.

Exploratory borehole – a small diameter borehole drilled in the earth for the purpose of gathering necessary data and information for a better understanding of the lithology in that area and its possible future production wells.

Hydraulic Conductivity (K) – a measure of the easy with which water, in the condition prevailing in the aquifer, can flow through the rock or soil.

Recharge – addition of water to the aquifer, usually from rainfall

Residual draw down – the distance the water level in a well has to rise during recovery after a pump test to reach the initial static water level.

Static Water Level (Swl) - is the level or elevation of water in a well under normal, undisturbed conditions

Storativity (S) – the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Transmissivity (T) – the rate at which water is transmitted (flows) through a unit width of an aquifer under a unit hydraulic gradient.

Water Well - is an excavation or structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifer.

1.0 INTRODUCTION

1.1 Background Information

The development and management of water resources in Tanzania is guided by the National Water Policy (NAWAPO 2002) and the Water Resources Management Act No 11 of 2009. The NAWAPO sets out future direction for the Water Sector in achieving sustainable development and utilization of the nation's water resources for social economic development and an increase in the availability of water supply and sanitation services. It provides key principles for water resources management and aims at developing a comprehensive framework for promoting optimal, sustainable and equitable development and use of water resources for the benefit of all Tanzanians. The policy is intended to synchronize and operationalize the water-related goals and aspirations expressed in several strategic documents, including the National Development Vision 2025, Sustainable Development Goals related to water sector and the National Five-Year Development Plan.

The National Water Policy stipulates the roles of private sector in groundwater development, especially in providing consultancy services and water well drilling. The policy further emphasizes on the review and dissemination of procedures and guidelines governing groundwater development and management, including groundwater exploration and drilling activities as well as operation of projects, which use groundwater resources.

The Water Resources Management Act No 11 of 2009 covers various aspects of water resources including the development and management of surface and groundwater resources. The Act also addresses issues of groundwater governance such as groundwater control areas, exploration and abstraction. It further requires anybody lawfully engaged in groundwater drilling or exploration activities to record and submit any relevant data on groundwater to the Basin Water Board. It also gives power to the Minister responsible for water to regulate the profession of groundwater drilling.

1.2 Objective of the Guidelines

These guidelines have been prepared to facilitate enforcement of Section 62 of the Water Resources Management Act, No. 11 of 2009. The main objective is to ensure that groundwater exploration and water well drilling activities are conducted in a professional manner.

1.3 Justification of the Guidelines

Water resources management in the country is faced with a number of challenges including depletion of water sources due to climate change and environmental degradation. Demand for water is also increasing concomitantly with increase in socioeconomic activities and population growth. Groundwater is becoming a more reliable source of water as surface water is depleting in both quantity and quality. Hence sustainable management and development of groundwater resource is inevitable.

Despite the presence and application of Groundwater (Exploration, and Drilling) Licensing Regulations since 2013, unprofessional drilling of water wells has continued to be a challenge in the country. This has resulted into poor practices in groundwater development, resulting into complaints to the Government for failing to regulate the industry. The main of poor practices has been found to be lack of the required knowledge among groundwater development actors.

To address this challenge, enforcement of the regulations and development of these guidelines to provide the required scientific norms and support the implementation of the Water Resources Management Act, 2009 is of ultimate importance. This will ensure compliance to standards and procedures by emerging – unprofessional – groundwater development actors, hence minimizing the possibilities of unsuccessful wells and high costs incurred in water well drilling. Moreover, the guidelines are required not only by Basin Water Boards to regulate the groundwater drilling activities in the country but also enable clients, who employ the drilling companies, to be able to monitor the drilling process and hence realize value for money.

1.4 Methodology of Developing the Guidelines

The guidelines were prepared in a participatory manner by involving different stakeholders. The document was drafted by a team of experts drawn from sector ministries and institutions, private sector and Non-Governmental Organizations. The process of developing the document involved preparation of Terms of Reference for the team of experts, literature review and preparation of the draft document. The draft document was thereafter shared to stakeholders for review and comments. The views of stakeholders were incorporated to the document and finally came up with these guidelines.

2.0 GROUNDWATER EXPLORATION

Groundwater exploration is the investigation of underground formations to understand the hydrologic cycle, the groundwater quantity and quality; and identify the nature, number and type of aquifers. During groundwater exploration, the Basin Water Board (BWB) will ensure that the siting of groundwater exploration and monitoring boreholes is undertaken by a qualified and experienced Hydro-geophysicist / Hydrogeologist. The Hydrogeologist will undertake the following tasks in siting boreholes:

A. Understand the scope and objectives of the assessment and the purpose of the borehole(s),

B. Identify or select the general area within the aquifer where boreholes are required,

C. Interpret the Digital Elevation Models (DEM), airborne magnetic data (if any), geological and topographical maps in and surrounding the area of interest to identify structural features (e.g. dykes, faults, fracture zones), weathering and other features (e.g. karst) of importance to groundwater occurrence,

D. Undertake a geological appraisal and select sites for the geophysical survey, and

E. Undertake a geophysical survey involving the application of proven and appropriate techniques. Such techniques will involve one or more of the following:

   i. Electrical resistivity
   ii. Electromagnetics
   iii. Magnetics
   iv. Gravity, and
   v. Seismics.

Groundwater exploration shall be done by a licensed person (an individual, a company, consulting firm/contractor, Government Agency or Non-Governmental Organization) as stipulated in the Groundwater (Exploration and Drilling) Licensing Regulations, 2013. The following should be observed in conducting groundwater exploration in mainland Tanzania.

A. Before conducting groundwater exploration at any area, the client is advised to consult the respective Basin Water Board for advice on appropriateness of the proposed area.

B. Any licensed groundwater exploration person, before embarking on groundwater exploration activities, shall inform the respective Basin Water Board.

C. Groundwater exploration shall be carried out in four stages, namely:

    i. Desk study/literature review

    ii. Hydrogeological survey or mapping

    iii. Geophysical method and

    iv. Exploratory Borehole

2.1 Desk Study/Literature Review

The objective of a desk study is to collect, scrutinize and evaluate the available and relevant meteorological, geographical, geological, morphological, biological (botanical), hydrological, hydrogeological and groundwater (quantity and quality) data. The tasks involve gathering available data/information by obtaining information related to: -

- Hydrology
- Topography/Geomorphology (Satellite Images, QDS, or DEMs)
- Biological/Land Cover
- Geological and hydrogeological
- Previous Borehole logs
- Previous Geophysical profiles of exploration and/or monitoring boreholes
- Previous pumping test results, and
- Groundwater quality data

2.2 Hydrogeological Survey/Mapping

This stage involves surface geological mapping with special emphasis on hydrogeological characteristics of surface configuration and weathered zones; and comprehensive well census in all wells within the study area. It essentially includes the determination of locations, water levels, borehole designs, well depths, open hole sizes, casing sizes, well yields, pump sizes, pump positions and the rate of pumping. The stage also involve the determination of the historical water level records, water quality, amount of abstraction from wells, and water use from each borehole.

2.3 Geophysical Exploration

After gathering enough data and information, the licensee will plan and execute appropriate geophysical exploration to locate a potential groundwater drilling site/point.

A. Geophysical exploration method should be done by using at least two geophysical methods; one of them must be Vertical Electrical Sounding (VES) method.

B. After completion of any exploration activity, the licensee shall prepare and submit a technical report to the client and send a copy to the respective Basin Water Board (for follow up and record keeping/advice/information).

2.4 Exploratory Borehole

An exploratory borehole is a relatively small diameter borehole drilled to ascertain the findings of both geological and geophysical groundwater surveys. The borehole is important in the determination of the extent of drilling the final borehole, in terms of depth and diameter, hence for the final investment plan for a particular well. Drilling of exploratory borehole is done by following normal drilling procedures as elucidated under part 3 of these guidelines.

2.5 Groundwater Exploration Report

The report shall include but not limited to the following chapters:

i. Introduction
ii. Physiography
   - Location (name, coordinates, altitude, sketch map and topographical map of the area),
   - Population,
   - Climate and Precipitation,
   - Topography, geomorphology and drainage, and
   - Vegetation and groundwater dependent ecosystems.

iii. Geology (Structural geology, map all relevant surfaces and subsurface features)
iv. Hydrogeology
   - Existing boreholes and possible source of recharge

- Description of aquifer – areal extent, compartmentalization
- Groundwater levels, groundwater quality, aquifer parameters, springs (including capture zones and groundwater / surface water interaction, if any)
- Groundwater flow regime and
- Groundwater resource units

v. Geophysical investigation
   - Outline of the investigations
   - Purpose, methodology and principles.

vi. Data interpretation procedure of each site with interpretation curves and geographical coordinates indicated, software used and its developer and the flow chart of the automatic inversion. Field raw data (to be provided as attachment).

vii. Conclusion and recommendation which includes recommended sites for drilling, methods of drilling, depth and diameter for exploratory borehole. (The minimum diameter for exploratory borehole shall be 4 inches).

A. If there is any existing borehole in the vicinity, the appropriate distance between the borehole and the recommended site shall be determined by the respective Basin Water Board based on the hydro-geological conditions of the aquifer(s) within that area.

B. A well should be located at sufficient distance away from sources of pollution to prevent contamination of the well through groundwater flow or seepage. Recommended minimum distances of a selected drilling site from a source of pollution shall be as follows:

S/N	Facility	Minimum Distance (metres)
1	Animal pen	30
2	Burial site (cemeteries)	50
3	Informal vehicle services	20

S/N	Facility	Minimum Distance (metres)
4	Communal dumping sites	100
5	Abattoir	50
6	Domestic dumping site	30
7	River and lake	20
8	Laundry/washing slab	20
9	Roads, air strip and railway line	20
10	Pit latrine	30
11	Dwelling house	10
12	Store for pesticides, fertilizers or fuel	100
13	Soak away and septic tanks	20

C. The sites for well drilling shall be marked by concrete permanent beacons with identification VES number.

3.0 GROUNDWATER DRILLING

Groundwater drilling shall be done by a licensed firm (company, consulting firm/contractor, Government Agency or Non-Governmental Organization) as per the Groundwater (Exploration and Drilling) Licensing Regulations of 2013.

The firm through a licensed driller is obliged to comply with the relevant laws and regulations and carry out the drilling activities in a professional manner observing general and technical requirements as described below:

3.1 General Requirements

A. All drill rigs used for well drilling shall be marked with the name, address and licence number of the owner in letters not less than 10 centimetres high,

B. All drill rigs used for well drilling shall bear a registration number in letters not less than 30 centimetres high and one (1) centimetre wide marked on a metal plate fixed on the near end of mast,

C. There should be a site Hydrogeologist or Hydrogeologist technician during the whole duration of groundwater borehole drilling,

D. Site location verification: the site geologist, the driller and the client should verify and agree on the recommended site as indicated in the Groundwater Exploration Report.

E. The site Hydrogeologist should verify the drilling methodology, rig setting, safety gears, specified tools and accessories before starting the drilling operation.

F. Each water well must be given an identification number, its geographical position on the ground clearly indicated on a sketch map or in the reports, owners name and altitude in meters above mean sea level taken from the ground at the well point.

G. Before starting the drilling operations, the licensed driller should accurately fill in Form No. 1 (General Information) annexed to this Guideline.

H. The licensed driller, upon completion of the drilling operation, shall request a well identification number from the Director of Water Resources.

I. Pump should be positioned in a pump chamber made of plain casing not in screens.

3.2 Drilling Operations

A. The drilling operations should be conducted by a licensed driller possessing a Driller License granted by the Director of Water Resources and supervised by qualified hydrogeological technician with a minimum qualification of a diploma in hydrogeology.

B. During drilling, the site Hydrogeologist should properly collect drilling cuttings that will be a representative of depth intervals of 2.0m. Where there is change in geological formation, in between the said interval, it should be noted down.

C. Drilling cuttings should be kept in sample boxes for lithological logging at the site and fill in Form No. 6. However, a small portion (250 g) of each sample must be placed in sample bag, properly labeled and sent to the respective Basin Water Board for storage and future use.

D. Borehole geophysical logging (SP, Gamma, Caliper, Temperature, pH, Conductivity) has to be carried out for all wells except for wells intended for individual/personal domestic water supply. All wells logging information should be sent to the respective Basin Water Board.

E. The site Hydrogeologist should, where applicable, collect water samples for every water strike and perform the preliminary in-situ water quality analysis using Water Quality Test Kit to determine colour, pH, salinity, taste, temperature, turbidity and electrical conductivity.

F. If the upper section of a well is in an unstable rock formation, temporary or permanent casing must be installed.

G. The water well should be properly installed with plain and screen casings and plugged according to the design recommended in the Groundwater Exploration Report. No open water well will be allowed/ permitted.

H. All casings and screens to be installed in a production water well have to be properly chosen to prevent chemical and/or galvanic corrosion and thus guarantee structural integrity of the well, long life and good water quality.

I. Construction of the well (installation of screen and casing of good quality) should be followed by well graded, rounded and cleaned silicate gravel packing with grain size of 2-5 mm.

J. The selection of gravel pack should be done after carrying out sieve analysis of aquifer material, to ensure the well efficiency is not below the international standard. The annular space should be at least 5cm to fulfill the above condition.

K. The drilling cuttings should not be placed in the well as gravel pack.

L. Water well should be constructed in a manner that would not allow surface water to enter into the well.

M. During the drilling operations the driller should carefully fill in Form No. 3 (Drilling Operations) appended to these guidelines.

3.3 Well Development

A. After completion of drilling and construction of the water well, well development by air lift, surging, over-pumping or any other technically acceptable method must be carried out until the water becomes clear.

B. Backfill should be done at least 10 meters above the gravel pack.

C. A proper sanitary seal of 1m (or intermediate seals) must be placed to preserve, conserve and protect groundwater resources quality and reservoir pressure potential. This also prevents contaminated water from entering and mix with aquifer waters.

3.4 Pumping Test

Pumping test serves two primary objectives. The first is an assessment of the production capacity (yield potential) of the borehole and the second is to address the productivity of the groundwater resource. Three types of borehole tests are performed separately and sequentially to meet these objectives. These are identified as: (1) Step test (2) the constant discharge test and (3) the recovery test. Factors determining which of these tests must be performed include: (1) the potential yields of the borehole and (2) the intended rate and duration of pumping.

The appropriate time interval for water level measurements varies in frequency during pumping test whereby water levels are measures at small time intervals at the beginning of a test, when water-levels are changing rapidly, and progressively the interval increases at a logarithmic scale towards the end of the test, when water level change is slow. Though specified intervals need not be followed rigidly, each logarithmic cycle should contain at least 10 data points spread through the

cycle. The discharge will be measured at each logarithmic cycle of the water level measurements.

The following should be observed during pumping test:

A. Pumping test should be carried out after well drilling, starting with step pumping test followed by constant pumping test and recovery test.

B. Step pumping test should be carried out for at least three steps of at least two hours each. Five steps are required for public supply wells and for wells with high yields.

C. Constant rate pumping test should be carried out for at least 24 hours for individual wells intended for domestic supply depending on the yield of the well. The test should be conducted for 72 hours for boreholes intended for Commercial or Municipal/Public water supply. The constant pumping test should immediately be followed by recovery test until 90% of initial Static Water Level (SWL) is attained. It should be noted that, if the water level stabilizes before 24 hours after constant pumping test, the test should be repeated using a higher capacity pump and/or for a longer duration than before.

D. After the completion of pumping test, water level recovery will be monitored with almost the same frequency used during the constant pumping test. The measurements will commence immediately upon pump shut down and continue for the same duration as the constant phase until the water levels have reached 90 percent of the initial, pre-pumping static water level.

E. The site Hydro-geologist should fill in the respective Form (Form No. 7-9) at each stage.

F. The pumping test must be witnessed by the client or his/her representative.

G. Evaluation of pumping test results shall be used to determine safe yield, aquifer and well parameters such as Specific yield (Sy), Storativity (S), Transmissivity (T), well efficiency, safe yield, storage coefficient, and Hydraulic Conductivity (K)

H. Water samples must be collected at the last hour of pumping test for physical, biological and chemical analysis. The analysis should be done by a recognized and qualified laboratory which will fill in Form No. 10**.**

I. For domestic water supply boreholes, disinfection must be undertaken after well installations and pumping test has been completed to ensure that the water will be safe for human consumption.

3.5 Restoration of the Environment

A. After completion of the drilling activities the site Hydro-geologist and the driller should ensure the environment at the drilling site is restored to its original state.

B. Any well that will be dry or with poor water quality must be abandoned.

C. The abandoned well should be properly and perfectly back filled to protect ground water contamination.

D. Report must be submitted to the client and Basin Water Board.

3.6 Well Commissioning

After all the drilling operations have been done; the contractor should hand over the well to the Client. The handing over should include submission of all records properly compiled in a Well Completion Report to:

(a) Well owner

(b) Basin Water Board

(c) Water Resources Division

Borehole drilling Supervisor will prepare borehole completion report that will include maps, borehole geological logs of the lithology, design, number of plain and screen casings, casing materials, development, test pumping data analysis and results, the values of hydraulic parameters such as Transmissivity (T), Hydraulic Conductivity (K) and Storativity (S), well efficiency, safe yield, pump position, water quality assessment, aquifer assessment and classification, protection zones and the delineation of potential target areas, as applicable.

A construction log of the borehole indicating drilling and casing diameters, depth, location, number and size of inserted formation stabilizers, lithological and geophysical logging information, grouting and completion details

A hydrogeological log of features important to groundwater occurrence, including weathering depth, fracturing, wad, fissures, cavities, karst and information concerning depth of water strikes and blowing yield, lost circulation and signature for measured quantities agreed on site with the driller.

The Hydrogeologist will ensure that the appointed contractor has signed the relevant technical specifications.

For Government Projects

Exploratory, production/monitoring boreholes must be drilled to the required technical specifications by an experienced contractor. The Hydrogeologist will ensure that the appointed contractor understands and signs the relevant technical specifications.

Field supervision should be undertaken under the supervision of the Hydrogeological Technician appointed by a senior hydrogeologist to ensure that the boreholes are drilled:

i. In the correct location

ii. To the required depth, and

iii. According to the applicable specifications.

Field operations should be undertaken under the supervision of the Hydrogeologist appointed by the Basin Water Officer to ensure that the boreholes are tested in accordance with the required specifications. The supervisor will sign for measured quantities agreed on site with the testing contractor.

Water samples should be collected from newly-drilled exploratory/monitoring boreholes according to the protocols outlined in form No 5 in order to provide data to supplement that collected during hydro-census. This data is used to determine prevailing groundwater quality across the aquifer(s) within the catchment.

ANNEXES: WELL COMPLETION RECORD FORMS

Form No. 1: General Information

<table>
<tr><td colspan="3">Drilling Clearance Permit Date:</td></tr>
<tr><td colspan="2">Borehole identification No.</td><td>Use:

i. Community
ii. Household/Private
iii. Health Facility
iv. Education Facility
v. Company Premises
vi. Test Well
vii. Other (Specify)…….</td></tr>
<tr><td colspan="2">Location

Village/Street:

District:

Region:Basin:</td><td>Owner Name:</td></tr>
<tr><td>Coordinates/GPS

Reference (Top sheet No.):</td><td>Grid Ref (UTM):

Long. E:

Lat. N:</td><td>Owner Address:</td></tr>
<tr><td colspan="3">Financing Programme/Project/Private:</td></tr>
<tr><td colspan="2">Name of Drilling Company:

Address</td><td>Name of Driller:

Driller’s License No:</td></tr>
</table>

Sketch Map:

Form No. 2: Drilling Operation

Start Date:		Completion Date:
Total Depth: (m)		Main Water Strike(s): (m)
	Drilling Method(s): i. Hand Drilled ii. Percussion iii. Mud Rotary iv. Air Rotary v. Combination (details):……	

		Rig No. Rig make:		Compressor make:	
From (m)	To (m)		Drilling Diameter (mm/inch)	Method	Penetration Rate(m/hr)

Form No. 3: Casing and Well Completion

Casing Material: Casing Joints: Threaded/Glue and socket			Screen Open Area (%) …… Bottom Plug: Yes/No
Casing			
From (m)	To (m)	Diameter mm/inch	Type

Screen				
From (m)	To (m)	Diameter mm/inch	Type	Slot Size
Gravel Natural/Artificial				
From (m)	To (m)	Grain size	Volume used	
Backfill and Sanitary Seal				

From (m)	To (m)	Diameter mm/inch	Type and details Backfill/Sanitary seal	
Alignment and Verticality Test Remarks:				
Well head and Platform				
Well Cap: Yes/No				
Comments:				

Form No. 4: Well Development and Pumping Test Summary

Development:	Pumping Test
i. Air lift ii. Over pumping iii. Surging iv. Backwashing v. Jetting Duration (hr):……	i. Air lift capacity evaluation ii. Constant Rare Test (CRT) iii. Step Drawdown Test Duration (hr):…… Discharge: …… Dynamic water level (m)……. Drawdown (m)…… Recommended pump position for production (m) ..... Recommended pump capacity (m^3/hr) .....

Form No. 5: Water Quality Summary

Sample taken: Yes/No Date:……	Chemical Quality: pH: Laboratory:…….. (for more parameters see separate sheet)
Field Parameters: i. Clear/Turbid ii. Colour:…….. iii. Taste:…….. iv. Odour:…….. v. Turbidity:……..NTU vi. Temp: ……..^{o}C vii. TDS ……..mg/l viii. EC……..µS-cm ix. pH……..	Bacteriological Quality: Faecal coliform:…… cfu per 100ml Laboratory:……
Comments:	

Form No. 6: Lithological Logging

<table>
<tr><td colspan="3">Borehole Reference No:</td></tr>
<tr><td colspan="2">Location:</td><td>Owner Name:</td></tr>
<tr><td>Coordinates/

GPS Reference:</td><td>Grid Ref:

Long. E: Lat. N:</td><td>Owner Address:</td></tr>
<tr><td colspan="3">Financing Program/Project/Private:</td></tr>
<tr><td colspan="2">Name of Drilling Company:</td><td>Name of Driller:

Driller’s License No:</td></tr>
<tr><td colspan="3">Borehole Logged by:</td></tr>
</table>

Depth (m)	Description	Colour	Grain Size	Texture	Degree of weathering	Sorting	Roundness	Stratigraphic unit (if known)	Remarks (e.g. consolidation, porosity, mineralogy, structures and features drilling, water)	Penetration rate(min./m)	Discharge

NOTE: Data to be recorded at a minimum of 2 m intervals

Description:

Characteristics to be evaluated and assessed during logging of drilling samples

i. Colour

In order to aid objectivity, a definitive colour chart e.g. Munsel ® Colour Chart may be used for classification. Munsel® colours are referred to by two or three words such as brownish yellow, or light bluish grey and a number.

ii. Grain Size

The visible grains can be compared with a comparator standard diagram, a grain sample card or the naked eye. A hand lens or microscope may be required to see grains which are not visible to the naked eye.

iii. Texture

Is the sample compact and dense, or light and friable? Is it granular or plastic? Can it be moulded or rolled? Can the fragment be scratched with a steel blade or fingermail Moh's Scale of Hardness is an indicator.

iv. Degree of weathering

The extent of weathering of rocks affects the availability of groundwater. Essentially, the weathering profile comprises the three basic units of soil, weathered rock and fresh rock. Rock weathering is described in terms of distribution and relative proportions of fresh and discoloured rock, decomposed and disintegrated rock.

v. Degree of Sorting

Sorting describes the variability of attributes such as rounding and grain size. In well-sorted materials the component grains are mostly of a similar size, shape and roundness. Sorting can be classified as very well sorted, moderately sorted, poorly sorted and very poorly sorted as set out in the grain size and sorting chart.

vi. Roundness

Grains are usually classified as angular; sub-angular, sub-rounded, rounded or well rounded as shown in the chart.

vii. Formation/Stratigraphic unit (if known – add codes based on the local stratigraphic nomenclature)

An experienced geologist or driller may be able to identify stratiographic units. However it is important to distinguish between interpretation and observation.

Form No. 7: Step Drawdown Test (for mechanised borehole supply)

<table>
<tr><td colspan="3">borehole number……Client……</td><td colspan="3">Supervisor……</td></tr>
<tr><td colspan="3">Duration (minutes)……</td><td colspan="3">Drilled depth (m)…… Installation depth: (m)……</td></tr>
<tr><td colspan="3">Step test start date (ccyy-mm-dd)……</td><td colspan="3"></td></tr>
<tr><td colspan="3">Static water level (DDDD.dd)……</td><td colspan="3">Wl after insertion of pump (m)</td></tr>
<tr><td colspan="3">Step test start time (hh:mm)……</td><td colspan="3"></td></tr>
<tr><td colspan="3">Water Level status: □Drawdown □Recovery</td><td colspan="3">Pump type:……Pump position (m)……</td></tr>
<tr><td colspan="3">Abstraction measurement type: □Abstraction readings (l/s)

□Abstraction quantities (m³)</td><td colspan="3">Final water level (m):……
Weather:……</td></tr>
<tr><td rowspan="2">Step No 1</td><td>Step test start time (hh:mm)</td><td>Time since pumping started (min)</td><td colspan="2">Water level measurement type</td><td>Abstraction measurement (m³)</td></tr>
<tr><td></td><td></td><td>Actual water level (m)</td><td>Drawdown (m)</td><td></td></tr>
</table>

		0			
		1			
		2			
		3			
		4			
		5			
		6			
		7			
		8			
		9			
		10			
		15			
		20			
		25			
		30			
		35			
		40			
		45			
		50			
		55			
		60			

Form No. 8: Constant Rate Test

<table>
<tr><td rowspan="2">Borehole No:……

Date:……</td><td></td><td rowspan="2">Client:……

Tested by
:……</td><td>□Observation well</td><td rowspan="2">District

Weather:</td><td>……</td></tr>
<tr><td>Start time……</td><td>□Pumping well</td><td>……</td></tr>
<tr><td colspan="6">Plain casing dia(m):……Screen length (m): …… Aquifer thickness (m):…… Annulus dia(m):……</td></tr>
<tr><td colspan="6">Depth after inserting the pump:…… Distance to pumping well:……m Discharge measuring device:……</td></tr>
<tr><td rowspan="2">Aquifer type:
……

Depth of open Hole:
(m)……</td><td>Pump type……</td><td rowspan="2">Depth of pump in (m):……

Diameter of open hole (inch)……</td><td colspan="3"></td></tr>
<tr><td>Drilled depth:……</td><td colspan="3">End time:……</td></tr>
<tr><td colspan="6">Static Water Level (m) prior to pumping:…… Water level after insertion of pump(m):…… Water level (m) at end of pumping:……</td></tr>
</table>

Type of Test	□**Constant Discharge Test** □**Recovery**						
Time (hours)	Time since pumping started (t) Min.	Water level (m)		Draw down (m)	Discharge rate Q (m^3/hr)	Pump Speed (RPM)	Co co pH
		Actual water level (m)	Corrected wl (m)				
	0						
	0.5						
	1						
	1.5						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	15						
	20						

	25						
	30						
	35						
	40						
	45						
	50						
	55						
1hr	60						
	70						
	80						
	90						
	100						
2hrs	120						
	140						
	160						
	180						
	200						
	220						
4hrs	240						
	270						
	300						
	330						
6hrs	360						
	420						
	480						
	540						

	600						
	660						
	720						
	780						
	840						
15hrs	900						
	1000						
	1100						
	1200						
	1300						
24hrs	1440						

Form No. 9: Recovery Test

Borehole No:……..		Client:……..	□Observation well	District	……
Date:…….. ….	Start time……	Tested by :……..	□Pumping well	Weather :	…… …
Plain casing dia(m):……Screen length (m): …….. Aquifer thickness (m):… Annulus dia(m):……..					
Depth after inserting the pump:…….. Distance to pumping well:……..m Discharg device:……..					
Aquifer type: ……..		Pump type……..	Depth of pump in (m):……..		
Depth of open Hole: (m)……..		Drilled depth:……..	Diameter of open hole (inch)……..		End time:

Static Water Level (m) prior to pumping:…… Water level after insertion of pump(m):…… (m) at end of pumping:……							
Type of Test	□**Constant Discharge Test** □**Recovery**						
Time (hours)	Time since pumping started (t') Min.	Water level rise (m)		Residual drawdown s	t/t'	S'	Comm colou pH, T
		Actual water level (m)	Corrected wl (m)				
	0						
	0.5						
	1						
	1.5						
	2						
	3						
	4						
	5						
	6						

	7						
	8						
	9						
	10						
	11						
	12						
	15						
	20						
	25						
	30						
	35						
	40						
	45						
	50						
	55						
1hr	60						
	70						
	80						
	90						
	100						
2hrs	120						
	140						
	160						
	180						
	200						
	220						

4hrs	240						
	270						
	300						
	330						
6hrs	360						
	420						
	480						
	540						
	600						
	660						
	720						
	780						
	840						
15hrs	900						
	1000						
	1100						
	1200						
	1300						
24hrs	1440						

Form No. 10: Water Quality Analysis

Borehole Reference No:			Maximum Permitted Level According to National Standards / Guidelines or WHO Guidelines (WHO 2008)
Constituents	Unit	Concentration	
PHYSICAL			
Colour		Mg/l Pt (TCU)	
Odour			
Taste			
Temperature	Celsius		
Turbidity	NTU		
Electrical Conductivity	µS/cm		
CHEMICAL			
Chloride (Cl-)	mg/l		
Sulphate (SO_4^{2-})	mg/l		
Nitrate (NO_3^-)	mg/l		
Fluoride (F^-)	mg/l		
Sodium (Na^+)	mg/l		

Potassium ($^{+}$)	mg/l		
Calcium (Ca^{2+})	mg/l		
Magnesium (Mg^{2+})	mg/l		
Arsenic (As)	µg/l		
Iron (Fe)	mg/l		
Manganese (Mn)	mg/l		
Nitrite (NO^{2-})	mg/l		
pH			
Total Dissolved Solids	mg/l		
Microbiological			
Thermo-torerant Coliform (E. Coli)	Count/100ml		
Fecal Coliform	Count/100ml		
Total Coliform Count	Count/100ml		

Form No. 10 Daily Driller's log

Drilling data							
Owner ……. …….	Location…….. ……..		Contractor…….. ……..			Report no…….. ……	
Date…….. …….	Driller…….. ……..	Start date……..		Hydrogeologist…….. …….			
Bit type and size…….. …….		Drilling fluid type…….. ……..				Rig type…….. ……	
Drilling method …….. ……		No of personnel at site…….. …….				Finish date…….. …….	
Borehole data							
Borehole diameter……from…….. …..to……..		Depth of surface casing…….. ……				…….. ……..	
Struck depths…….. ……..		Completion diameter…….. …….		…….. ……..		…….. …….	
Bit record					**Mud record**	**Geological data**		
Time	Depth	Penetration rate	F&D	DB	Mud/ water	Depth From-to	Well log description	Color

Well/bore construction	**Gravel pack**	**Pumping test**	**Borehole sealing**
Bore depth (m)……	Gravel type……	Static water level (m)……	Depth sealed……
Casing depth (m)……	Average size……	Pumping rate (m^3)……	Sealing material……

<table>
<tr><td colspan="3">Casing diameter (m)…….</td><td colspan="2">Inserted from ……..to…….. …..</td><td colspan="2">Draw down…….. …….. Pump capacity…….. ……..</td><td>Total (m^3)…….. ……..</td></tr>
<tr><td colspan="3">Material …….. ……..</td><td colspan="2">Total (m^3)…….. ……..</td><td colspan="2">Duration of pumping (hrs)……..</td><td>…….. ……..</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2">Pump type…….. ……..</td><td></td></tr>
<tr><td colspan="3">Screens</td><td colspan="2">Borehole development</td><td colspan="2">Finish of section uncased</td><td></td></tr>
<tr><td colspan="3">Diameter…….. ……..</td><td colspan="2">Dev. Method…….. ……..</td><td colspan="2">Hole uncased…….. ……..</td><td rowspan="5"></td></tr>
<tr><td colspan="2">Intervals</td><td rowspan="2">Slot size/type</td><td colspan="2">Dev. Hours…….. ……..</td><td colspan="2">Backfilled to…….. ……..</td></tr>
<tr><td>From</td><td>To</td><td colspan="2">Water quality</td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Observation on site…….. ……..</td><td colspan="2">Site Map</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Sample taken…….. ……..</td><td colspan="2"></td></tr>
</table>

			Analysed by……..……		
			Remarks		