Small Scale Irrigation Development

Level II

MODEL TTLM

Learning Guide #20

Unit of Competence: Understand and Assess Groundwater

Module Title: Understanding and Assessing Groundwater

LG Code: AGR SSI1 M02 LO1-11

TTLM Code: AGR SSI1 02TTLM 1218V_2

Nominal Duration: 30 Hours

Instruction Sheet	Learning Outcome 1-2

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Understand groundwater hydrology
- Assessment of groundwater

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- ✓ Identify and recognize different components of hydrologic cycle
- ✓ Identify occurrence and source of groundwater
- ✓ Identify different water bearing strata (aquifers)
- ✓ Gather and apply groundwater information
- ✓ Collect groundwater peiziometric data

Learning Activities

1. **Read the specific objectives of this Learning Guide.**
2. **Read the information written in the "Information Sheet"**
3. **Accomplish the "Self-check".**
4. **If you earned a satisfactory evaluation proceed to the next "Information Sheet". However, if your rating is unsatisfactory, see your facilitator for further instructions or go back to Learning Activity.**
5. **Submit your accomplished Self-check. This will form part of your training portfolio.**
6. **Read and Practice "Operation Sheets".**
7. **If you think you are ready proceed to "Job Sheet".**
8. **Request you facilitator to observe your demonstration of the exercises and give you feedback.**

INFORMATION SHEET#1	**LO#1: Understand groundwater hydrology**

INTRODUCTION :

All water beneath the land surface is referred to as underground water (or subsurface water). The equivalent term for water on the land surface is surface water. Underground water occurs in two different zones.

- ❖ One zone, which occurs immediately below the land surface in most areas, contains both water and air and is referred to as the unsaturated zone.
- ❖ The second zone is almost invariably underlain by a zone in which all interconnected openings are full of water. This zone is referred to as the saturated zone.

Water in the saturated zone is the only underground water that is available to supply wells and springs and is the only water to which the name ground water is correctly applied. Recharge of the saturated zone occurs by percolation of water from the land surface through the unsaturated zone. The unsaturated zone is, therefore, of great importance to ground-water hydrology. This zone may be divided usefully into three parts:

- ➢ the soil zone,
- ➢ the intermediate zone, and
- ➢ the upper part of the capillary fringe.

The soil zone extends from the land surface to a maximum depth of a meter or two and is the zone that supports plant growth. It is criss crossed by living roots, by voids left by decayed roots of earlier vegetation, and by animal and worm burrows.

1.1. Identifying and recognizing Diffèrent components of hydrologic cycle

Hydrologic cycle

Water in our planet is available in the atmosphere, the oceans, on land and within the soil and fractured rock of the earth's crust Water molecules from one location to another are driven by the solar energy. Moisture circulates from the earth into the atmosphere through evaporation and then back into the earth as precipitation. In going through this process, called the Hydrologic Cycle (Figure 1), water is conserved – that is, it is neither created nor destroyed.

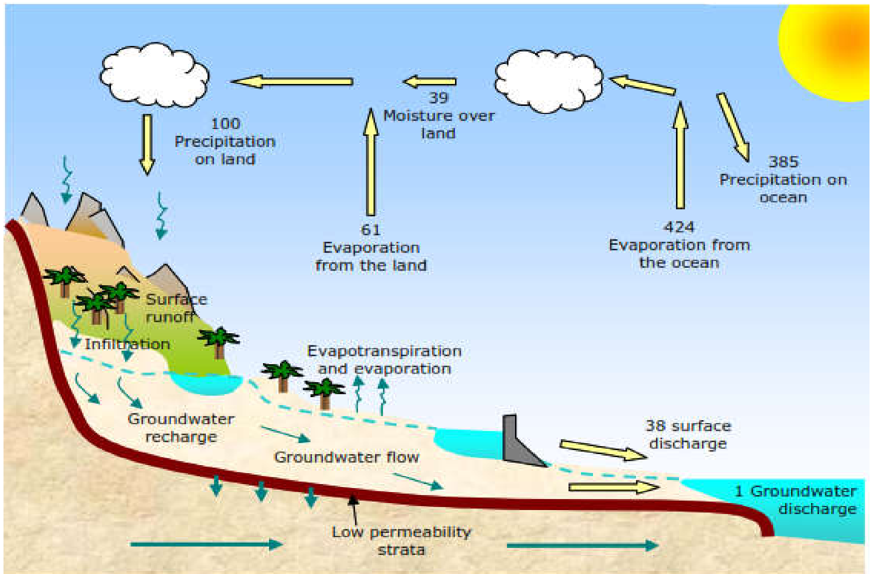


Figure_1. Schematic representation of the hydrologic cycle

The above figure is a schematic representation of the hydrologic cycle. A convenient starting point to describe the cycle is in the oceans. Water in the oceans evaporates due to the heat energy provided by solar radiation. Water vapor moves upwards and forms clouds. While much of the clouds condense and fall back to the oceans as rains, a part of the clouds is driven to the land areas by winds. There they condense and precipitate on to the landmass as rain, snow, hail, etc. A part of the precipitation may evaporate back to the atmosphere even while falling. Another part may be intercepted by vegetation, structures and other such surface modification from which it may be either evaporated back to atmosphere or move down to the ground surface.

A portion of the water that reaches the ground enters the earth's surface through ***infiltration*** enhance the moisture content of the soil and reach the ground water body. Vegetation sends a portion of the water from under the ground surface back to the atmosphere through the process of ***transpiration***. The precipitation reaching the ground surface after meeting the needs of infiltration and evaporation moves down the natural slope over the surface and through a network of gullies, streams and rivers to reach the ocean. The ground water may come to the surface through springs and other outlet after spending a considerable longer time than the surface flow. The portion of the precipitation by a variety of paths above and below the surface of the earth reaches the stream channel is called ***runoff*** once it enters a stream channel, runoff becomes ***stream flow***

Further, it is a continuous re-circulating cycle in the sense that there is neither a beginning nor an end or a pause. Each part of the hydrologic cycle involves one or more of the following aspects:

(i) Transportation of water

(ii) Temporary storage, and
(iii) Change of state

Components of hydrology cycle:

Water is most commonly found in its liquid form, in rivers, oceans, streams, and in the earth. The sun's rays constantly warm the water found in these places and, whether through this heat or through man-made means, the water particles gain energy and spread, turning the water from a liquid into a vapor through evaporation. The water vapor, thus becoming less dense, rises with the warm air into the sky where it sticks to other water particles to form clouds.

Evaporation – is frequently used as a catch-all term to refer to the process of water turning to water vapor, however there is another distinct term for the evaporation of water from a plant's leaves.

Evapotranspiration – makes up a large portion of the water in the planet's atmosphere due to the sheer surface area of the globe covered by flora. The majority of water in the atmosphere comes from lakes and oceans – around ninety per cent – but in terms of land-based water, evapotranspiration is an important player.

Sublimation – as the process is called, results from when pressure and humidity are low as noted above. It is not only liquid water that can evaporate to become water vapor, but ice and snow, too. Due to lower air pressure, less energy is required to sublimate the ice into vapor. Other factors which can aid in sublimation are high winds and strong sunlight, which is why mountain ice is a prime candidate for sublimation, while ground ice sublimation is not so common. A good, visible example of sublimation is dry ice, which emits a thick layer of water vapor due to its lower energy requirement.

The further above sea level one gets, the cooler the air. When water vapor reaches this plane, it cools significantly and clumps together. So stuck together, this newly formed cloud is subject to the movement of the wind and the changes in the air pressure, which is what moves the water around the planet. There are a couple of things that can happen to the vapor in this state.

Precipitation/Rainfall – refers to vapor that cools to any temperature above freezing point (zero degrees centigrade) will condense, becoming droplets of liquid water. These droplets form when the water vapor condenses around particles and other matter that rises up with the water during evaporation, giving a nucleus to the water droplet so that it can clump together. Once a number of this tiny, particle based droplets form, they collide and clump together as larger droplets. At a certain point, the droplet will become big enough that its mass will be subject to the force of gravity at a rate faster than the force of the updraft in the air around it. At this point, the water falls to earth.

Snow – refers to frozen water falling from the sky. When it is particularly cold or the air pressure is exceptionally low, these water droplets will crystallize before falling.

Sleet – is a bitterly cold, half-frozen slush. This third state occurs when the conditions are not quite cold enough to keep the crystals frozen and the water either does not freeze fully or if precipitation occurs in particularly cold conditions, or conditions in which the air pressure is very low, then these water droplets can quite often crystallize and freeze. This causes the water to fall as solid ice, known melts somewhat in the process.

When water falls to earth, it quite often ends up on tarmac or over man-made surfaces where it quickly evaporates again.

Infiltration – is water that doesn't evaporate after precipitation and falls into soil and other absorbent surfaces. The water moves throughout the soil, saturating it.

Groundwater Storage – is water that has not precipitated or run off into streams or rivers, but instead moves deep underground forming pools known as "groundwater storage".. In groundwater storage, water joins up in the soil and forms pools of saturated soil instead of escaping the soil. These pools are called "aquifers".

Springs – occur when an aquifer becomes oversaturated, and the excess water leaks out of the soil onto the surface. Most commonly, springs will emerge from cracks in rocks and holes in the ground. Sometimes, if conditions are particularly volcanic, the spring will heat up and form "hot springs".

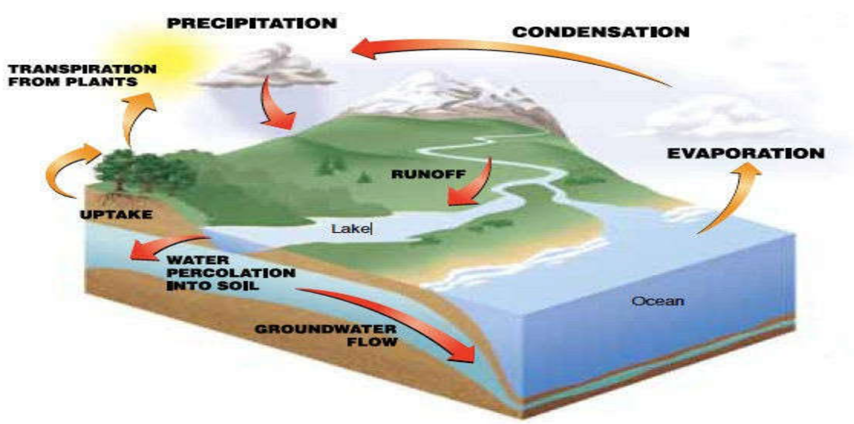
Runoff – After heavy rainfall has saturated the soil it will cease to absorb water and additional rainfall, as well as melted snow and ice, will simply flow off of the surface. The flow follows gravity down hills, mountains, and other inclines to form streams and join rivers. This is known as "runoff", and it is the principle way in which water moves along the Earth's surface. The rivers and streams are pulled by gravity until they pool together to form lakes and oceans.

Stream flow – is the direction the runoff takes to form a stream and it is this flow which dictates the river's currents depending on how close they are to the ocean. Because ice and snow make up a large portion of the water involved in runoff, heat waves are a principle cause of flooding as the water stored on the surface is suddenly released into runoff flow. In particular, a warm spring following a cold winter can result in quite spectacular flood, as a large volume of water gets stored in ice and snow only to quickly melt and form new streams.

Ice Caps – occur when a large volume of snow falls and is not evaporated or sublimated, the ice compacts under its own weight to form these caps. Ice caps, glaciers, and ice sheets contain a huge amount of water, and those found in the polar regions of the planet are the largest stores of ice found in the world. As the atmosphere warms up slowly, more and more of this ice melts and evaporates, releasing more water into the hydrologic cycle. It is this process which causes rises in the ocean levels.

1.2. Occurrence and source of groundwater

Hydrologists use the term *groundwater* to represent water in the zone of saturation. Practically, all groundwater constitutes as a part of the *hydrological cycle.* However, a little amount of water may enter the cycle from other sources (e.g., magmatic water). The *hydrological cycle* is the series of transformations that occur in the circulation of water from the atmosphere to the surface and into the subsurface regions of the earth, and then back from the surface to the atmosphere. Precipitation becomes surface water, soil moisture, and groundwater. Groundwater circulates back to the surface, and from the surface all water returns to the atmosphere through evaporation and transpiration.



Figuire_2 : Occurrence and source of groundwater

The main source of groundwater is infiltration. The infiltrated water after meeting the soil moisture deficiency percolates deeply and becomes groundwater. This process is called ***recharge***. The formation below the earth's surface is divided into two zones by an irregular surface called the *water table*. At all points on the water table, the pressure is atmospheric. The zone between the ground surface and the water table is called the *unsaturated zone* or the *vadose zone*. In the zone below the water table all the soil pores are completely filled with water and hence it is called the *zone of saturation* or the *phreatic zone*.

What happens to the water that is infiltrated at the surface of the unsaturated soil during application of water from above? It moves downward due to gravity through inter connected pores that are filled with water. With increasing water content, more pores fill, and the rate of downward movement of water increases.

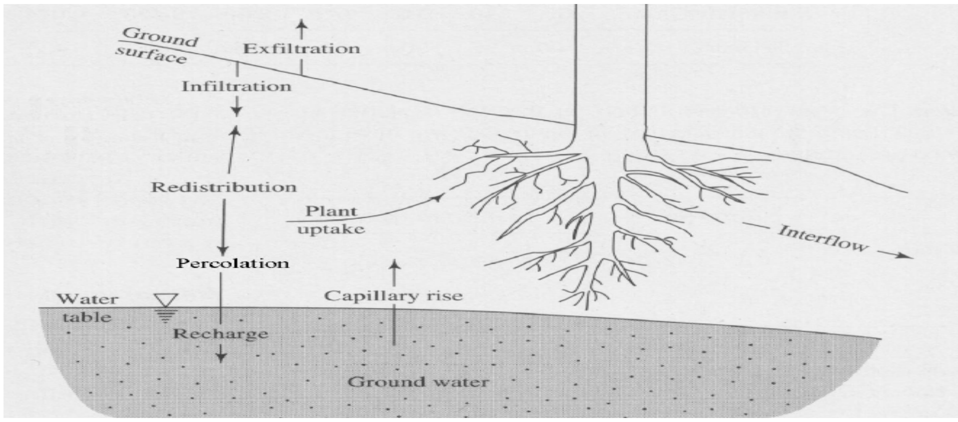


Figure_3: Subsurface water movement

The term '*groundwater flow'* is used generally to describe the flow of water in the saturated portion of soil or fractured rock. The water that infiltrates through the unsaturated soil layers and move vertically ultimately reaches the saturated zone and raises the water table. Since it increases the quantity of water in the saturated zone, it is also termed as 'recharge' of the groundwater.

Groundwater system is the zone in the earth's crust where the open space in the rock is completely filled with groundwater at a pressure greater than atmospheric. Groundwater stretches out below the groundwater table. Groundwater table, which is the top most part of groundwater, may be located near or even at land surface and not fixed meaning it fluctuate seasonally.

Two zones can be distinguished in which water occurs in the ground:

a) The unsaturated zone/ Zone of aeration
b) The saturated zone

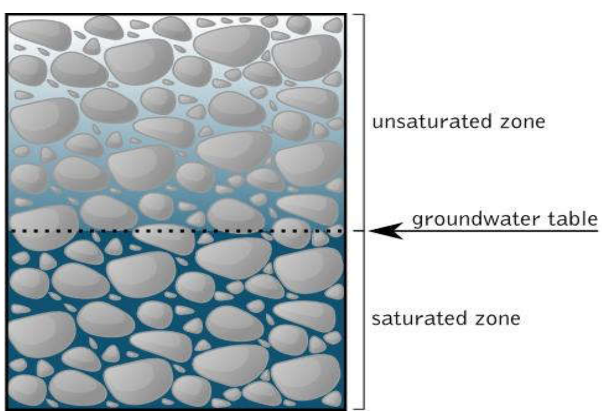


Figure_4. Schematic representation of subsurface water in the soil

a. Unsaturated Zone (Zone of aeration):

This is also known as *zone of aeration*. In this zone the soil pores are only partially saturated with water. The space between the land surface and the water table marks the extent of this zone. Further, the zone of aeration has three sub zones: *soil water zone*, *capillary fringe* and *intermediate zone*.

The soil water zone lies close to the ground surface in the major root band of the vegetation from which the water is lost to the atmosphere by evapotranspiration. Capillary fringe on the other hand hold water by capillary action. This zone extends from the water table upwards to the limit of the capillary rise. The intermediate zone lies between the soil water zone and the capillary fringe.

The thickness of the zone of aeration and its constituent sub-zones depend upon the soil texture and moisture content and vary from region to region. The soil moisture in the zone of aeration is of importance in agricultural practice and irrigation engineering. This part is however concerned only with the saturated zone.

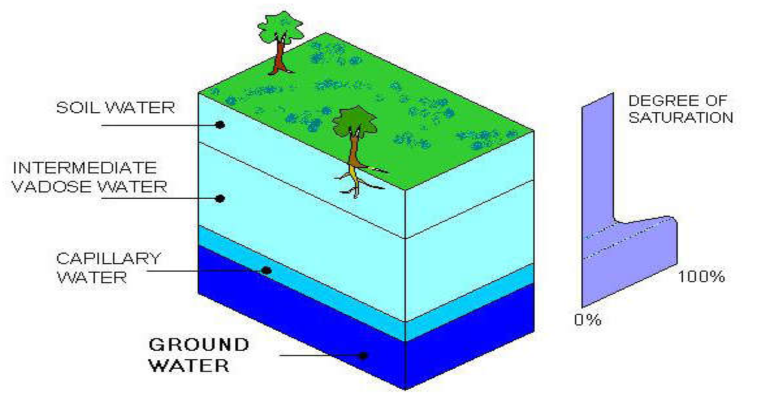


Figure_5: Classification of subsurface water and variation in degree of saturation

b. Saturated Zone

Groundwater is the water which occurs in the saturated zone. All earth materials, from soils to rocks have pore spaces although these pores are completely saturated with water below the groundwater table or phreatic surface (GWT). From the groundwater utilization aspect only such material through which water moves easily and hence can be extracted with ease are significant.

1.3. Water bearing strata (aquifères) and their characteristics

A geological structure fully saturated by water, capable of producing sufficient quantities of water that can be economically used and developed, is known as aquifer (Latin; to bear water).

Examples include sandstone layer, unconsolidated sand and gravel, limestone, fractured plutonic and metamorphic rocks which act as aquifers.

For a description or mathematical treatment of groundwater flow the geological formation can be schematized into an aquifer system, consisting of various layers with distinct different hydraulic properties. The aquifers are simplified into one of the following types.

a) **Unconfined aquifer (also called phreatic or water table aquifer)**: Such type of aquifer consists of a pervious layer underlain by a semi- impervious layer. This type of aquifer is not completely saturated with water. The upper boundary is formed by a free water-table (phreatic surface) that is in direct contact with the atmosphere. In most places it is the uppermost aquifer.

b) **Confined aquifer**: Such an aquifer consists of a completely saturated pervious layer bounded by impervious layers. There is no direct contact with the atmosphere. The water level in wells tapping these aquifers rises above the top of the pervious layer and sometimes even above soil surface (*artesian wells*).

c) **Semi-confined or Leaky aquifers**: consists of a completely saturated pervious layer, but the upper and/or lower boundaries are semi-pervious. They are overlain by aquitard that may have inflow and outflow through them.

d) **Perched aquifers**: These are unconfined aquifers of isolated in nature. They are not connected with other aquifers.

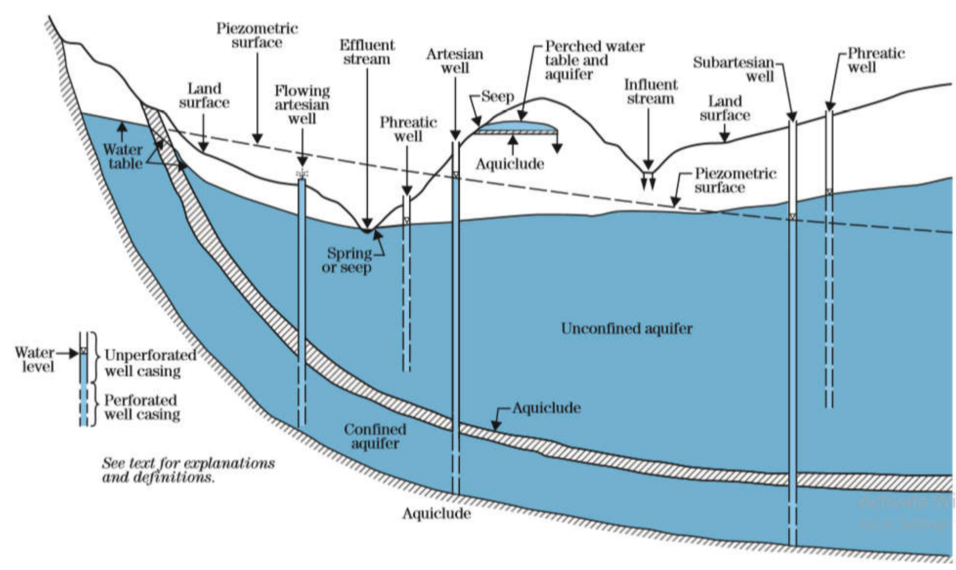


Figure_6: Different types of aquifer formations

Self-Check 1	Written Test

Name: ________________________ **Date:** ______________

Directions: ***Answer all the questions listed below.***

1. Write the occurrences and sources of ground water?(5pt)
2. Explain the zone of ground water?(5pt)
3. What is hydrological cycle means and explain the component part of hydrological cycle?(5pt)
4. List and explain water bearing strata of ground water and their characterstices?(5pt)

Note: **Satisfactory rating – 20 points** **Unsatisfactory – below 20 points**

INFORMATION SHEET#2	LO#2: Assessment of groundwater

2.1. Gathering and applying groundwater information

The main stages of a groundwater exploration program which will allow you to assess groundwater resources are summarized in the table below, with an indication of costs. Some more detail is given in the sections below, but this page is not a comprehensive guide to groundwater development.

Groundwater exploration

Searching for water located below the earth's surface, in phreatic layers or aquifers, in order to pump it. This is done with the utmost care and precision, using appropriate techniques, in order to dig or drill wells in the best possible places and thereby avoid costly, discouraging failures.

In actual fact, it consists of different methods ranging from the most rudimentary – but nevertheless of interest for people or small communities with little means, such as *dowsing – to* *the most sophisticated such as the prior analysis of satellite photos or proton magnetic resonance* (PMR) investigations.

The search for groundwater sources must take account of *technical (hydrogeological)* criteria as well as *socio-economic criteria* (closeness to a village cost of investigation). In actual fact, closeness to the beneficiaries often remains the prime criterion.

A. Reconnaissance

Every good football manager and army general knows the importance of reconnaissance. Only with accurate intelligence on key parameters is it possible to plan a strategy for success. The same is true for water projects. Before a water project can be planned, key socio-economic, institutional and physical information must be gathered – in this manual we are only concerned with the physical issues. There is no point in planning a groundwater project if there is no groundwater available, or in buying sophisticated exploration equipment where groundwater is ubiquitous. In this chapter we describe some simple ways to carry out simple, effective reconnaissance.

1. Experience

It is always helpful to find someone who has worked in the area before. Not only can they give their own opinion of the area, but they can help point in the direction of other projects in the area or maps and reports that might have been written. The box below gives a list of information that would be useful to discuss with someone who has experience in the area. However, all advise and information given should be treated cautiously and always checked in the field. In our experience, people can often give misleading information in their enthusiasm to be helpful.

Questions to discuss with someone with previous experience of the project area *What was their involvement in the area?* *How easy is it to find groundwater – what was their success rate?* *What do they know about the geology?* *Do they have records/reports of borehole drilling, or the project in general?* *Ask them to draw a map of the area, showing geology and easy/difficult areas to find water. Any poor water quality in the area?* *What techniques would they consider for finding groundwater?* *What other projects do they know of and people knowledgeable about the area?*

2. Observations - geology and previous success

The first visit to a project area is very important. It is at this time that lasting impressions are made. The project is also at its most fluid in the early stages so design alterations are much easier. If possible a visit should be made when the water problems are at their worst – during the height of the dry season. Several days should be spent visiting different parts of the area, trying to get a balanced overview of the water problems in the area. This will be easier if maps can be gathered before such a visit. The aim must be to cover much ground and make a rapid assessment, rather than making a detailed assessment in only one or two areas. lists information that should be gathered as follows.

A first field visit. Take a GPS , magnifying glass, hammer, water EC meter and any maps. If you have spaces also take a water level dipper, pH meter and compass-clinometer. Drive along main roads cutting across the area and stop where there is rock at the surface (often in river valleys). Examine and describe the rocks, and take a sample. Take a GPS reading of any stop you made so it can be marked on the map. At representative villages discuss carefully the water supply problems. Walk to the dry season water source and try to work out why there is water there, measure the water EC and pH. Note any successful or dry wells and boreholes and measure depth, depth to water level, EC and pH. Discuss any previous unsuccessful drilling and work out the geology for the village from samples at the bottom of wells, or nearby river valleys. Note areas (discussing with local NGOs or government officials) where there are successful wells and boreholes, and areas where boreholes and wells have been unsuccessful.

3. Maps and reports

Useful information often exists hidden away on people's shelves or locked in government filing cabinets. For most areas it should be possible to gather basic information, such as topographic and geological maps. Often other information exists, such as aeromagnetic maps, aerial photographs and even hydrogeological maps. If other projects have been carried out in the area there will be project reports, and possibly databases of boreholes. Universities are also good sources of information. Geology Departments of nearby Universities will often know most about the current geology, and may have undertaken studies in the area. International consultants can often be useful sources of information and may have access to information that is now not available in country and also have access to academic literature. Table1. Lists different organisations that are useful to contact, and the information that may be available in each.

Table 2.1 Information available from different organizations

Institution	Data & Information
Mapping Institute	Topographic maps, aerial photographs
Geological Survey	Geological maps, aerial photographs, hydrogeological maps, aeromagnetic maps
Rural Water Department	Databases of boreholes, reports of previous projects or statewide surveys
Universities	Geological maps, local research in the area.
Local NGOs, local government	Databases of boreholes, consultant's reports, records of those who have worked in the area.
International Geological Organisations (such as BGS)	Geological maps, Consultants reports, academic literature.

4. Siting boreholes and villages on maps

Knowing where most of the villages are is an important part. It is then possible to plot them on maps and therefore estimate what geology underlies each village. At the reconnaissance stage this gives a good idea of the proportion of villages underlain by each geological unit. In the same manner each improved water source (such as borehole or improved well) can be located on maps, and each abandoned borehole. This will help assess which areas are easy to find groundwater and which are difficult. With the advent of GPS (global positioning system) it is now very easy to locate wells and villages on maps. GPS are small inexpensive pieces of equipment about the size of a mobile phone or calculator. When switched on they track the position of satellites and from this information can accurately locate where they are on the ground. They can give a read out in decimal degrees or in many local grid systems. For greatest accuracy they should be set up to the same grid system as the maps on which the information will be plotted.

5 further techniques

Satellite interpretation

It is sometimes useful to use information from satellites to help create a base map for the area. A satellite image contains information from the light spectrum and is interpreted to help give an indication of changing conditions on the ground. Under good conditions changes in geology can sometimes be observed. Fracture zones, rivers and roads are interpretable with experience. Information from satellite images can be presented on maps at about 1:50000 scale. Although useful for a reconnaissance of an area, satellite images cannot normally be used by themselves for siting wells or boreholes.

Geographical information systems (GIS)

GIS are excellent tools for water supply projects. They allow map information to be combined, analysed and presented in many different ways. This means that tailor made maps can be easily created for different project stakeholders. However, to set up a GIS demands specific expertise and considerable effort to get all the data in the appropriate format. To create a GIS for an area available data are put into digital form. That means digitizing topographic and geological maps and making sure they are in the same map registration. Once this is done other information, such as village locations can be added and plotted on top. Once some investigations have been done preliminary groundwater potential maps could be drawn up and printed for use in the field.

B. Techniques for siting wells and boreholes

Different hydrogeological environments also demand different levels of siting. Where groundwater is easily found (Figure 1) little siting is required for wells and boreholes and hydrogeological considerations are of little priority. In other areas groundwater is not ubiquitous, but siting methods are well established and standard techniques can be used (e.g. weathered basement rocks). However, there are many hydrogeological environments which are complex and no standard techniques are available for siting wells and boreholes. In these areas, geophysical and other techniques must be tested to provide new rules of thumb that are appropriate for that environment.

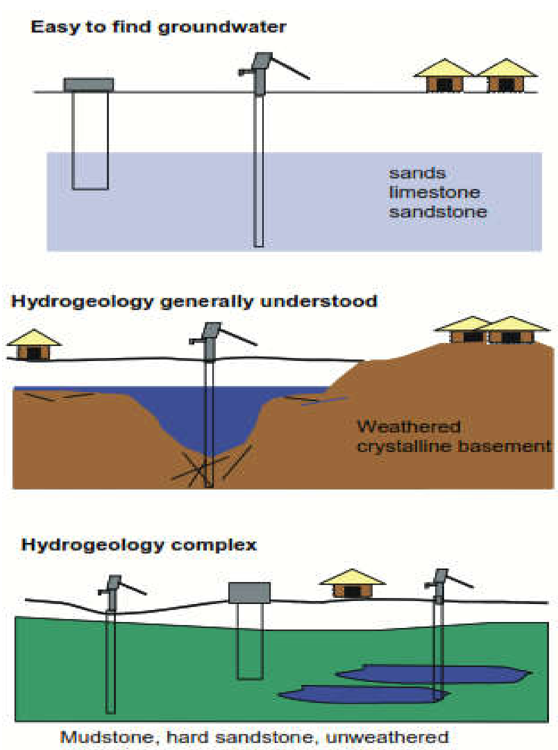


Figure 1. Siting wells and boreholes in areas where it is easy to find groundwater, where groundwater occurrence is generally understood, and in complex areas.

1. Geological triangulation – maps, observation and geophysics

For an accurate assessment of the potential for groundwater at a village it is important not to rely on just one technique or approach. Maps can often be wrong, community discussions can be misleading and geophysical surveys cannot be interpreted properly unless the geological environment is known first. An approach that has been used successfully in many groundwater projects is to use a combination of maps, observation and geophysics. This is called geological triangulation.

a. **Maps**. Target area should be located accurately on available geological and topographic maps. The coordinates of each village are determined using a global positioning system (GPS). Once located, the map provides an indication of the basic geology at the village site.

b. **Observation.** The local geology must be examined with care and discussed with the local community. The nature of the rocks should be noted. Local wet and dry season sources of water need to be visited, as should any locations that the community considers as possible groundwater sources. Rock samples need to be collected from local rock exposures; and rock spoil from shallow wells examined.

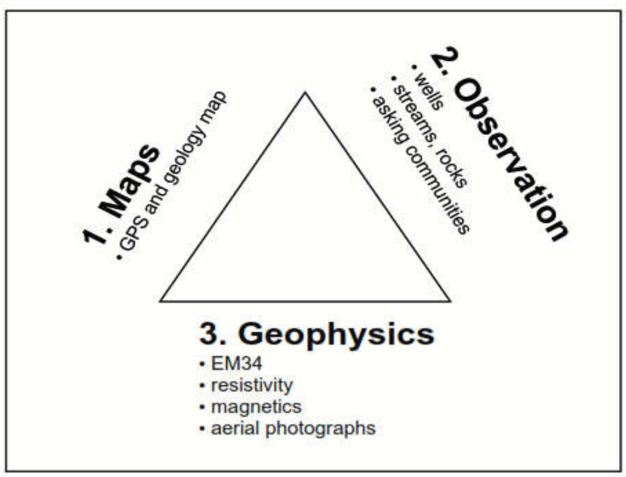


Figure 2. The geological triangulation method.

c. Geophysics. Geophysical surveys can be undertaken at sites based upon geological observations made within the village. The type of geophysical survey depends on the rock types present. The survey results should support the observation data, confirming the type of rock present. The survey results can then be collated with observed data to identify targets for boreholes or wells.

2. Community discussions and village observation

Tapping into the experience and knowledge of local communities plays an integral part in understanding the geology of a village. Community members have the greatest experience of the surrounding environment and the history of water development within their village. Discussions and observations at a village are usually to help answer the following questions: what is the rock type at the village? Has there been any exploration there before? Where are there current wet and dry water sources? Useful people to meet are any well diggers, women who fetch water and children.

What is the rock type of the village?

- Prepare by looking at the geological map for the area and what sorts of rock are likely to be there.
- In discussion find out where the rocks in the area are exposed (children often know the best)
- Visit any wells that have been dug and identify the soil rock profile with depth. Examine a sample of the deepest rock. Find from well diggers how hard the rock is.
- Visit any borehole sites (failed or working) and look for any rock chippings from drilling.
- Visit places where rocks are exposed – make sure they are the true bedrock and not just rocks that have been carried into the area. Good places to look are river valleys and small hills (Figure 3).
- Observe boulders in the village used for seats, grinding stones etc. and find out where they have come from.

Hints: concrete looks very much like sandstone; do not be fooled by rocks that have been brought into the area or washed down in rivers. Take samples where possible and get a second opinion.

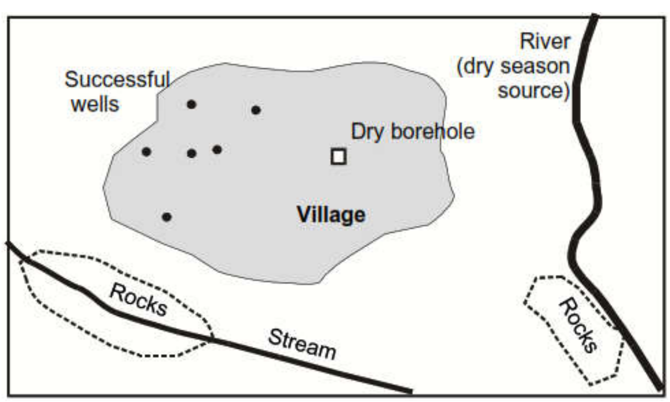


Figure 3. Places to visit on a reconnaissance visit to a community.

Where are there current wet and dry season sources?

- Prepare by looking at any old files, reports or databases from previous projects.
- Discuss with community members all sources of water within the village.
- Visit well sites, measure water levels and salt content of the water. Find out how much water is taken at different times of the year – particularly at the peak of the dry season, and in drought.
- Visit boreholes; discuss depth with community (e.g. number of rods used in its drilling, or lengths of screen and casing in its construction) and yield at different times of the year.
- Visit pond or river sources. Measure salt content of water. Discuss how many people use the source, at what time of year, how much and for what purpose.

This information should give some indication of the likelihood of groundwater in the area. If some wells and boreholes have considerable groundwater throughout the year or pond sources have a high salt content and are sustainable throughout the year, then groundwater is likely to exist in the area.

What are the sources of pollution around the village?

Information should also be gathered on potential sources of pollution in and around the village. However, care and tact must always be used when discussing sources of pollution. Most water projects should have a sanitation component, with qualified staff and individual techniques to discuss sanitation. Things to look out for are:

- Type and location of on-site sanitation
- Burial grounds
- Cattle pens
- Market areas

One of the greatest barriers to tapping into this knowledge is language. Not only different spoken languages, but radically different ways of describing things. Those with experience of geology or water engineering describe rocks and water in a certain manner which is alien to most other people. It is always important to find an example of what is being described. It may take more time, but helps reduce uncertainty.

3. When are geophysical techniques required?

Geophysical techniques are required if maps and observation alone do not give sufficient information to help site a successful well or borehole. They measure physical properties of rocks (hence the name 'geophysics'). They do not directly detect the presence of water, and cannot be used as a failsafe method for siting wells and boreholes. All they do is help interpret what rocks are present in the area, and in some instances help locate where they may be more fractured.

There are many different geophysical techniques available and countless pieces of equipment. Many require sophisticated equipment or complex analysis and are therefore not appropriate for use in rural water supply programs. A comprehensive list of different techniques is given in Table 2. The two most useful in the context of rural water supply are electrical resistivity and ground conductivity. Magnetic techniques are also sometimes useful. The working and analysis of these three methods using the most common equipment are described below.

Table 2. Summary of common geophysical techniques used in groundwater investigations.

Geophysical technique	What it measures	Output	Approximate maximum depth of penetration	Comments
Frequency domain EM (FEM)	Apparent terrain electrical conductivity (calculated from the ratio of secondary to primary EM fields)	Single traverse lines or 2D contoured surfaces of bulk ground conductivity	50 m	Quick and easy method for determining changes in thickness of weathered zones or alluvium. Interpretation is non-unique and requires careful geological control. Can also be used in basement rocks to help identify fracture zones.
Transient EM (TEM)	Apparent electrical resistance of ground (calculated from the transient decay of induced secondary EM fields)	Output generally interpreted to give 1D resistivity profile	100 m	Better at locating targets through conductive overburden than FEM, also better depth of penetration. Expensive and difficult to operate.
Ground penetrating radar (GPR)	Reflections from boundaries between bodies of different dielectric constant	2D section showing time for EM waves to reach reflectors	10 m	Accurate method for determining thickness of sand and gravel. The technique will not penetrate clay, however, and has a depth of penetration of about 10 m in saturated sand or gravel.
Resistivity	Apparent electrical resistivity of ground	1-D vertical geoelectric section; more complex equipment gives 2-D or even 3-D geoelectric sections	50 m	Can locate changes in the weathered zone and differences in geology. Also useful for identifying thickness of sand or gravel within superficial deposits. Often used to calibrate EM surveys. Slow survey method and requires careful interpretation.
Seismic refraction	P-wave velocity through the ground	2-D vertical section of P-wave velocity	100 m	Can locate fracture zones in basement rock and also thickness of drift deposits. Not particularly suited to measuring variations in composition of drift. Fairly slow and difficult to interpret.
Magnetic	Intensity (and sometimes direction) of earth's magnetic field	Variations in the earth's magnetic field either along a traverse or on a contoured grid	30 m	Can locate magnetic bodies such as dykes or sills. Susceptible to noise from any metallic objects or power cables.
VLF (very low frequency)	Secondary magnetic fields induced in the ground by military communications transmitters	Single traverse lines, or 2D contoured surfaces.	40 m	Can locate vertical fracture zones and dykes within basement rocks or major aquifers

C. Gathering information during drilling

If the results of reconnaissance and geophysical surveys have been favorable, drilling a borehole or digging a well can get underway. This provides an invaluable opportunity to actually observe what the rocks are like under a community. For surprisingly little effort or expense, information can be gathered on the location and nature of the water producing horizons. Where the water table is shallow and the material soft, communities can dig wells. These wells provide limited geological data on the shallow weathered zone. More detailed geological and hydrogeological data can be obtained during borehole drilling, and can show the distribution of weathered, non-weathered and fractured rocks at greater depths, and groundwater occurrence within them. Much useful information can be obtained from drilling during ongoing rural water supply projects, without the need for purpose-drilled exploration boreholes. This chapter describes some simple techniques for collecting data.

Equipment required

Some basic equipment is useful for collecting and analyzing data from drilling (Figure 4). The combined list costs much less than drilling one borehole (roughly one fifth) and much of it will last for many years, the consumable items are very cheap – plastic bags and pens. A camera can also be useful. Photographs of chip samples, or even the drilling process can be a useful record and help to jog memories about various sites.

Figure 4. Equipment required for collecting and analyzing data during drilling

2.2: Collecting groundwater peiziometric data

2.2.1: Introduction to Collection of Groundwater Data

To obtain data on the depth and configuration of the water table, the direction of groundwater movement, and the location of recharge and discharge areas, a network of observation wells and/or piezometers has to be established.

i. Existing Wells

Existing wells offer ready-made sites for water table observations. Many villages and farms have shallow, hand-dug wells that can offer excellent observation points.

Because they are hand-dug, one can be sure that they will not penetrate more than slightly below the lowest expected level to which the groundwater will fall. They will thus truly represent the water table.

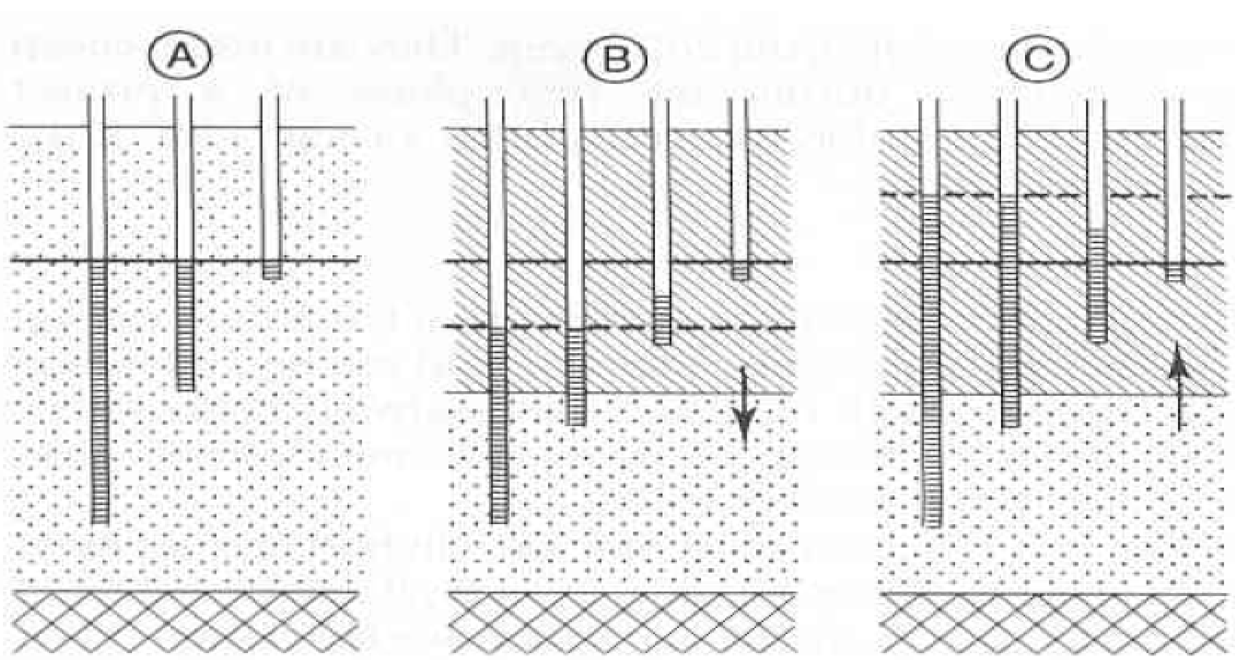
ii. Observation Wells and Piezometers

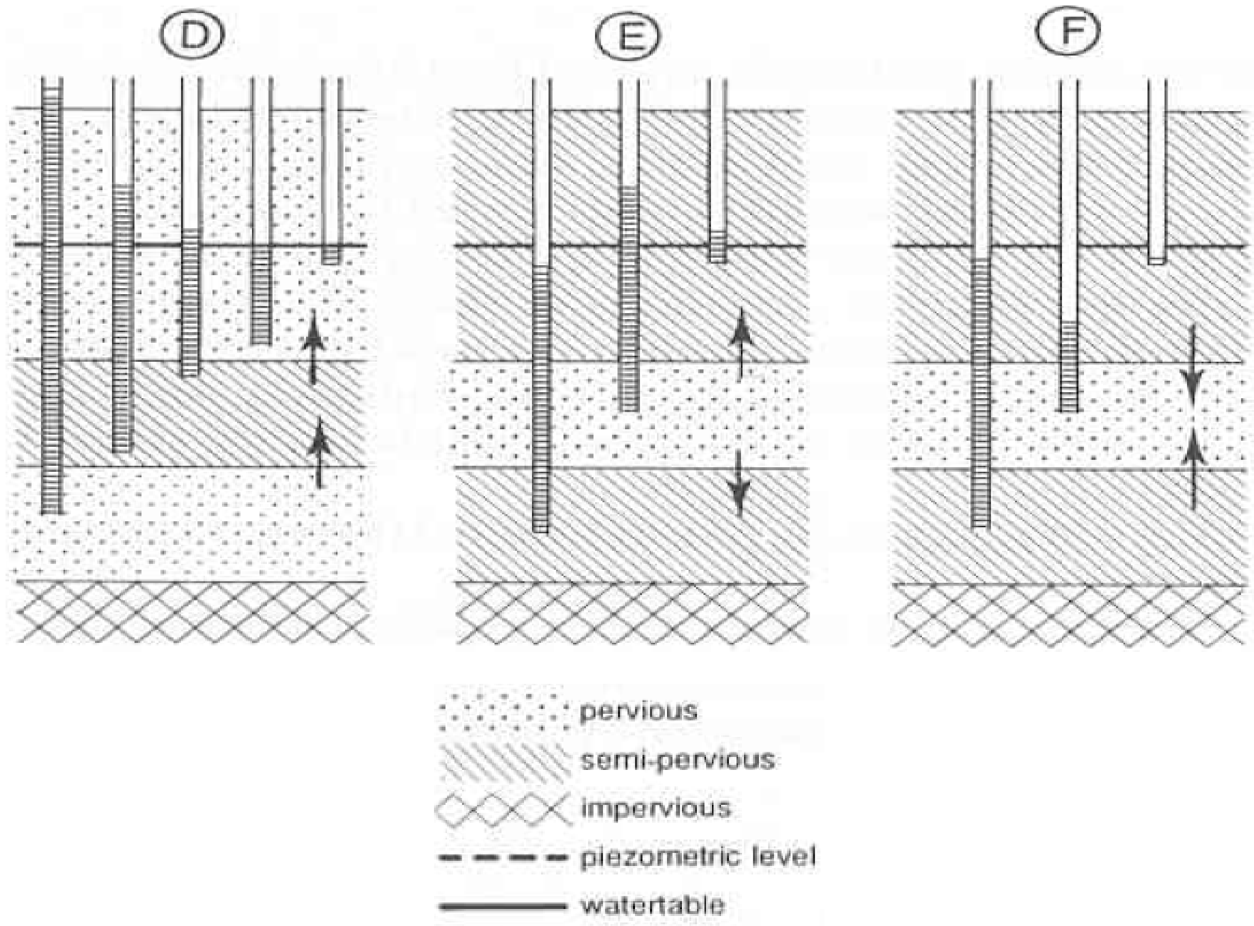
In addition to properly selected existing wells, a number of water table observation wells should be placed at strategic points throughout the project area. They may be cased or uncased wells, depending on the stability of the soil at each location.

Piezometers

A piezometer is a small-diameter pipe, driven into, or placed in, the subsoil so that there is no leakage around the pipe and all water enters the pipe through its open bottom. Piezometers are particularly useful in project areas where artesian pressures are suspected or in irrigated areas where the rate of downward flow of water has to be determined.
A piezometer indicates only the hydrostatic pressure of the groundwater at the specific point in the subsoil at its open lower end.

Figure: Peziometer





2.2.2: Peiziometric data collection

Peiziometric data is used to detect problems that can be encountered in the monitoring of groundwater level fluctuations and trends. Data can be collected from measurement and interpretation and recorded data.

Frequency of Measurements

The water table reacts to the various recharge and discharge components that characterize a groundwater system and is therefore constantly changing. Important in any drainage investigation are the (mean) highest and the (mean) lowest water table positions, as well as the mean water table of a hydrological year.

For this reason, water level measurements should be made at frequent intervals for at least a year. The interval between readings should not exceed one month, but a fortnight may be better. All measurements should, as far as possible, be made on the same day because this gives a complete picture of the water table.

Self-Check # 2	Written Test

Name: ________________________ **Date:** ______________

Directions: ***Answer all the questions listed below*.**

1. Define what a peiziometer mean and what is its function*? (5points)*
2. How can we collect groundwater level data*? (5points)*

Note: **Satisfactory rating – 5 points** **Unsatisfactory – below 5 points**