DACAAR

Basic Hydrogeology

Water and Sanitation Programme
Human Resource Management Section

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Introduction to Basic Hydrogeology

MRRD/DACAAR

Engineers Training Course

Duration: 3 days

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1. The Goal of the Hydrogeology Training Course

Through extending participants knowledge and understanding of Hydrogeology they should better understand the origins of ground water and the many influences that alter the quantity the quality of ground water. This knowledge should assist in their professional development and influence them to realize the importance of having technical knowledge and expertise in order to construct reliable water points.

1.1 Course Objectives:

After completion of this course the participants will have a broader understanding of:

- Hydrogeology.
- The hydrologic cycle.
- Climate and precipitation in Afghanistan
- Aquifer, transmissivity, storativity, porosity and permeability.
- The description of rocks including their mineral composition and texture.
- Soils and the particle size and classifications of clay, silt, sand and gravel.
- Groundwater and ground water quality.
- Wells and how wells influence each other.
- Well hydraulics
  Duration Step Test - Multi Stage Pump Test

2. Daily Time Table

Day One

Time	Topics	Resource Person
0830-0955	Introduction, Knowing each other, Fears and Expectation, Methodology and schedule	Participants Trainers
0955-1015	What is hydrogeology?	
1015-1045	Tea break	
1045-1130	Hydrologic cycle	
1130-1230	Climate precipitation and land forms in Afghanistan	
1230-0130	Lunch / prayers	
0130-0230	Introduction to the main types of rocks	
0230-0245	Tea break	
0245-0330	Main types of rocks	
0330-0345	Wrap up session	

Tea breaks 1005 am and 0230 pm Lunch and prayers from 1230 pm-0130

Day Three

Time	Topics	Resource Person
0830 – 0900	Review of the previous session	Participants Trainers
0900 – 0945	Springs	
0945-1005	Kareez	
1005-1030	Tea break	
1030-1115	Types of wells in Afghanistan	
1115-1230	Cone of Depression and Draw Down	
1230-0130	Lunch/prayers	
0130-0245	Well hydraulics, pump test.	
0245-0300	Tea break	
0300 – 0400	Evaluation of the training course and Presentation of certificates	

Tea breaks 1005 am and 0245 pm Lunch and prayers from 0100 pm – 0200 pm

3. Summary of Training Sessions

Day 1
Opening session **Introduction to basic hydrogeology** **The hydrologic cycle** **Climate and precipitation in Afghanistan** **Rocks and Aquifers**

Day 2
Aquifers-A layer within the Earths Crust that Stores and Transmits Water **Saturation zone aeration zone, porosity and permeability** **Transmissivity.** **Ground water levels in humid and arid region** **Impervious rocks and artesian ground water** **Springs** **Kareez**

Day 3
Wells in Afghanistan **Introduction to well Hydraulics**

Day 1

4. Design and Timing

Training Events	Time Needed	Training Methodology	Supporting Documentation
Opening session Introduction, fears and expectations, methodology, schedule & objectives	1 hour 25 minutes	Brainstorming Written exercise	Handout A B& C
Introduction to basic Hydrogeology	50 minutes	Brainstorming Presentation	Annex 1 Handout 1.1
Hydrologic cycle?	60 minutes	Brainstorming Presentation	Annex 1 Handout 1.1
Climate, precipitation and landforms in Afghanistan.	45 minutes	Brainstorming Presentation	Annex 1 Handout 1.1
Rocks and aquifers	2 hours	Brainstorming Presentation & group work.	Annex 1 Handout 2
Wrap up Session	30 minutes		
Total Time		6 hours 30 minutes + 1 hour for lunch and 30 minutes for morning tea break and 15 minutes for afternoon tea break	

Title: Opening Session

Session Summary

Objectives:
After completion of this session the participants have:

- Fill out the attendance registration list and profile list.
- Be more familiar with the course objectives and the other participants.
- Become aware of the trainers and each other's needs.
- Become familiar with what everyone expects by setting rules.

Time:
1 hour 25 Minutes

Method:
Presentation brainstorming

Materials:
Handout A, B and C color cards, course stationary.

Physical setting:
Participants sitting in U shape.

Process:
- Welcoming the participants.
- Trainers introduce themselves and give some short information about the training.
- Distribute participants stationary (files, pens, notebook color cards and profile list etc)
- Activity filling out color cards
- Game Fears and Expectations
- Setting ground rules using brain storming method.
- Brief explanation of course objectives and schedule.

5. Opening Session

A participant recites some verses of the Holy Qoran

An introductory activity for the participants to meet each other – game.

1.2 Fears & Expectations

The participants' briefly outline their expectations and fears on different coloured cards. Pin the cards on the board and reflect on the key fears and expectations highlighted by the participants and explain whether it will be possible to address them in the course of the training.

The trainer should say to the participants that he has a fear and some expectation. The trainer fears that participants will expect the trainer to be giving them knowledge. Training is not filling participants with knowledge

- Training is about introducing new ideas to participants and encouraging them to use them.
- Training is organising the knowledge that participants already have in such a way that they recognise their knowledge and can better use it.
- Training is to enable participants' to exchange ideas and experiences so that they enrich their knowledge and improve their skills.

1.3 Ground Rules

Ask the participants to state what is allowed and what is not. Get a consensus and write the rules on a flip chart. The rules are to be followed by all.

1.4 Course Objectives

Explain the Course Objectives Handout D. Discuss each point briefly to ensure clarity.

1.5 Schedule

Show the Course Schedule Handout No. B. Point out the topics to be covered. Be sure to emphasise the need to be on time for all sessions and to observe the ground rules

6. What is Hydrogeology?

Objectives

After completion of this session the participants will:

Have an overview of the discipline hydrogeology and an understanding of the distribution of water on earth.

Title: What is Hydrogeology?

Session Summary

Objective:
After completion of this session the participants will:

- Have an overview of the discipline hydrogeology and an understanding of the water distribution on earth

Time:
50 Minutes

Method:
Brainstorming and presentation

Material:
Refer Handout 1, 1.1 Annex 1, 4
Flip chart and markers lap top and projector if available.

Physical setting:
U shape

Process:
- Trainer asks participants what they understand about hydrogeology?
- What do you think the study of Hydrogeology can teach us?
- Does anyone know of any of the substances we find in ground water in Afghanistan?
- Why is it important for us to understand the origins of ground water?
- Trainer presents presentation based on these questions.

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What is Hydrogeology?

Hydrogeology:
The discipline that studies the movement of water underground and the origin and history of the rocks and soil it passes through.

Suggested Question to open the topic:

Step 1:
Trainer asks the question-

What affect did the drought in Afghanistan have on the water supply?

Trainer records responses on the flip chart for all to see

(An alternative process suggested is to divide participants into groups to discuss the question and record responses. Each group chooses a person to report findings to the forum.)
Ground water table went down further each year of the drought.
Many wells dried out
The water in our rivers and dams dropped.
Afghanistan's electricity supply was reduced because most of the electricity is hydroelectricity coming from the dams in our mountains.
Some of the rivers dried up.
Animals died from lack of water
Many fruit trees died from lack of water
Farmers were unable to grow crops

Step 2
Trainer asks

Does anyone know a definition for hydrogeology?

Trainer records all the different suggestions commenting on each one,

Trainer says

Hydrogeology:
The discipline that studies the movement of water underground and the origin and history of the rocks and soil it passes through.

Trainer writes a definition for all to see.

Step 3
Trainer asks the question

What do you think the study of Hydrogeology can teach us?

Trainer writes down the responses
How the ground water gets under the ground?
At what depth we will find the ground water?
When we are digging it helps us know what the different types of rocks and soils are?
Avoid incidents of drilling in locations where there is no water.
Hydrogeology can advise where not to drill. Contractors have been reported to continue drilling into the bedrock because of lack of information. Incidents like this waste our scarce resources.
Help us not to make mistakes like many people have and put the filter of the pump in the wrong place and consequently the well going dry.
How to choose the right filter hole size for the different aquifers
It gives us insight into the reason why so many wells fail

Step 4
The Trainer asks the following questions to encourage the group or forum discussion-

Why is it important for us to understand the origins of ground water?

It helps us to realise that deciding where to put the filter is a specialised job.
We wont be so confident next time we hear someone say don't worry I know how deep to put it.
We learn how water properties are altered by the rock minerals they move through under ground
Pure water is made up of two atoms of hydrogen and one of oxygen but the water we get from the ground has many extra substances. See Annex 4.

Step 5
Teacher says

Does anyone know of any of the substances we find in ground water in Afghanistan?

Trainer records the suggestions and asks which one causes us the most problem

Step 6

Trainer says we call the seeping of the water into the ground water strata, recharge.

Where in Afghanistan do you think most of the recharge occurs?

Trainer records answers
Two areas of Afghanistan were glacial in the past. Hindu Kush and Badakhshan Permir and Wakhan in Badakhshan. These areas get the heaviest rainfall and snow in winter

Trainer asks

Are there some people not aware of the dangers of drinking contaminated water?

Trainer accepts responses

How can we in Afghanistan better conserve and develop our water resources?

Trainer accepts responses

Necessity of conservation and development of water resources
Constructing wells, dams, redirecting river water
Redirecting river water for the artificial re-charging of ground water and irrigation as the Chinese project on the Pancher River planned to do.
Save some of the 96% of Afghanistan's river water that goes back into the ocean.

Step 7

Trainer gives presentation supported by a power point
Importance of water resources
Distribution of water on Earth

7. Hydrologic Cycle

Objectives
After completion of the session the participants will:

Understand the water cycle of evaporation, transpiration, condensation, precipitation, run off and infiltration.

Title: Hydrologic Cycle

Session Summary

Objective:
After completion of this session the participants will:

- Understand the water cycle of evaporation, transpiration, precipitation, run off and infiltration

Time:
50 minutes

Method:
Brain storming presentation supported by power point presentation summarizing all points covered in the presentation.

Materials:
Refer to Handout 1.1, Annex 1, and glossary.
Flip chart, markers, and laptop and projector if available.

Physical setting:
U shape

Process:

- Presentation based on questions
- How does the water get underground?
- Has the seawater value?
- What is the hydrologic cycle?
- Cover the processes of evaporation, transpiration, condensation, precipitation, infiltration and surface run off.
- Record responses on the flip chart.

The Hydrologic Cycle

Step 1:
Trainer leads participant discussion by asking

We know that there is a good supply of water under the ground but how does it get there?

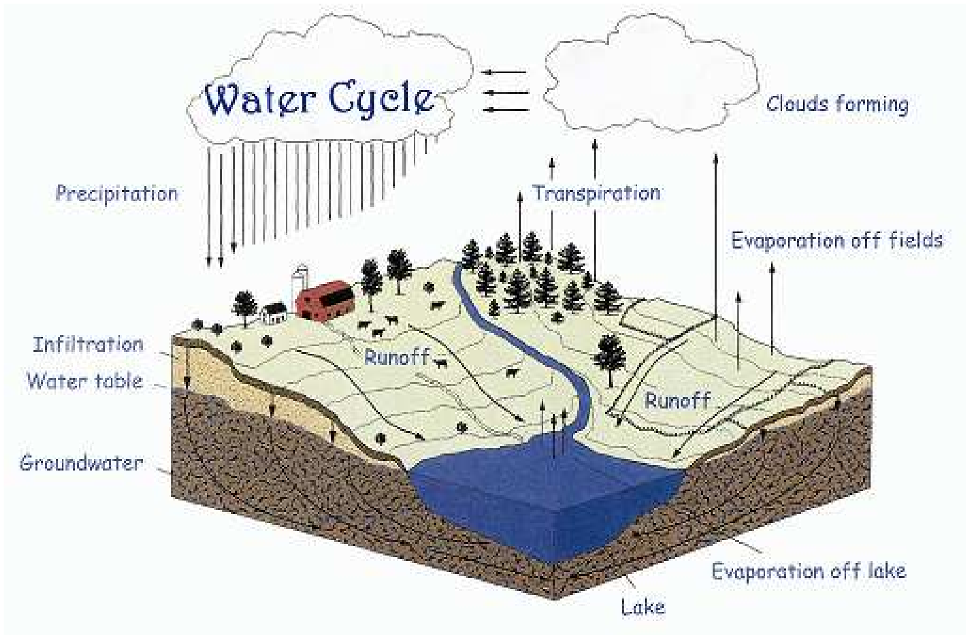
Several participants can explain
Trainer assists them by asking questions
But where did it come from before that?
What happens after that?
Where does the water from rivers end up?

Step 2:
Trainer says the water in the sea is too salty to drink

Has the seawater value?

Step 2:
When all the stages of the cycle have been mentioned the
Trainer repeats the points illustrating the cycle on the flip chart.
Evaporation from oceans, lakes, dams, rivers, streams
Transpiration: Water evaporating from the leaves of plants
Condensation of the clouds, water vapor condenses when it meets cooler air.
Precipitation Snow, rain, sleet, hail etc
Infiltration, seepage, leeching, recharge
Surface run off, springs, ground water, rivers and streams

Step 3:
Trainer gives a presentation based on the illustration below explaining the cycle of water on earth from clouds, condensation, water on earth, to evaporation. See Annex 1 for Hydrologic cycle.
Participants are encouraged to ask questions



Step 4:
Trainer asks a participant to summarise the cycle

Title: Climate, Precipitation and Landforms in Afghanistan

Session Summary

Objective:
After completion of this session the participants will:
- Be informed of the climate, rainfall spread and landforms in Afghanistan.

Time:
60 minutes

Method:
Participants share information, presentation.

Materials:
Refer to Annex 1; glossary, Handout 1.1.

Flip chart, markers, laptop and projector if available.

Process:
Presentation based on questions

Where does Afghanistan's precipitation come from?
Which months in Afghanistan are the driest months?
Why do you think these months are the driest months?
Which part of Afghanistan receives the heaviest precipitation?

- Can anyone tell us what causes the clouds to precipitate?
- General discussion covering drought in Afghanistan.

What affects the rainfall?
Trainer recording responses

8. Climate, Precipitation and Landforms in Afghanistan.

Step 1:
Trainer asks the participants

Where does Afghanistan's precipitation come from?

Trainer leads a general discussion covering the topic, drawing a schematic map (or a map of the region) and illustrates the points.
Source of Afghanistan's rainfall

Step 2:
Asks the question

Which months in Afghanistan are the driest months?

Trainer records answers

Why do you think these months are the driest months?

Trainer records answers

Step 3:
Trainer asks

Which regions of Afghanistan are dessert, savannah grasslands, irrigation regions, and mountains?

Trainer draws schematic map of Afghanistan showing where the landforms are.

Step 4:
Trainer asks

Which part of Afghanistan receives the heaviest precipitation?

As we mentioned before two areas of Afghanistan were glacial in the past. Hindu Kush and Permir and Wakhan in Badakhshan. These are the regions that receive the heaviest precipitation

Trainer asks

Can anyone tell us what causes the clouds to precipitate?

The clouds move from the Mediterranean Sea during summer and when they reach the cooler air of the mountains of Afghanistan they precipitate.

Trainer asks

Does anyone know how much of Afghanistan is mountainous

Answer is approximately 75%

Trainer says, when a water and sanitation Engineer says,
A well that has water in it in November it will never dry out"

What do you think makes him say that?

Step 5:
Refer to Handout 1.1, Annex 5 Earths Water. Trainer presents prepared information on the topic supported by a power point presentation. Participants are encouraged to participate and ask questions

9. Rocks and Aquifers

Objectives:

After completion of the session the participants will become familiar with:.

- Rocks that store and transmit ground water (aquifers).
- Aquiclude non permeable materials such as clay
- Aquifuge an absolutely impermeable unit that will neither store nor transmit water.
- Leaching of rocks, gravel and soil and the affects leaching has on water

Title: **Introduction to the Main Types of Rocks.**

Session Summary

Objective:
After completion of this session the participants will be more informed about:

- The different categories of rocks
- Rocks that store and transmit ground water
- Aquifers,
- Aquiclude a non permeable strata such as clay.
- Aquifuge. An absolutely impermeable unit that will neither store nor transmit water, impervious solid rock without fractures that water cannot pass through
- Types of rock or soil that make a good aquifer.
- What causes cracks in hard rocks

Time:
120 minutes

Method:
Group discussion presentation and brainstorming

Materials:
Refer: Annex 1 glossary, Handout 2.
Rock samples to demonstrate porosity and permeability.

Process:
Trainer sets a topic for groups to discuss and record results.
What are the different types of rocks?
Each group is assigned a trainer or participant who has some knowledge of geology.
Group presentation-reporting their findings.
Trainer explains and adds to the information presented and displays examples of each type of rock for participants to view and examine.
Special emphasis is put on recognizing aquifer rocks.

10. Introduction to Types of Rocks

Step 1:
Introduces topic by asking the participants

What different types of rocks do you know are found in Afghanistan?

Trainer lists the different types suggested on the flip chart and also the origins of the different rocks.

Step 2:
Trainer asks

Does anyone have any information on how the Earth was formed many millions of years ago?

Trainer briefly describes the earth starting as a ball of gas then the outer crust cooling. The centre of the earth remains as molten iron

Step 3:
Trainer explains, - there are three major types of rocks,
Sedimentary, metamorphic, and igneous rocks.

Does any one know how any of them were formed and the major characteristics that enable us to identify these rocks?

Sedimentary rocks:
Rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock, sand, stones or mud, transported from their sources and deposited by water; (2) rocks formed by or from secretions of organisms, such as most limestone.

Metamorphic Rocks:
Alteration of the minerals, textures and composition of a rock caused by exposure to heat, pressures and chemical actions.

Igneous rocks:
Originate from molten rock below the earths surface. Igneous rocks are either from a volcano erupting or from magma cooling under the earth’s crust **Basalt or granite** igneous rocks are two of the most common rocks on the earth’s surface.

Granite:
A course grained, intrusive igneous rock composed mostly of light coloured Minerals. Granite is thought to be one of the main components of the earths crust.

Basalt:
A dark coloured fine-grained extrusive igneous rock. Thought to be one of the main components of the ocean crust.

Step 4:
Place the participants who have studied geology in different groups
Trainer divides participants into groups of five and gives them samples of rocks and containers of clay, gravel, sand, etc asks them to discuss how each might have formed and the characteristics of each sample.
Each group chooses a leader and records their findings. Trainer visits each group and giving support pointing out the identifying features of the rocks

Groups are asked

Which type of rocks or soil do you think would make a good aquifer?

1. Unconsolidated sedimentary rocks River sediments are the best ones River sediments are loose rocks and have good permeability and porosity.
2. Consolidated sedimentary rocks. Soft conglomerates, soft sandstone, limestone and dolomite Water dissolves limestone making caverns, tubes, caves, chimneys, and spaces underground through which the water can move.
3. Igneous and metamorphic rocks can be an aquifer when they have cracks' open joints, faults and fractured zones that water can infiltrate, percolate and move through. These rocks are hard and without fractures they are impervious.
4. A thin strata aquifer of highly permeable material although made of good water bearing material will not bear enough water.

What do you think would cause such hard rocks to crack?

Step 6[2] :
Trainer adds to the information giving further explanations and information about where we are likely to find these rocks.

[2] There are several different types of Sedimentary rocks, rocks originating from glacier, river sediment and lakes.

Day **2**

11. Design & Timing

Training Events	Time Needed	Methodology Used	Supporting Documentation
Opening session (Review of previous day's session)	40 minutes	Brainstorming	
Rocks and aquifers	45 minutes	Presentation Brainstorming	Annex 1 Handout 2.
Porosity and permeability	40 minutes	Brainstorming Presentation exercise	Annex 1, 2 Handout 2.
Transmissivity	30 minutes	Presentation	Annex 1, 2, 3 Handout 2.
Ground water levels in humid and arid region	30 minutes	Presentation Brainstorming	Handout 2.
Impervious rocks and storativity of ground water	30 minutes	Presentation Brainstorming	Annex 1 Handout 2
Wrap up session	15 minutes		
Total Time		6 hours - 1 hour for lunch and 30 minutes for morning tea break and 15 minutes for afternoon tea break.	

Title: Aquifers: A layer within the Earths Crust that Stores and Transmits Water.

Session Summary

Objective:
After completion of this session the participants will have studied the rocks and materials that:

- Store and transmit ground water
- Form an aquiclude a non-permeable strata such as clay.
- Form an aquifuge. An absolutely impermeable unit that will neither store nor transmit water, impervious solid rock without fractures through which water cannot pass

Time:
1 hour 45 minutes

Method:
Group discussion presentation and brainstorming

Materials:
Refer: Handout 2, Annex 1.
Rock samples in plastic bottles with tops cut off to demonstrate porosity and permeability, Laptop and projector if available.

Process:
Presentation based on questions
Trainer sets a topic for groups to discuss and record and present results
Does anyone remember the name of the ground water strata?
What characteristics must this strata and the recharge layer have?
What happens to the water if the rain falls on impervious landforms?
How do you think it is possible to sink a well where there is a stratum containing salty water?

12. Aquifers-A layer within the Earths Crust that Stores and Transmits Water

Trainer asks for a participant to explain and illustrate

Earth's water cycle

Step 1:
Trainer asks the participants

Does anyone remember the name of the ground water strata?

Trainer draws a diagram illustrating an aquifer and summarises how the water reaches a well source.

Step 2:
Trainer asks the question

What characteristics must the aquifer strata and the recharge region have?

Trainer records and encourages discussion and participant's responses.
Good porosity – spaces, loose material
Connected pores- spaces that are connected making channels
Layers should absorb water-
Layer should transmit water -water needs to be able to move through the material
Layer should be thick if it is going to supply enough water for a well

Step 3:
Trainer says we divide the aquifer material into two types, loose material and cemented material

Consolidated aquifer – cemented material
When the aquifer is made of limestone, soft conglomerate sandstone or fractured rock we call it a consolidated aquifer
Unconsolidated aquifer –Loose material
Is made of unconsolidated material. Material in the aquifer is not cemented together such as sand, pebbles and gravel.

Step 4:
Trainer asks

What happens to excess rainwater and the water that falls on impervious landforms?

Trainer records answers
Runoff forms rivers, streams, dams, lakes or runs into the sea.

Step 5:
Trainer asks

Does anyone know what water you find relatively close to ground level in the area of Proja Taimani, Chaman-e- babrak, Kart-e-now and Dasht-e-barchi.

Trainer accepts responses then explains
This water is not in the aquifer it belongs to a large clay deposit that was once a lake-bed. It is not suitable for drinking
Many well diggers have mistaken this layer for an aquifer and placed the filter and pump in it only to find after some time the water goes salty. The water in this layer is salty. This is very common in the areas around Kabul.

We still sink wells in these areas. Refer to Annex 6

How do you think it is possible to sink a well where there is a strata of salty water?

Participants give suggestions
Trainer adds referring to annex 6
In some areas of Kabul wells are sunk a 100 meters deep to reach the water under the clay layer.
Wells are constructed more than 180 meters deep below the clay in other areas reaching the ground water
In Proja Taimani there is a course layer of sand 18 to 22 meters under the clay in which there is a reliable aquifer.
Trainer asks

Do people succeed to dig hand -dug wells in these parts of Kabul?

Why not?

How do most of the people who live in these areas get their water?

Step 6:

Sometimes the water that infiltrates the earth's surface keeps sinking[3] there is no stratum to restrict its movement down. Once it reaches a restricting stratum it begins to move horizontally. When it flows and it forms a very deep aquifer and when it is lodged between two restricting stratum the weight of the water causes it to be under pressure. This aquifer is called a confined aquifer. If you bore a deep borehole to

[3] Gravity: Gravity pulls water down toward the center of the Earth. That means the water on the surface will try to seep into the ground

reach this water it will rise- up to the level of the Piezometric level without being pumped.

The trainer asks does anyone know what we call these wells.

Do you know what we call these wells?

The water that is deep down and rises up without a pump is called artesian water or an artesian flowing aquifer
The wells are called artesian wells

Step 9
Trainer summarises the main points of the session

13. Ground Water

Objectives

After completion of the session the participants will have an understanding of:

- Saturation zone and aeration zone
- The difference between porosity and permeability and rocks and materials that are porous and those that are permeable
- Transmissivity
- Ground water level in humid and arid region
- Impervious rocks and storativity of ground water

Title: Saturation Zone Aeration Zone, Porosity and Permeability

Session Summary:

Objectives:
After completion of this session the participants will have covered the topics:

- Saturation zone and aeration zone
- Porosity and permeability

Time:
45 minutes

Method:
Presentation and illustrations on flip chart power point presentation and brainstorming

Materials:
Refer**:** Handout 2, Annex 1, 6.
Flip chart, markers, laptop and projector, if available.

Process:

- Gravity compels water to soak into the ground
- Porosity describes soil or rock with many spaces that the water can fill?
- Can anyone tell me what permeability means?

[5] Material Porosity%

14. Saturation Zone, Aeration Zone, Porosity and Permeability

Step 1:
Trainer illustrates the two zones on the flip chart covering the following points:

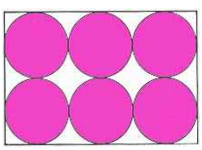
- Gravity compels water to soak into the ground and it sinks until it meets an impassable layer (strata).
- The area where the water accumulates and settles is called the saturation zone because the pores and cracks are filled with water.
- Above this area where it is not saturated although there is some moisture, is called the aeration zone.

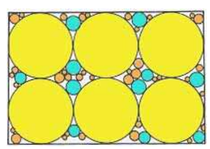
Porosity5 and permeability

Step 2:
Trainer explains

- Porosity describes soil or rock with many spaces that the water can fill
- When there is a lot of space the material can hold a lot of water

Trainer illustrates material with high and low porosity





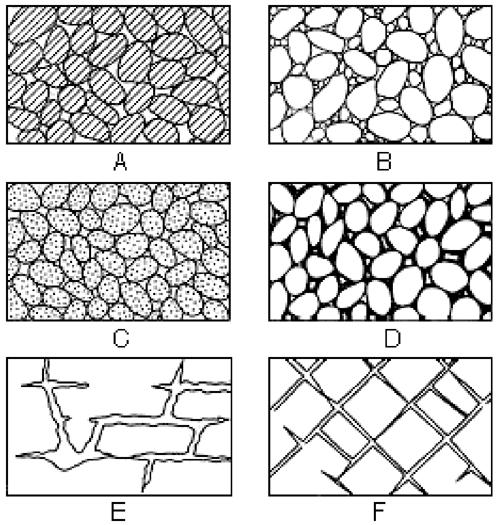
High Porosity Low porosity
Containers containing similar materials are displayed and passed around for close observation

Trainer asks the participants

Can you describe the first diagram? What do you think it represents?

Trainer repeats the question for the second diagram.

Step 3:
Trainer then displays these diagrams



Trainer repeats the exercise with the diagrams above
Diagrams illustrating several types of rock intensities and the relationship between rock texture to porosity.

A. Well-sorted sedimentary deposit having high porosity; Sorted means particles are of a similar size.
B. Poorly sorted sedimentary deposit having low porosity;
C. Well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity;
D. Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices;
E. Rock rendered porous by solution;
F. Rock rendered porous by fracturing[6].

Trainer refers to each diagram and chooses participants to describe what they see in each diagram.

Step 4:
Trainer introduces permeability by asking

Can anyone tell me what permeability means?

Permeability describes porous soil or rock where the air spaces are joined so that water can move easily through it.
Sand and gravel are porous and permeable because the many air spaces are joined and water can pass through gravel and sand easily.
The bottom of a river usually is sand and the water seeps away easily.

[6] (From Meinzer, 1923)
Fractured aquifers: fractured aquifers are rocks in which the ground water moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite and basalt. Limestone is often a fractured aquifer but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns. Water can dissolve limestone and when the water circulates through the fractures it can enlarge them.

Step 5:
Trainer displays examples of permeable rocks and soils and porous rocks and some porous rocks that are not permeable.

Step 6:
Trainer explains that. When clay becomes saturated it stores the water[7]. The water does not move through it. Clay is porous but not permeable.
Trainer demonstrates by pouring water on sand and pouring water on local soil. The water sinks quickly through the sand and takes much longer through the local soil. The local soil contains much clay

Much of the soil around Kabul contains clay, We can see the light clay particles in the air

What do you think the origins of clay are?

Trainer accepts responses

Step 7:
Trainer asks the participants

What are the properties and special uses we have for clay?

Trainer records the different properties and uses we have for clay. Then adds further explanation
All of these properties are because clay is porous but not permeable.

All of these uses are because clay is porous but not permeable.
Clay has many tiny air spaces but because the particles are so compact water cannot pass through clay.
Clay stores the water
When clay gets wet it gets sticky and sticks to our shoes.

Because of these properties we use clay to seal the bottom of a reservoir or dam to stop seepage

Well diggers use clay to seal the sides of the borehole Refer Annex 6
Well diggers seal and back fill wells in front of salty or contaminated water.
Engineers when designing a dam wall in Afghanistan used clay and not concrete because if there is an earthquake concrete will crack where as clay will not.
Clay was used as cement or mortar to seal the rocks in the wall of Ghazi dam in Kabul.

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[7] **Clay:** A classic mineral particle of any composition that has a grain smaller than 1/256mm. Clay has high porosity and low permeability because pore spaces are not well connected. Clay often creates confining layers in the subsurface. **Mineral:** A naturally occurring inorganic solid with definite chemical composition and an ordered chemical structure. Minerals are not formed from animal or vegetable matter.
Example. gold and salt.

Step 8 Trainers describes the materials we find in an aquifer. Aquifers are made of porous materials that are permeable. Consolidated materials rocks with cracks and conglomerates and unconsolidated materials course sand and gravel.

Step 9 Session concludes reviewing porosity and permeability

Title: Transmissivity.

Session Summary
1.5.1.1.1.1.1.1
Objective:
After completion of this session the participants will:

- Understand transmissivity the movement of the groundwater in the aquifer.

Time:
15 minutes

Method:
Presentation and brainstorming.

Materials:
Refer Handout 2**,** Annex 1, 2, 3
Flip chart and markers, laptop and projector if available.

Process:

- Describe transmissivity?
- Trainer gives an explanation of transmissivity
- Power point presentation.

15. Transmissivity

Step 1:
Trainer asks participants if they can describe transmissivity?

Can anyone describe transmissivity?

Trainer gives an explanation
Transmissivity is a word used to describe the movement of the ground water in the aquifer.
Transmissivity: A measure of the amount of water that can be transmitted horizontally by the fully saturated thickness of the aquifer under a hydraulic gradient of one (1).
The transmissivity of a rock is its capacity to transmit water under pressure.

Step 2:
Trainer writes the following transmissivity measures:
Gravel 10 meters per day
Sandstone 1 meter a day
Fractured Limestone is100 meters per hour[8]

The coefficient of transmissibility is the field coefficient of permeability multiplied by the saturated thickness, in feet, of an aquifer.

The speed of water depends on the permeability of the media and the load!

Step 3:
Trainer explains Darcy's law- a simple method of describing the movement of water through a porous, permeable medium. See Annex 1, Handout 2

Step 4:
Opportunity for participants to ask questions and discuss the topic

Step 5:
Optional exercise: If trainer thinks participants will benefit from completing an exercise using Darcy's law this exercise can be included in the session. See Handout 2 and Annex 2 for exercises

[8] **Particle size classifications are**
1. Clay: 0.00024-0.004 millimeters (mm);
2. Silt: 0.004-0.062 mm;
3. Sand: 0.062-2.0mm;
4. Gravel: 2.0-64.0mm

Title: Ground Water Levels in Humid and Arid Region

Session Summary

Objective:
After completion of this session the participants will:

- Understand that the ground water table is at different depths in different climates and regions.

Time:
15 minutes

Method:
Discussion and presentation and brainstorming

Materials:
Refer Handout 1.
Flip chart and markers

Process:
Trainer conducts discussion with participants to learn of their previous knowledge.
Trainer records responses
Presentation on the topic

16. Ground Water Levels in Humid and Arid Climates

Step 1:
Trainer asks the participants

How do you think different climates such as humid and arid climates affect the ground water level?

Trainer records responses on the flip chart
Then adds any points that have been missed out
In arid regions where there are few trees and ground covers the water runs off and does not infiltrate.
In humid regions where the ground, humus and vegetation are permanently damp the absorption of water into the earths surface is continuous. Removal of trees can greatly effect the environment. Roots of plants loosen the soil and provide a pathway for the entry of water
More study is required on management on plantations as certain types of trees can reduce the quantity of ground water.
When the water table is close to the surface and unconfined, transpiration and evaporation occur and can result in daily fluctuations of the water table.
The maximum height of ground water is during the morning and as the day progresses it lowers. During the night it recovers.
Groundwater can be found almost everywhere and the level may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise, or an extended period of dry weather may cause the water table to fall.
Ground water flow- estimating the lowest dry season ground water flow: The quantity of rain is not an exact criterion for recording long term alterations in ground water levels. The quantity of ground water changes when the amount drawn off is greater than the quantity from the infiltration.

Step 2 Trainer summarises all the points mentioned

Title: Impervious Rocks and Artesian Ground Water

Session Summary

Objective:
After completion of this session the participants will:

- Understand that ground water confined by impervious rock and held under pressure is called an artesian aquifer.
- Water held under pressure rises to the Piezometric[9] surface.

Time:
15 minutes

Materials:
Refer Handout 2 Annex 1.
Flip chart, markers, diagrams of artesian well and perched aquifer, lap top and projector if available.

Method:
Brainstorming

Process:
- Asking participants about their previous knowledge?
- How do you think the ground water was deposited under this stratum?
- Trainer giving an explanation.

[9] **Piezometric surface:** As generally used, the pressure indicating surface of an artesian aquifer:

17. Impervious Rocks and Artesian Ground Water

Step 1:
Trainer asks participants

Do you remember what an artesian aquifer is?

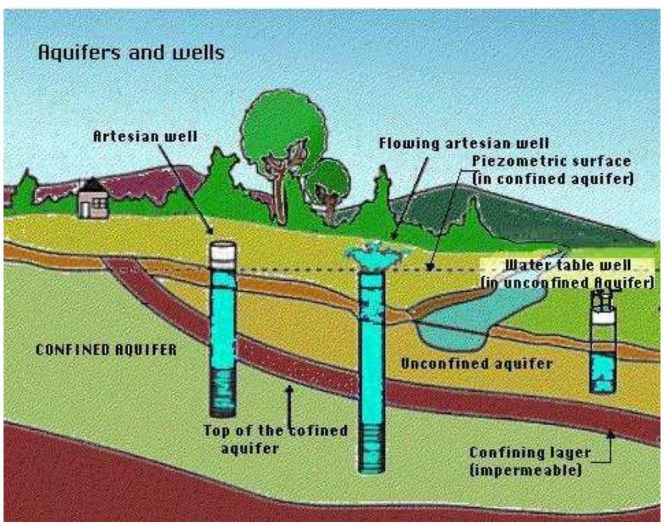
Trainer records all responses
Trainer explains with an illustration on the flip chart

Step 2:
Trainer says when we drill in some parts of Afghanistan we have to drill through very hard solid rock to reach the ground water

How do you think the ground water was deposited under this stratum?

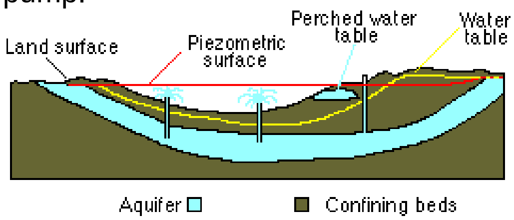
Trainer listens to explanations then invites a participant to explain using an illustration

Step 3:
Trainer presents the following information



Using a diagram illustrate how impervious rock and strata form barriers to the movement of water See Handout 2
Illustrate how impervious rock strata can cause the aquifer to be well below the water table.

When a well is sunk to tap water confined below the water table the water rises/releases with pressure up to the Piezometric level and often does not require a pump.[10]



Step 4:
Trainer illustrates a perched aquifer or uses the above illustration See Handout 2
Impervious rock can also result in a perched water table. The impervious rock stops the water sinking and it is confined above the water table.

Step 5:

Trainer summarizes session.

[10] **Ground water fluctuation arising from atmospheric phenomena:** Atmospheric pressure and rain cause fluctuations in the quantity of water in wells drawing from confined aquifers. The increase in the pressure of the atmosphere causes a decrease in the ground water flow.

Day 3

18. Design and Timing

OHP No.1.3

Training Events	Time Needed	Training Methodology	Supporting Documentation
Opening session (Review of previous day's session)	30 minutes	Brainstorming	
Springs	45 minutes	Brainstorming Presentation Group work	Handout 2.1,Annex 1
Kareez	20 minutes	Brainstorming Presentation	Handout 2.1
Wells in Afghanistan.	45 minutes	Brainstorming Presentation	Handout 2, 2.1
Cone of Depression and Draw Down	45 minutes	Brainstorming Presentation	Handout 2.1, Annex 3
Pumping Tests	1 hour	Brainstorming Presentation	Handout 2.1 Annex 3
Evaluation of the training Course and Distribution of certificates	1 hour	Written Exercise	Handout C, D, E.
Total Time		6hours 15 minutes + 1 hour for lunch and 30 minutes for tea breaks	

Title: Springs

Session Summary

Objective:
After completion of this session the participants will:

- Have gained further knowledge about the different types of springs found in Afghanistan

Time:
45 minutes

Method:
Brain storming, group activity, and trainer giving presentation.

Materials:
Refer to Handout 2.1**.**
Flip chart and marker

Process:

- Trainer asks participants: What is a spring? Trainer records responses on the flip chart.
- Groups identify different types of springs and their characteristics are identified and this is recorded on the flip chart.

19. Springs

Step 1:
Refer to Handout 2.1 for necessary information
Trainer asks the participants to explain

What is a spring?

Trainer records on the flip chart the explanations
Springs are more often a simple outcrop of the water table, helped by a local excellent permeability. A spring occurs when ground water finds a vent and comes to the surface naturally. Springs are common in mountainous areas with water running from the roadside cuttings. People living in mountainous areas often arrange a simple catchment and a hose pipe and divert the water to where they want it. Often you see the water running non- stop from a pipe beside their house. Springs maintain the flow of streams in dry periods.

Step 2:
Trainer asks the participants

What are some different types of springs?

List types suggested
Thermal spring, mineral spring, false spring, descending spring, strata spring, valley spring, barrier spring, ascending spring, springs on the seabed etc

Divide participants into groups and ask them to describe the characteristics of each type of spring and if possible illustrate a spring

Step 2
Groups report back to the forum

Trainer asks participants

What do you think the quality of spring water is?

Trainer records responses

Step 3 Trainer gives presentation supported by a power point explanation.

Title: Kareez

Session Summary

Objective:
After completion of this session the participants will:

- Have an increased knowledge of a Kareez and its historical origins in Afghanistan

Time:
20 minutes

Method:
Trainer explanation and brainstorming

Materials:
Refer Handout 2.1.
Flip chart and markers.

Process:
Trainer asks participants:

- What is a Kareez?
- How were Kareez built?
- How are Kareez cleaned out?
- Why does the water in Kareez often dry up when wells are constructed close by?
- Trainer summarizes discussion and adds any further information needed

Note for Trainer: Organise visit to observe a Kareez in Kabul

20. Kareez

Step 1:
Trainer asks one of the participants to volunteer to explain and illustrate

What is a Kareez?

2 Participants are encouraged to contribute their knowledge.

A kareez is an underground tunnel found in Afghanistan constructed in the past to channel water possibly dating back 3,000 years. Kareez although called by a different name are also found in Iran Iraq and Egypt. Some Kareez have been known to be as long as 30 kilometres

Step 2:
Trainer asks participants

How were Kareez built?

Participants explain

Trainer asks participants

How are Kareez cleaned out?

Participants explain

Why does the water in Kareez often dry up when wells are constructed close by?

Trainer presents power point presentation that includes information about an existing Kareez that is being renovated on the out skirts of Kabul

Step 3:
As part of the field trip a Kareez outlet will be visited

Title: Dug Wells and Tube Wells

3 Session Summary

Objective: After completing this session the participants will

- o Have knowledge about the different types of wells found in Afghanistan and their different sources of water

Time:
45 minutes

Method:
Large outline of Afghanistan drawn on two sheets of flip chart for each group Presentation brainstorming

Materials:
Refer Handout 2.1.
Flip chart, and markers.

Process:
3.1.1.1.1.1.1.1.1 Group activity

- What is the most common type of well in Afghanistan?
- In which of these areas do you think there would be open wells and few hand pumps?
- In which parts of Afghanistan do we find tube wells?
- Why do we find groundwater a dry riverbed near or in?

Presentation of power point with trainer discussing topic with participants

21. Dug Wells and Tube Wells

Step 1:
Trainer asks the participants

What is the most common type of well in Afghanistan?

Trainer encourages discussion amongst the participants and writes the responses on the flip chart and orders the responses from most common to least common.

Step 2:
Trainer asks participants to form groups and answer four questions
Each group has a large outline of Afghanistan to mark on

What parts of Afghanistan do we find hand dug wells?

In which of these areas do you think there would find open wells and few hand pumps?

In which parts of Afghanistan do we find tube wells?

How did the people in the areas where there are now tube wells get their water before tube wells were introduced?

Groups discuss and report back
Groups give hydrogeological reasons why the particular wells are found in each region.
Trainer indicates the areas on a map of Afghanistan.
Trainer asks participants

Why do you find ground water near a river?

Trainer accepts participants responses then explains

The water is often only a few meters from the surface of a dry riverbed. Rivers often lose part of their water underground. The yield of a river can be ¼ above the surface and ¾ below the surface. When a river is dry there is often water a few meters just below the surface. In Northern and Southern Afghanistan many rivers do not reach the sea because they lose their water underground. There is a good probability to find good water in a well close to a river or by just digging in the sediment of a dry riverbed. A river has a bed load of sediment, a suspended load, and dissolved load. In a crowded city like Kabul this water would most likely be contaminated because people are throwing rubbish into the river and using the riverside to construct latrines.

22. Cone of Depression and Draw Down

Objective:
After completion of this session the participants will:

- Realize the importance of a pumping test to learn the capacity of a well.
    - Understand the draw down and cone of depression of a well

Title: Cone of Depression and Draw Down

Session Summary

Objective: After completion of this session the participants will:

- Understand the draw down and cone of depression of a well
- How the cone of depression can influence the water level in a neighboring well

Time:
1 hour 15 minutes

Method:
Presentation brainstorming diagram illustrating how neighbouring wells influence each other

Materials:
See Handout 2.1**,** Annex 2, 3 diagram representing cones of depression of two wells

Process:
Questions to encourage participation
How do we know that wells that are dug close together influence each other?
What happens to the water in the aquifer after the people in the village have been using the pump all day?
Why is it valuable to know the draw down of a well after pumping?

Drawing to illustrate
What physically happens to the water levels after constant pumping?
The extents of the cones vary with the yield and the time of pumping
Getting bigger with time.
When pumping stops, the cones reduce and after the recovery time the static water level returns and the cones disappear.

23. Cone of Depression and Draw Down

Cone of depression and draw down resulting from the pumping of water from a well

Step 1:
Trainer asks participants

How do we know that wells that are dug close together influence each other?

Trainer records responses on the flip chart.[11]
Wells that were once reliable after having another well built near by have a reduced pumping capacity.
Hydrogeologist use stop watches to see if well sources are linked and time how long dye takes to travel from one well to a well close by.
Chlorine placed in a well after some time can be traced to a neighbouring well.

Step 2:
Trainer asks participants

What happens to the water in the aquifer after the people in the village have been using the pump all day?

After responses are accepted trainer gives an explanation. Participants can illustrate.
Trainer explains using diagrams illustrating the cone of depression
Explains the draw down and cone of depression that results from pumping water from the well.
Given time the water level returns to pre-pumping levels 'the recovery'[12].

Step 3

Why is it valuable to know the draw down of a well after pumping?

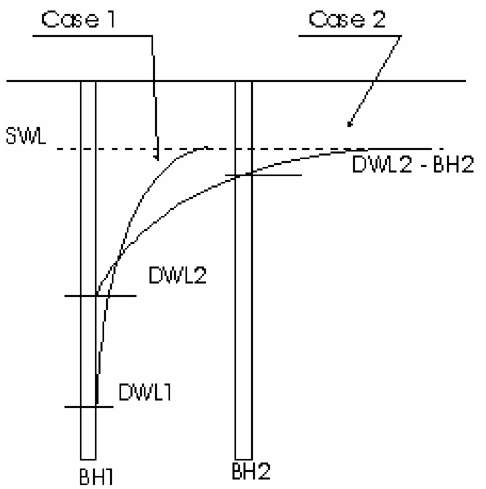
Trainer records responses
Trainer explains
If we know the pumping rate of the pump and we know the draw down level we will place the filter below the dynamic water level to ensure the pump will never go dry

Step 4
Trainer explains
Depression cones of neighbouring wells.
Every borehole, when pumped, creates a "depression cone" in the water table around it. The shape and dimension of this depression cone can be calculated with great precision having appropriate pump test data and the drilling log of the boreholes involved.
The drawing below illustrates what physically happens:

[11] It could be interesting to make a parallel between the depression cone and the vulnerability of the aquifer (because of the flowing directions, if something dangerous rejoins the draw down cone, it would pollute the water well – that's why the larger the draw down is, the more protect the area.
[12] When a well is pumped for some time, it takes approximately the same time to come back to the original level after the pump is stopped.

In this case we have 2 boreholes: BH1 and BH2. SWL is common to the two boreholes, as

long as they are drilled in the same aquifer. BH1 is pumped, so that the water level will drop in the hole to the DWL (dynamic water level). The shape of the depression cone depends on the characteristics of the aquifer: in case 1 (deep DWL, narrow cone) there is a small permeable aquifer, in case two (shallow DWL, large cone) we have a very permeable aquifer. It is clear that in this case BH2 can be influenced, being the SWL disturbed (or in the so called influence area of BH1). The extent of the cones varies with the yield and the time of pumping, getting bigger (with an inverse logarithmic low) with time. When pumping stops, the cones reduce and after the recovery time the static water level returns and the cones disappear.



Note for Trainer: Refer to Annex 2 for other diagrams that can be used to illustrate the cone of depression.

Step 4:
Trainer asks participants

Why do some wells have quicker recovery rates than other wells?

Trainer records all responses
(Alternative exercise: group discussion to answer the question and return to forum to present report)

Step 5:
Trainer explains: all wells when pumped create a depression cone in the aquifer. The shape and dimension of this depression cone can be calculated with great precision having appropriate pump test data and the drilling log /sample box records, of the wells involved (Refer Annex2, 3).

24. Pumping Test.

Objective: After completion of this session the participants will:

- Have an increased knowledge of the Multi Stage Pumping Test (to record the draw down and cone of depression)
- Realize the value of a pump test to assist us to choose the best location to place the cylinder and pump
- Realize that a pumping test to assist us detect construction errors

Title: Pumping test

Session Summary

Objective: After completion of this session the participants will:

- Have gained knowledge of the Multi Stage Pumping Test recording the Dynamic Water Level when pumping at different rates.
- Value of a pumping test to assist us to choose the best location for the pump and to detect construction errors
- To understand the Dynamic Water Level and Static Water Level**.**

Time:
1 hour 15 minutes

Method:
Presentation, and brainstorming

Materials:
Refer Handout 2.1, Annex 2

Process:
Why do we carry our pump tests on a well?[13]
Ask participants what pump tests do they know about?
Bailer test and open channel test
For what kind of situation are these tests used?
Trainer uses the graph to explain The Step Test- Multi Stage Pumping Test, (MSPT).
You can use the Step Test to calculate the efficiency of the well.
Trainer asks participants questions about the graph

[13] There are practical reasons why pump tests are performed, and there are practical reasons why every well should be pump tested.
When pumping commences, the level of water in the well drops, initially very fast, and then slower and slower, with a logarithmic law. After constant pumping for some time the level of the water in the well stabilizes. If you increase the pumping rate the level drops again, with the same modalities. When you stop pumping, the water comes back to the Static Water Level (SWL) with the same modality: very fast at the beginning, than slower and slower, until the initial level is restored.

In practical terms, given the yield of the pump we install (i.e. hand pump) we want to know how much the level of water in the well will drop during pumping, and avoid the pump going dry by setting the pump lower than that depth. We also want to know how long the water table takes to come back to the original level when we stop pumping,.

25. Pumping Test

Process:

Step 1:
Trainer asks participants

Why do we carry our pump tests on a well?[14]

Trainer writes down all the suggestions then says
We want to learn how much the level of the water in the well will drop after constant pumping, when pumping at a regulated yield per second.
When we have enough information to estimate the level the water will drop after eight hours of constant pumping we will place the pump well below this level.

Step 2:
Trainer asks the participants if anyone has knowledge of Bailer Test, Gallon Test and Open Channel Method. See Annex 1

What is a gallon test?

Participants explain what they know and trainer adds further information
These methods are commonly used in Afghanistan

Step 3:
The Step Test- Multi Stage Pumping Test, (MSPT).[15]

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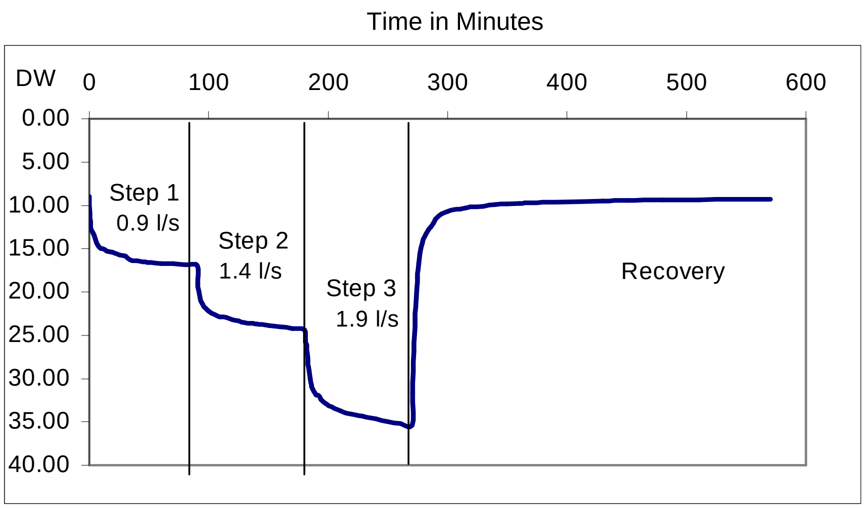
[14] There are practical reasons why pump tests are performed, and there are practical reasons why every well should be pump tested.
When pumping commences, the level of water in the well drops, initially very fast, and then slower and slower, with a logarithmic law. After constant pumping for some time the level of the water in the well stabilizes. If you increase the pumping rate the level drops again, with the same modalities. When you stop pumping, the water comes back to the Static Water Level (SWL) with the same modality: very fast at the beginning, than slower and slower, until the initial level is restored.

In practical terms, given the yield of the pump we install (i.e. hand pump) we want to know how much the level of water in the well will drop during pumping, and avoid the pump going dry by <u>setting the pump lower than that depth</u>. We also want to know how long the water table takes to come back to the original level when we stop pumping,

[15] SWL is 8.97 m. The pump was started at 0.9 liters per second.
The level of water dropped very fast and then slower and slower, with a logarithmic law.
After 90 minutes the DWL stabilized at 16.95 m, with a draw down of 7.98 m (16.95-8.97).
After 90 minutes the yield of the pump was incremented to 1.4 l/s. What was the DW after 180 m?
Then a last step was taken. Was the DWL stabilized? .
After 3 steps of 90 minutes, the pump was stopped and the residual DWL measured. It can be noticed that it took app. more 4.5 hours to come back to the original level.

Trainer says
The calculation of the exact specific draw down and well equation needs specific techniques. We are not going to attempt that in this course
We are going to look at an example of a pump test. This kind of test is called "Step Test". Each participant is given a hand out copy of the graph
You can use the Step Test to calculate the efficiency of the well.
If a well is badly constructed, it can be discovered!

The Step Test- Multi Stage Pumping Test, (MSPT).[16]



Trainer explains the graph to the participants pointing out

Every 90 minutes the yield of the pump was raised

Asks the participants what was the yield in the first 90 minutes

What was the dynamic water level after 90 minutes?

After the last step was the DWL stabilized?

When a well is pumped for some time, it takes approximately the same time to come back to original conditions after the pump is stopped.

This is only an approximate and general rule, with many exceptions:

[16] SWL is 8.97 m. The pump was started at 0.9 liters per second.
The level of water dropped very fast and then slower and slower, with a logarithmic law.
After 90 minutes the DWL stabilized at 16.95 m, with a draw down of 7.98 m (16.95-8.97).
After 90 minutes the yield of the pump was incremented to 1.4 l/s. What was the DW after 180 m?
Then a last step was taken. Was the DWL stabilized? .
After 3 steps of 90 minutes, the pump was stopped and the residual DWL measured. It can be noticed that it took app. more 4.5 hours to come back to the original level.

How long did it take in fact to come back to the SWL, in this example?

Step 4:
The trainer relates DACAAR's experience

Every well should be pump tested. We have a practical problem though when we drill 100 wells in one area, we have to decide how deep those wells have to be to supply enough water for our hand pumps.

Each well has its own characteristics that can be summarized in a simple well equation. We don't have the well equation of each well; neither can we perform a pump test on each.
But we know something we always install the same kind of pump, the AFRIDEV hand pump. The yield of this pump is always the same[17]: 600 liters per hour (0.16 l/s).

We can assume that in certain areas the conditions are similar, so we can estimate the average, approximate specific capacity of the wells. So we know that, to safely get our 0.16 l/s, we need the pump to be at least 10 m below the SWL.

DACAAR standard for silt terrains in Afghanistan is 10 m below the SWL.

Now, what happens when the users of a well complain that, after a while, the pump goes dry, and they have to wait some time to get water? It means that the specific capacity of the well is low, we haven't positioned the pump deep enough to supply the pump with 0.16 l/s, so the DWL reaches the pump, and we have to wait for recovery before pumping again.
It could be that the well is badly constructed filters, gravel pack etc, but may also be that the specific capacity of the area is lower than expected which depends on the formation i.e. Transmissivity and Storativity.

If all other wells in the area have water, the well must be badly constructed.

<u>Drill the next wells deeper,</u> even more than the 10 m in the strategy.

If you have a good drilling log, you should see if the conditions of this specific well are different less sand, more clay to justify the lower specific capacity.

If you encounter a good permeability layer i.e. gravel, the specific capacity of that point will also be very good. This is why it is so important to get a good drilling log, and put the filters just in front of good layers!

Step 4
Trainer summarises the content of the session

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[17] In fact we know that it depends on how strong the user pumps the handle. 600 l/hour it is the maximum value.

26. Course Evaluation and Assessment

Objective:
Through the completion of this questionnaire the trainers will have understood the strengths and weaknesses of the course and the extent to which the participants have understood the concepts discussed with them.

- To identify the strength and weaknesses of the course
- To assess the degree of information being assimilated by the participants.
- To get an idea about effectiveness of the facilitators

Time:
35 minutes

Method:
Written exercise

Material:
See Handout C, D.

Physical Setting:
Seated in U Shape

Process:
Trainer explains the reason for the assessment
Explains the questionnaires.
Participants' complete questionnaires and trainer collects them.
Trainer explains the reason for the evaluation
Explains the evaluation questionnaire
Participants' complete questionnaires and trainer collects them.

Note for trainer
Students should be given adequate time to complete the questionnaires.

Process

Step 1:
See Handout C

The Trainer hands out sheets and asks participants to write the answer to several questions. These questions are suggestions only

1 What material is found in a water bearing strata?
2. What is a water bearing strata called?
3. What is an artesian well?
4. What rocks might you find in a consolidated aquifer?
5. Why doesn’t clay make a good aquifer?
6. Which topic was the most relevant for your work?

Step 2:
See Handout D

Evaluation of the training methods and the general arrangements
Participants rate the following on a scale of 1 to 5.Five being excellent.

1. Were the objectives of the course achieved?
2. Were the methods participatory?
3. Were the trainers friendly?
4. Was the material useful?
5. Was the venue conducive to learning?
6. Was the catering adequate?

Step 3:
Presentation of Certificates

Step 4
Closing of the course

27. Annexes :

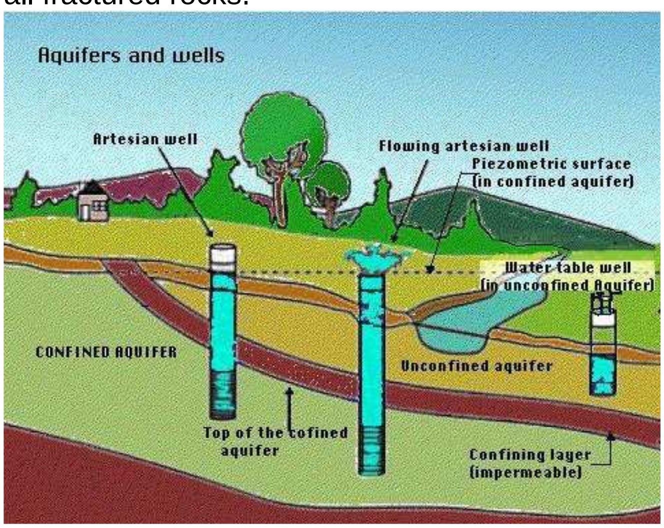
Annex 1. Course glossary

Acidic rock: igneous rock relatively high in silica content e.g. granite, ryolite
There is also acidic intermediate and ultra acidic rock.

Aeration zone: also known as the unsaturated zone the aeration zone is the zone above the water table.
Alkali materials: are rich in sodium and or potassium e.g. ultra basic roc

Anthracite: is the highest rank of coal. Anthracite is hard shiny and slow to burn.

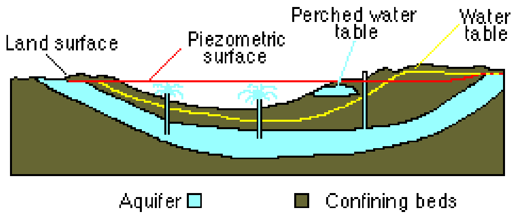
Aquifer: Is the area in the earth's crust where water is stored and moves slowly through layers of soil, sand and fractured rocks. An aquifer transmits useful quantities of water. Most aquifers that are of importance to us are unconsolidated porous media such as sand and gravel. Porous media where the grains are not cemented to each other are called unconfined aquifer. If the grains are cemented together such aquifers are called consolidated. Examples are limestone, soft conglomerate, sand stone and all fractured rocks.



Aquiclude:. Good porosity but no permeability (impermeable and impervious).

Aquifuge: Solid hard rock that has no porosity and no permeability water cannot penetrate it.

Artesian well: The ground water in an artesian well is confined well below the natural top level of the ground water the water table. When artesian water is tapped it flows out without a pump by natural pressure.



Bailer test: A bailer test is a simple test used to calculate the discharge of water from an electric pump. If the discharge is low, of the order of 150 liters to 600 liters per minute, it can easily be measured by an empty 220-liter drum. A stopwatch is used to measure the time it takes to fill the drum. A discharge of 220 liters per minute will take 60 seconds to fill the container.

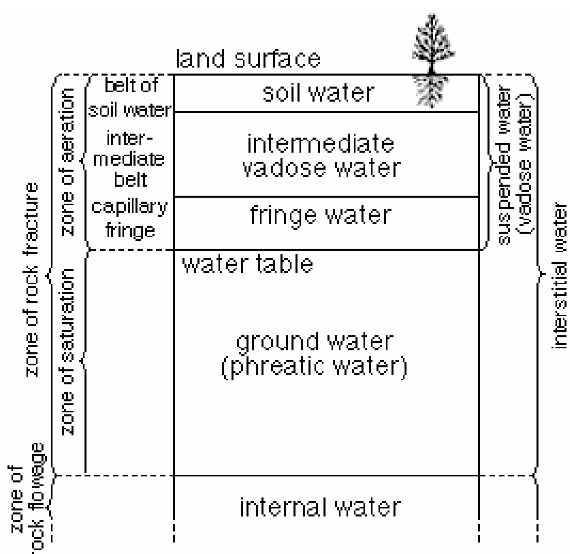
Base: A substance that has a pH of more than 7.

Basalt: A dark coloured fine-grained extrusive igneous rock. Composed of plagioclase, feldspar and pyroxene with a similar composition to gabbro. Basalt is thought to be one of the main components of the ocean crust.

Biochemical rocks: a sedimentary rock that forms from the chemical activities of organisms. Organic (reef fossiliferous) limestones and bacterial iron ores are examples.

Calcium: Calcium is a chemical element. It is a soft white metal found as a compound in teeth, bones and chalk.

Capillary fringe The zone directly above the water table in which water is held in the pore spaces by capillary action



Capillary water: Just above the water table, in the aeration zone, is capillary water that moves upward from the water table by capillary action. This water can move slowly and in

Clay: A classic mineral particle of any composition that has a grain smaller than 1/256mm. Clay has high porosity and low permeability because pore spaces are not well connected. Clay often creates confining layers in the subsurface.

Climate and ground water levels:

Clouds: Are made up of minute droplets of water

Coal: A hard black mineral used as a fuel

Condensation: Is when vapor (clouds/ minute droplets of water) reaches cool air and become a liquid (rain). Condensation is the opposite process of evaporation.

Confined aquifers: Are aquifers that are not usually found in the saturated zone. They are locked in place by impermeable material.

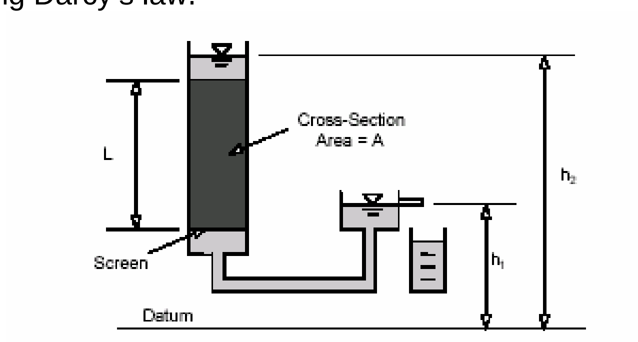
Conglomerates: Consolidated material of sedimentary rocks that are joined by a porous material

Conservation of water resources:
Rivers need protection from pollution and better use of the water

Cone of depression or depression cone: The region of an aquifer affected by the drawdown from the pumping of water from a well

Consolidated aquifer: The grains are cemented together, unlike gravel and sand. Limestone, soft conglomerate, sand stone and fractured rock.

Darcy's law: This very simple law is the base of all the well hydraulics.
The movement of water though a porous medium (underground) can be described using Darcy's law.



$$V_D = ki$$

Where: V_D is Darcian Velocity

k is Permeability

i is hydraulic gradient (□h/L)

In other words, the speed of water depends on the permeability of the media and the load!
V_D is called Darcian velocity because it is not the true velocity of water in the medium. We have learnt already that the water moves only through the voids of the rocks. Voids are only one part of all rock, and the ratio between the volume of voids and the total volume is defined porosity:

$$n=V_{void} / V_{total}$$

it means that the true velocity of water in the media is:

$$V=ki/n$$

This very simple law is the base of all the well hydraulics.

Diagenesis: All the changes that happen to sediment, excluding weather and metamorphism. Diagenesis includes compaction, cementation, leaching and replacement.

Discharge: The volume of water that passes a given location within a given period of time. Discharge is usually expressed in cubic feet per second.

Drawdown: A lowering of the ground-water surface caused by pumping.

Drilling log: Is the sample box used to record the strata when drilling a bore hole. Each sample is recorded. DACAAR recommends a scale diagram 10 millimeters equals 10 meters approximately . This should be attached to the New well report

Dynamic Water level (DWL): The level of the ground water measured from ground level after pumping. The multi stage pumping test keeps a record of the DWL while pumping over regular time spans. A greater rate of pumping (i.e. 1 liter per second compared with 2 liters per second) makes the DWL drop quicker.
See: Multi Stage Pumping Test

Earth: has a metal rich core surrounded by a rocky mantle and covered by a crust of low density minerals.

Evaporite mineral: is a chemical sedimentary rock formed from evaporating water E.g. Gypsum, salt, nitrates and borites.

Element: Simple chemical substance that contains atoms of only one type and cannot be split by chemical means into simpler substances e.g. gold, oxygen, and carbon.
Two atoms of hydrogen combine with one atom of oxygen to form a molecule of water.

Evaporation: When water is heated and turns into vapor (boiling the kettle dry). Sea water evaporates and rises to form clouds.

Fractured aquifers: fractured aquifers are rocks in which the ground water moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite and basalt. Limestone is often a fractured aquifer but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns. Water can dissolve limestone and when the water circulates through the fractures it can enlarge them

Fresh water: water with less than 0.5 parts per thousand of dissolved salts.

Gabbro: A black course grained intrusive igneous rock that is the compositional equivalent of basalt. Composed of calcium, feldspars, pyroxene and possibly olivine but contains little if any quartz.

Gallon: test is used to measure the discharge from a hand pump. How many liters per second (1 Gallon = 3.78541 liters)

Glass: Amorphous (without crystal structure) igneous rock that forms from rapidly cooling magma (molten rock) not allowing time for crystal formation

Granite: A course grained, intrusive igneous rock composed mostly of light coloured minerals. Granite is thought to be one of the main components of the earths crust and one of the most common rocks on Earth.

Gravel: Sedimentary particles of any composition that are over 2mm in diameter.

Gravity: Gravity pulls water down toward the centre of the Earth. That means the water on the surface will try to seep into the ground.

Ground water: Groundwater can be found almost everywhere. The water table may be deep or shallow; and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise, or an extended period of dry weather may cause the water table to fall. Ground water moves slowly in the same direction that the water table slopes.

Ground water contamination: As ground water flows through an aquifer it is naturally filtered. This filtering combined with long residence time underground means the ground water is free from disease causing microorganisms. Groundwater can be contaminated by landfills, latrines, leaky underground gas tanks, and from over use of fertilizers and pesticides. When the material above the aquifer is permeable latrine waste, from latrines constructed close to a well, can infiltrate and contaminate the well water. Though generally not harmful themselves, the presence of faecal coliforms indicates contamination of water with faecal (latrine) waste. Faecal coliforms indicate that the water may contain other harmful or disease causing microorganisms, including bacteria, viruses, protozoa or parasites such as Giardia. Drinking water contaminated with these organisms is not safe to drink and can cause stomach and intestinal illness including diarrhea and nausea. These effects may be more severe and possibly life threatening for children, the elderly or people with immune deficiencies or other illnesses.
To avoid ground water contamination it is important to locate wells uphill from a latrine. A latrine should be a minimum of 15 meters from a well. A well should not be near a graveyard.

Ground water fluctuation arising from transpiration and evaporation: When the water table is close to the surface and unconfined, water transpiration and evaporation occur and can result in daily fluctuations of the water table. Transpiration is water passing out of plants and leaves and evaporation is the water vaporizing from moist soil. The maximum height of ground water is during the morning and as the day progresses it lowers. During the night it recovers.

Ground water fluctuation arising from atmospheric phenomena: Atmospheric pressure wind and rain cause fluctuations in the quantity of water in wells drawing from confined aquifers. The increase in the pressure of the atmosphere causes a decrease in the ground water flow.

Ground water levels in different regions. The height of the water table is affected by the climate of a region

Ground water flow- estimating the lowest dry season ground water flow: The quantity of rain is not an exact criteria for recording long term alterations in ground water levels. The quantity of ground water changes when the amount drawn off is greater than the quantity from the infiltration.

Ground water movement: Ground water moves through the joined pore spaces in the aquifer. The movement of ground water through an aquifer is extremely slow, generally of the order of centimeters per day or meters per year. Ground water like surface water flows towards and eventually drains into streams, rivers, lakes and the ocean. Ground water flowing in the aquifer underlying surface drainage basins however is not always flowing in the same direction as the water on the surface.

Ground water quality: We often think of water quality as a matter of taste, clarity and odour, and in terms of other properties which determine whether water is fit for drinking Most of these properties depend on the kinds of substances that are dissolved or suspended in the water. Pure water is tasteless and odourless. A molecule of water contains only two atoms of hydrogen and one atom of oxygen. Water is never found in a pure state in nature. The eventual quality of the ground water depends on temperature, and pressure conditions, on the kinds of rock and soil formations through which the water flows and possibly the residence time. The chemical nature of water continually evolves as it moves through the hydrologic cycle. The kinds of chemical constituents found in groundwater depend, in part, on the chemistry of the precipitation and recharge water. Groundwater can be contaminated by infiltration from landfills, latrines, leaky underground gas tanks, and from over use of fertilizers and pesticides.

Hard water: Has significant amounts of dissolved calcium and magnesium ions. Soap will not lather in hard water.

Hindu Kush: The major mountain range in Eastern Afghanistan.

Hydraulic conductivity: The ability of porous material to transmit a fluid.

Hydraulic cycle: The complete cycle of phases through which water passes, commencing as atmospheric water vapor, passing into liquid and solid form as precipitation, thence along or into the ground, and finally returning to the form of atmospheric water vapor by means of evaporation and transpiration.

Hydraulic gradient: Gradient of the water table measured in the direction of the greatest slope, generally expressed in meter per kilometer. The hydraulic gradient in an artesian aquifer is called the pressure gradient and is measured on the piezometric surface,

Hydrology: The science of earth's water, its movement, abundance, chemistry, and distribution on, above and below earth's surface.

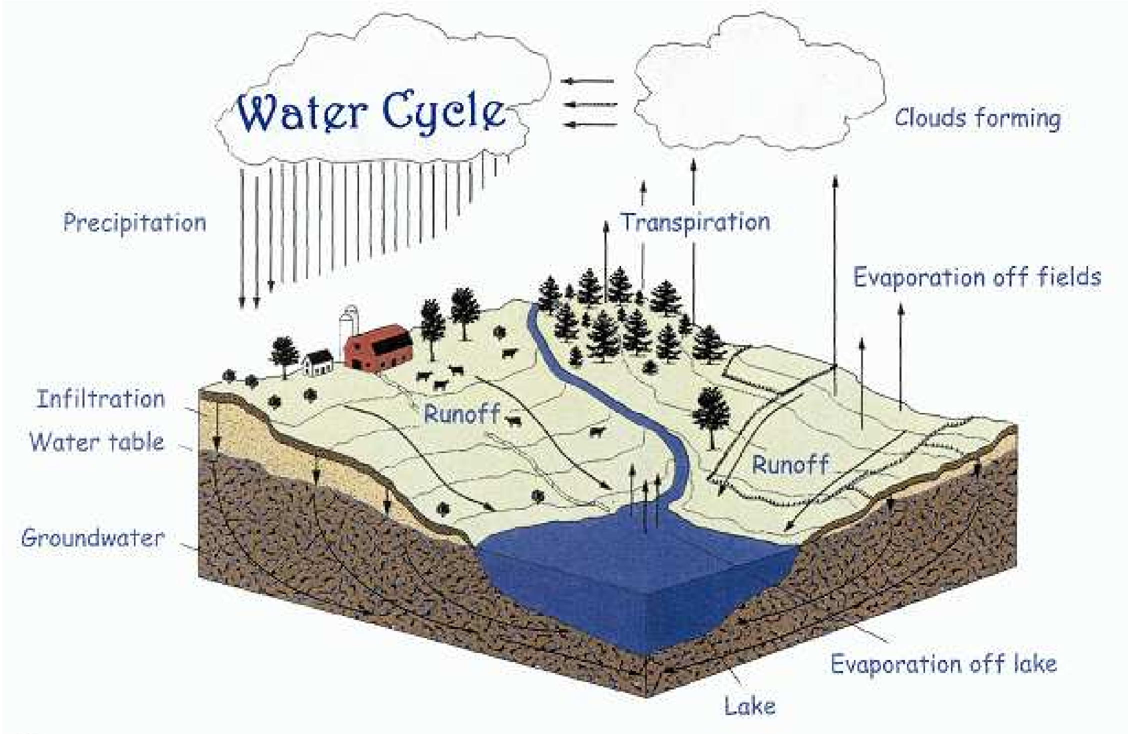
Hydrologic cycle: Is the cycle of water, precipitating from the clouds to the earth then evaporating mainly from the seas and other water sources on earth and rising back to the sky where it accumulates as clouds and condenses, precipitates and the cycle starts all over again. All fresh water, both above and underground, eventually comes from rain. "hydrologic cycle".

All the water of earth is in continuous circulation, as moisture and water on our planet. The heat of the sun evaporates water, mainly from the oceans, in to the atmosphere. The water vapor rises, and collects to form clouds. Under certain conditions, clouds condense and fall back to the earth as rain, or snow, the various forms of precipitation.

Precipitation that falls upon land areas, is the source of essentially all our fresh water supply. We depend upon it to replenish the quantity that is taken from lakes, streams and wells for man's numerous uses.

Some of this precipitation, after wetting the foliage and ground, runs off over the surface to streams. Another part soaks into the soil. Much of the water that enters the soil is detained in the plant root zone and eventually is drawn back to the surface by soil capillary action. Some of it, however, soaks below the plant root zone and under the influence of gravity continues moving downward until it enters the ground water reservoir.

Upon joining the body of ground water, the percolating water moves through the pores of saturated subsurface materials. Ground water can sometimes discharge naturally as surface water in some places; this is a spring. Springs maintain the flow of streams in dry periods. Streams and rivers eventually lead to the oceans.



Hydrogeology: The discipline that studies the movement of water underground and the origin and history of the rocks and soil it passes through.

Igneous rocks: Are formed from hot liquid rock. Igneous rocks are divided into two types magmatic and volcanic. Magmatic igneous is found under the earth's crust. Volcanic igneous rocks are formed from lava

Infiltration: The movement of surface water vertically through porous soil. The more openings in the surface (cracks, vents, pores, joints, chimneys, rock fractures) the more infiltration occurs.

Interstice: An opening or void in a rock. Interstices may be filled with any type of gas or liquid but in an aquifer are usually filled with water.

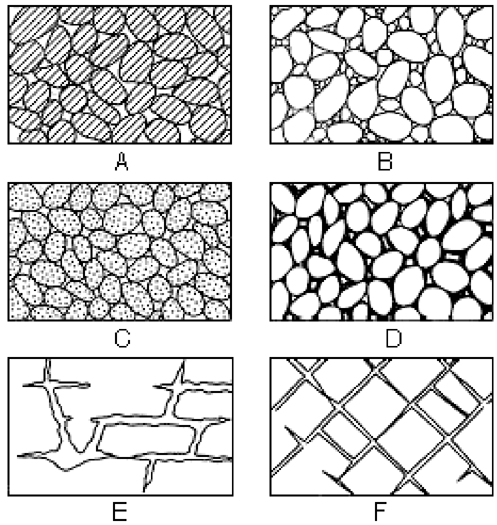


Diagram showing several types of rock intensities and the relation of rock texture to porosity. A. Well-sorted sedimentary deposit having high porosity; B. poorly sorted sedimentary deposit having low porosity; C. Well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; D. well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; E. rock rendered porous by solution; F. rock rendered porous by fracturing. (From Meinzer, 1923).

Impermeable layer: A layer of material (clay, solid rock) in an aquifer through which water does not pass.

Impervious rocks: Are rocks that cause barriers to the movement of water

Kareez: An ancient man made construction consisting of a series of wells joined by an excavated underground canal through which water gradually flows.

Lava: Hot liquid rock that is forced out when a volcano erupts.

Limestone: Sedimentary rock consisting of at least 50% calcium carbonate (CaCo2) by weight.

Magma: Very hot liquid rock found below the earth’s surface (lava: liquid rock that comes out of a volcano).

Metal: Type of solid mineral substance that is usually hard and shiny and that heat and electricity can travel through.

Metamorphism: Alteration of the minerals, textures and composition of a rock caused by exposure to heat, pressures and chemical actions.

Metamorphic rocks: Rock caused by exposure to heat, pressures and chemical actions.

Mineral: A naturally occurring inorganic solid with definite chemical composition and an ordered chemical structure. Minerals are not formed from animal or vegetable matter.
Examples gold and salt.

Moh's hardness scale mineral categories: 1. Talc 2.Gypsum 3.Calcite 4.Fluorite 5.Apatite 6.Orthoclase 7.Quartz 8.Topaz 9.Corundum 10.Diamond

Obsidian: Is a black rock that looks like glass. Is an igneous rapidly cooling mineral in which lattices did not develop.

Oil shale: dark coloured shale containing an unusual amount of solid organic matter. When heated can release gaseous and liquid hydrocarbons.

Open channel pump test: Used to measure the discharge of a spring, river or stream. If the section of the channel is uniform, straight, and rigid, it is ideal for the estimation of discharge A small channel that is straight and uniform approximately 10 – 20 meters long is made. . A mean value of the area of the cross section of the length of the channel to be used for the study is determined. This area is multiplied by the mean velocity of flow to give the discharge. The velocity of flow is determined by several methods. The simplest method is by a float. A small piece of wood or any floating body is thrown in the middle of the channel. The object is timed with a stopwatch to record how long it takes to travel the distance. The ratio of distance, S, in meters to time T in seconds, is the surface velocity
Discharge Q = Area x Velocity
Area = $\pi \times r^2$ Velocity = Discharge/Area

Ore mineral: A mineral that contains a high enough concentration of a useful element or compound that the element or compound can be extracted at a profit. An example is rock from which oil for petroleum is extracted.

Particle size The diameter, in millimeters, of suspended sediment or bed material.
Particle size classifications are

1. Clay: 0.00024-0.004 millimeters (mm);
2. Silt: 0.004-0.062 mm;
3. Sand: 0.062-2.0mm;
4. Gravel: 2.0-64.0mm

Pathogen: A disease producing agent; usually applied to a living organism. It generally describes any virus, bacteria, or fungi that cause disease.

Permeable: Capable of transmitting water (porous rocks, sediment, or soil).

Permeability: Allows water to pass through. The holes, cracks or spaces are joined together giving the water a passage to move through. Permeability is determined by the size of the spaces and the degree of inter-connectedness between the spaces. Permeability measures are expressed in units of velocity such as centimeters per second and assume a gradient of one foot of drop per linear drop.

Permeability
Permeability is a measure of a soil's or rock's ability to transmit water. Often the term hydraulic conductivity is used when discussing groundwater and aquifer properties.

Permeability differs from porosity because the void has to be interconnected to allow water to pass. We said before that a rock is porous when contains voids: if those voids are not connected with each other, in order to form channels, water can not pass, and the permeability, that is the capacity of a rock to allow water to pass, is low.

For example, clay has high porosity and low permeability because pore spaces are not well connected. Clay often creates confining layers in the subsurface.
In rocks with fractures, there can be high permeability if the openings are large and are well connected.

Material	Permeability or Hydraulic Conductivity (cm/s)
well-sorted gravel	10-2 to 1
well-sorted sands	10-3 to 10-1
silty sands, fine sands	10-5 to 10-3
silt, sandy silts, clayey sands, till	10-6 to 10-4
clay	10-9 to 10-6

Tab 03 - Permeability Ranges for Sediments (C.W. Fetter)

Petrology: The study and description of rocks, including their mineral composition and texture.

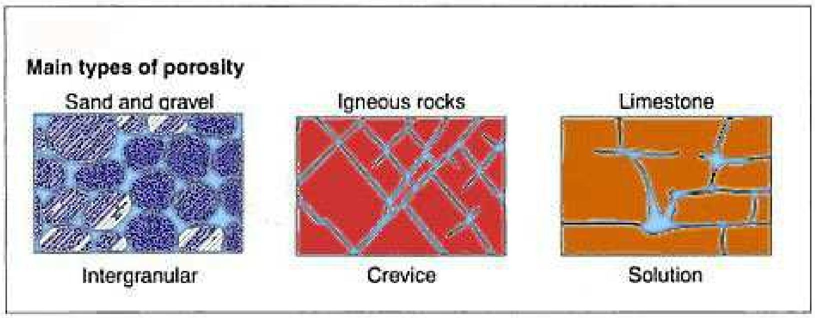
pH: a relative measure of the acidity or alkalinity of water based upon a scale that ranges from between 0 and 14 with 7 being neutral. Values of pH below 7 indicate acid solutions and values of pH above 7 indicate basic solutions.

Placer deposits: contain economically significant concentrations of mineral particles. Gold, magnetite and diamonds can be found in placer deposits.

Pollutants: In areas where material above the aquifer is permeable, pollutants can sink into the groundwater. Groundwater can be polluted by landfills, latrines, leaky underground gas tanks, and from overuse of fertilizers and pesticides.

Porous rock: A rock is porous when it contains voids: if those voids are not connected to each other, in order to form channels, water can not pass, and the permeability, that is the capacity of a rock to allow water to pass, is low. Some very porous materials are not permeable. For example Porous media where the grains are not cemented to each other are called unconfined aquifer If the grains are cemented together such aquifers are called consolidated.

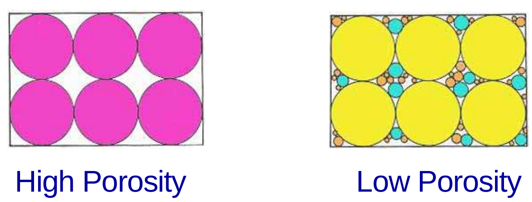
Porosity: Porosity or pore space is the amount of air space or void space between soil particles or in a rock or sediment. It is usually expressed as a percentage. Infiltration, ground water movement and storage occur in these spaces. The pore spaces can include openings between grains, fracture openings and caverns. Some very porous materials are not permeable because even though there are many spaces the spaces are not joined up and the water cannot move along. Clay, for instance, has many spaces between its grains, but the spaces are not interconnected enough to permit free movement of water.



Where groundwater can be found. It fills the spaces between sand grains, in rock crevices, and in solution openings.

Porosity measurement: The porosity of soil or geologic materials is the ratio of the volume of pore space in a unit of material to the total volume of material.

A mathematical equation of porosity looks like this: Porosity or $n = V_{void}/V_{total}$ Porosity is often expressed as a percentage of rock or soil void of material, so multiply the answer by 100.



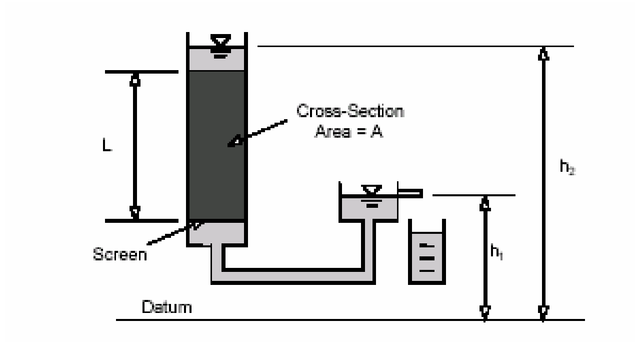
What could happen when smaller particles are mixed with larger particles? As the diagram shows, the smaller particles could fill in the void spaces between the larger particles, which would result in a lower porosity.

Not all particles are spheres or round. Particles exist in many shapes and these shapes pack in a variety of ways that may increase or decrease porosity. Generally, a mixture of grain sizes and shapes, results in lower porosity.

Material	Porosity (%)
well-sorted sand or gravel	25-50
sand and gravel, mixed	20-35
silt	35-50
clay	33-60

Tab 02 - Porosity Ranges for Sediments *(Based on Meinzer (1923); Cohen (1965); and MacCary and Lambert (1962))*

Darcy's law: This very simple law is the base of all the well hydraulics.
The movement of water though a porous medium (underground) can be described using Darcy's law.



$$V_D=ki$$

Where: V_D is Darcian Velocity

k is Permeability

i is hydraulic gradient (□h/L)

In other words, the speed of water depends on the permeability of the media and the load!

V_D is called Darcian velocity because it is not the true velocity of water in the medium. We have learnt already that the water moves only through the voids of the rocks. Voids are only one part of all rock, and the ratio between the volume of voids and the total volume is defined porosity:

$$n=V_{void} / V_{total}$$

it means that the true velocity of water in the media is:

$$V=ki/n$$

This very simple law is the base of all the well hydraulics.

Piezometric surface: As generally used, the pressure indicating surface of an artesian aquifer:

Pumice: Pumice comes from a volcano is a light grey colour has many hollows and is very light in weight. It has a very low specific gravity. Sometimes low enough to float in water.

Quartz: A mineral that occurs in sedimentary, metamorphic and igneous rocks. Quartz is one of the most abundant minerals in the earth's crust. One of the index minerals in Moh's hardness scale. Quartz has a hardness of seven and chemical composition of S1O 2. Quartz is often in crystal form and is used to make very accurate clocks and watches.

Quartz Arenite: Sandstone that is made up almost entirely of quartz grains.

Quartzite: A rock formed from the metamorphism of sandstone.

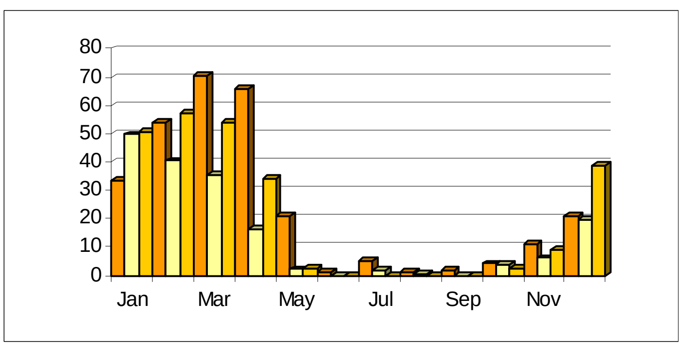
Rainfall in Afghanistan: Afghanistan is a land locked mountainous country, with semi arid to high mountain climate and the average total precipitation varies from 100 mm in the southern deserts to a 1000 mm per year in the Hindu Kush the North-Eastern Mountains.

The rain season starts in November-December and ends in April-May.

Measured in millimeters per month

Cities	Jan	Feb	Mar	April	May	J	Jul	Aug	Sep	Oct	Nov	Dec	
Kabul	33.2	53.6	70.3	66	20.7	1	4.9	1.3	1.5	4	11	20.9	289.3
K'har	49.6	40.3	35.5	16.2	2	0	1.9	0.5	0	3.7	6	19.3	174.3
Herat	50.5	57.1	54	33.9	2.6	0	0	0	0	2.4	9	38.4	243.8

Regional climate and rainfall: The landforms of central and southwest Asia range from steppe (grassland with few trees) to desert, with large areas of the region receiving little to no precipitation.
In Iran and Afghanistan, the precipitation primarily falls as winter storms moving eastward from the Mediterranean. The clouds move from the Mediterranean over the deserts of Iran, Western Afghanistan (Farah, Nimroz, Helmand, Uruzgan etc) and precipitation occurs when the clouds reach the cooler air of the Hindu Kush Mountains
This wintertime precipitation generally occurs between the months of November and April.
In the eastern and northern mountain regions of Pakistan, the primary rainfall season is summer. The rainfall over Iran and Afghanistan is generally suppressed during this time. In summer dust storms are prevalent through much of the region and often associated with the "wind of 120 days" which blows from north to south.



WHEN does it rain in Afghanistan?
-Pre-drought situation
⇐

WHERE does it rain? ⇓

Rain Shadow: Is an area that misses out on rain after clouds precipitate

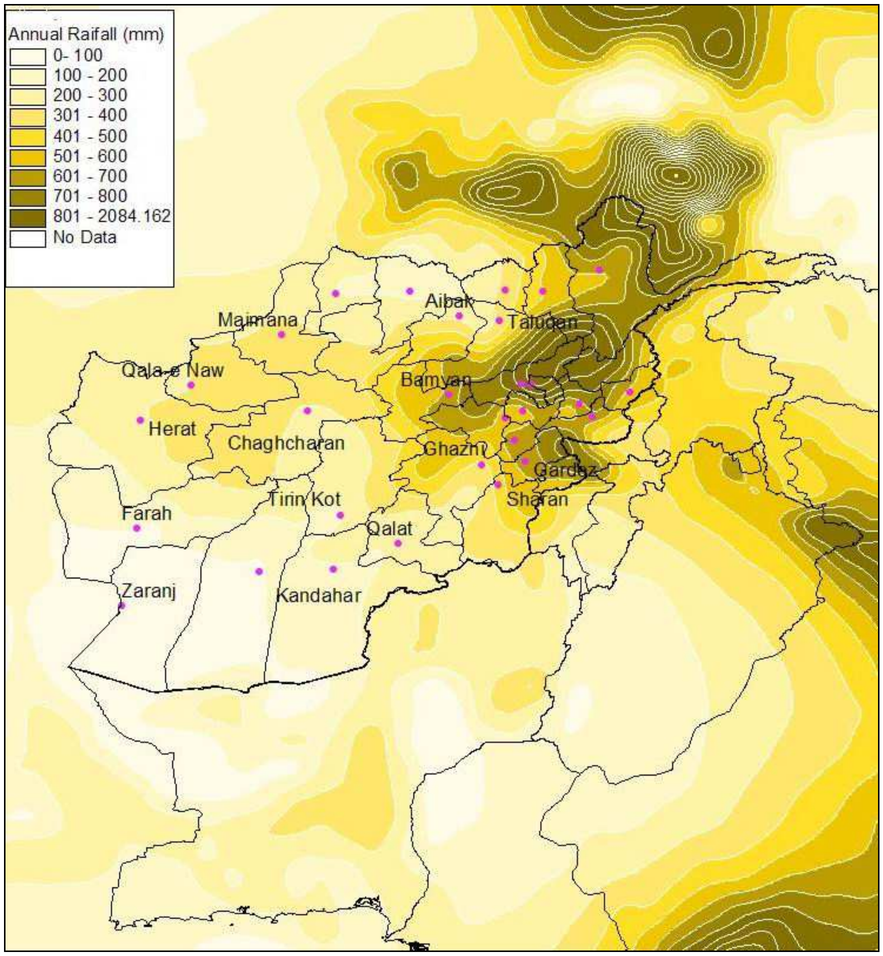
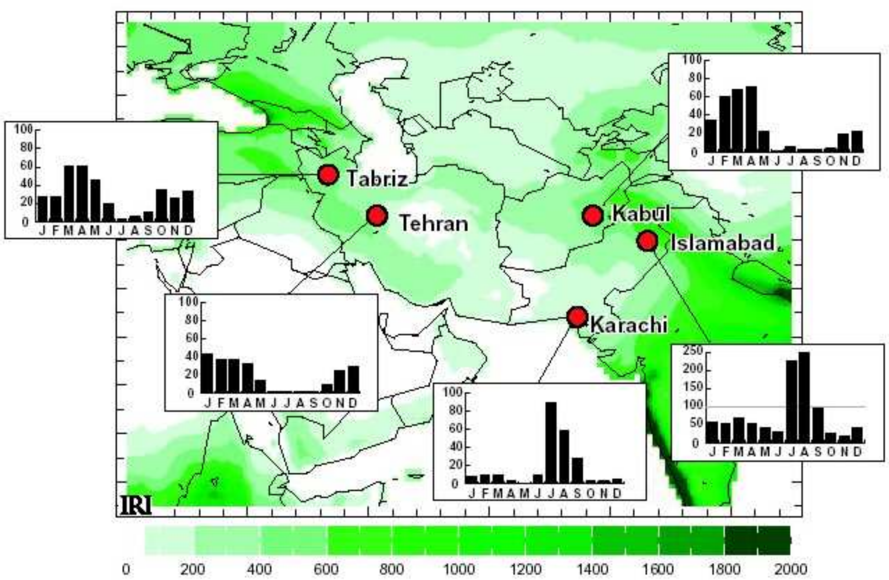


Fig.02 – Average rainfall in Afghanistan (data: USGS – map: DACAAR)



Amount of monthly precipitation in southwest of Asia (Internet)

Recharge: Water added to an aquifer or other water body. An aquifer is recharged by precipitation in an area where the aquifer has porous connection to the surface.

Rivers: Rivers often lose part of their water underground. The yield of a river can be ¼ above the surface and ¾ just below the surface. When a river is dry there is often water a few meters just below the surface. In Northern and Southern Afghanistan most rivers do not reach the sea because they lose all their water underground. Close to a river there is a good probability to find good water in the wells. A river has a bed load of sediment, a suspended load, and dissolved load.

Runoff: Water that is not absorbed into the earth's crust but enters streams, rivers lakes, dams, or the sea.

Salt: Sodium chlorine is referred to as table salt to distinguish it from other chemical salts The salts in water are dissolved and in solution and consist of sodium, salt, calcium carbonate, bicarbonate, sulfate and acid

Salinization: The condition in which the salt content of the soil accumulates over time to above normal levels; occurs in parts of Afghanistan where water containing high salt concentration evaporates from fields irrigated with standing water.

Saline water: Water that contains significant amounts of dissolved solids.
USGS parameters
Fresh water: Less than 1,000 parts per million (ppm)
Slightly saline water: From 1,000 ppm to 3,000 ppm
Moderately saline water: From 3,000 ppm to 10,000 ppm
Highly saline water: From 10,000 ppm to 35,000 ppm.

Saturation Zone: The portion below the earth's surface that is saturated with water is called the zone of saturation. The upper surface of this zone, open to atmospheric pressure, is known as the water table.

Sediment: Usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the water of streams, lakes, or seas.

Sedimentary rocks: Rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock, sand, stones or mud, transported from their sources and deposited by water; (2) rocks formed by or from secretions of organisms, such as most limestone.

Shale: A sand stone hardened by metamorphism it transmits water poorly. Shale splits easily into layers.

Silt: Sedimentary material

1. Clay: 0.00024-0.004 millimeters (mm);
2. Silt: 0.004-0.062 mm;
3. Sand: 0.062-2.0mm;
4. Gravel: 2.0-64.0mm

Spring: A spring is when ground water comes to the surface naturally. Springs maintain the flow of streams in dry periods. A spring is a localized natural discharge of ground water issuing on the land surface through well-defined outlets. The discharge may vary from a trickle to a stream. If water merely oozes out of the surface without distinct outlets the discharge is termed a seep. See Handout 2.1

Storage: Water stored in openings in the zone of saturation is said to be in storage. Discharge of water from an aquifer that is not replaced by recharge is said to be from storage

Static water level: The top level of ground water before pumping commences. After pumping the water level drops and the static water level eventually returns

Surface water: Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater, and run off.

Thermal pollution: An increase in water temperature from a coal fired power plant must be returned to a stream at the same temperature that it was withdrawn. If it returned still hot it is known as thermal pollution.

Transpiration: The process by which water absorbed by plants (usually through the roots) is evaporated into the atmosphere through the plant surface or leaves.

Transmissivity: A measure of the amount of water that can be transmitted horizontally by the fully saturated thickness of the aquifer under a hydraulic gradient of 1.The transmissivity of a rock is its capacity to transmit water under pressure. The coefficient of transmissibility is the field coefficient of permeability multiplied by the saturated thickness, in feet, of an aquifer.

The transmissivity of
Gravel is 10 meters per day
Sandstone 1 meter a day
Fractured Limestone is100 meters per hour

Unconfined aquifer: Is an aquifer that has the aeration zone above it where capillary action taking place. It is not under pressure like an artesian aquifer.

Unconsolidated aquifer: Is made of unconsolidated material. Material in the aquifer is not cemented together it is made of loose materials such as sand, pebbles and gravel.

Water (H_2O): An odorless, tasteless, colorless liquid made up of a combination of hydrogen and oxygen. Water forms streams, lakes, and seas, and is a major constituent of all living matter.

Water-bearing rocks- Several types of rocks can hold water, including: sedimentary deposits (sand and gravel) channels in carbonate rocks (limestone), lava tubes or cooling fractures in igneous rocks, and fractures in hard rocks.

Water resources and their importance

Water quality: An assessment of the physical, chemical and biological characteristics of water, especially how they relate to the suitability of that water for a particular use.

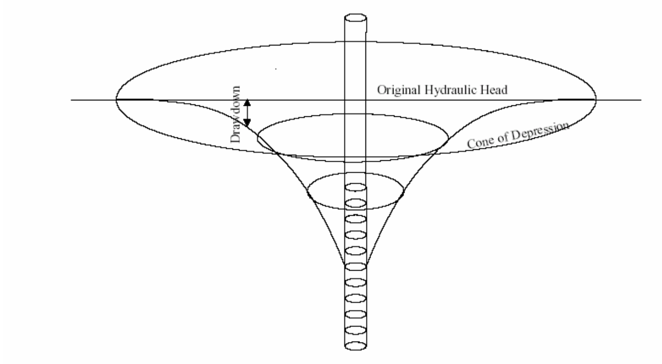
Water quality standard: recommended or enforceable maximum contaminant levels of chemicals or materials (such as nitrite, iron, and arsenic) in water. WHO have recommended different levels as standards.

Water table: When we dig down the place where we first hit water is called the water table. Below this level the soil and rock are saturated with water. This level is also known as the static water level.

Wells: A well is a pipe in the ground that fills with groundwater. This water then can be brought to the surface by a pump. Shallow wells may go dry if the water table falls below the bottom of the well. Some wells, called artesian wells, do not need a pump because of natural pressures that force the water up and out of the well

Annex 2 --Well hydraulics

What Happens when the Pump Is Turned On?
When the pump is turned on, the water level drops in the well and in the aquifer adjacent to the well being pumped. The drawdown is the decline of water level observed in the well and the aquifer being pumped. The amount of drawdown is at a maximum at the well being pumped and diminishes to zero some distance away. The region affected by drawdown from pumping is called the cone of depression (figure 04). The size of the cone of depression and the drawdown will increase until there is a balance between the pumping rate and the flow into the well from the surrounding aquifer. Once the pump is turned off, the cone of depression reduces in size and water levels will recover to near pre-pumping levels as flow continues to move into that portion of the aquifer affected by drawdown. This process is called “Recovery”.



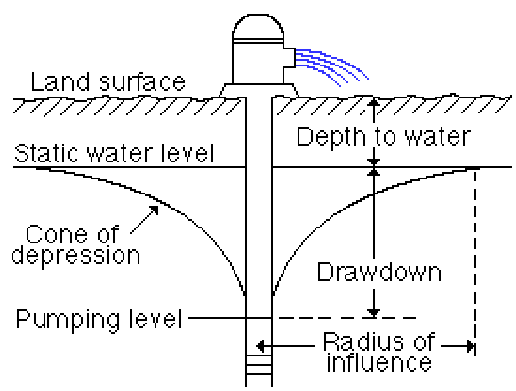
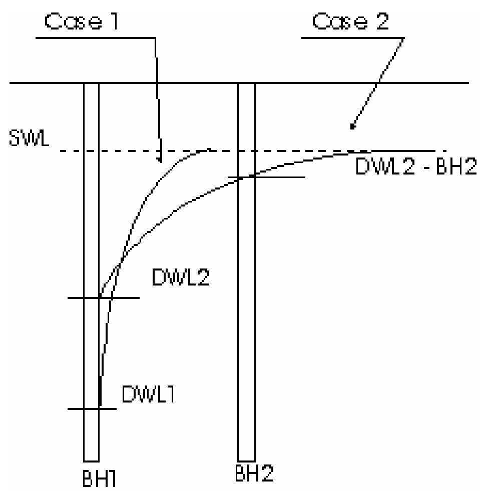


Figure 04--Cone of depression resulting from drawdown from pumping. (Internet)

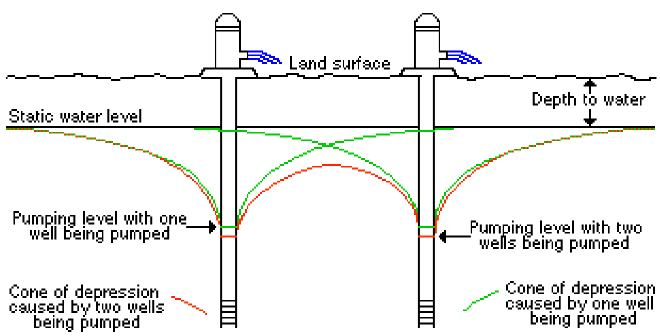
The size of the cone of depression and the amount of drawdown depend on the pumping rate and the ability of the aquifer's material to transmit water to the pumping well. The aquifer's ability to transmit water to the well is directly related to its permeability (the capacity of a porous material for transmitting a fluid) and total thickness. Aquifers that are more permeable and have greater thicknesses allow larger volumes of water to flow toward the pumping well.

Depression cone
Every borehole, when pumped, creates a “depression cone” in the water table around it. The shape and dimension of this depression cone can be calculated with

great precision having appropriate pump test data and litho-stratigraphies (the drilling log) of the boreholes involved.
The drawing below illustrates what physically happens:
In this case we have 2 boreholes: BH1 and BH2. SWL is common to the two boreholes, as long as they are drilled in the same aquifer. BH1 is pumped,



so that the water level will drop in the hole to the DWL (dynamic water level). The shape of the depression cone depends on the characteristics of the aquifer: in case 1 (deep DWL, narrow cone) we have a small permeable aquifer, in case two (shallow DWL, large cone) we have a very permeable aquifer. It is clear that in this case BH2 can be influenced, being the SWL disturbed (or in the so called influence area of BH1). The extent of the cones varies with the yield and the time of pumping, getting bigger (with an inverse logarithmic low) with time. When pumping stops, the cones reduce and after the recovery time the static water level returns and the cones disappear.



(RS, Internet)

Annex 3--Pump tests:

Once a well is completed you can check its performance by performing a pump test. The pump test is a wells quality control.

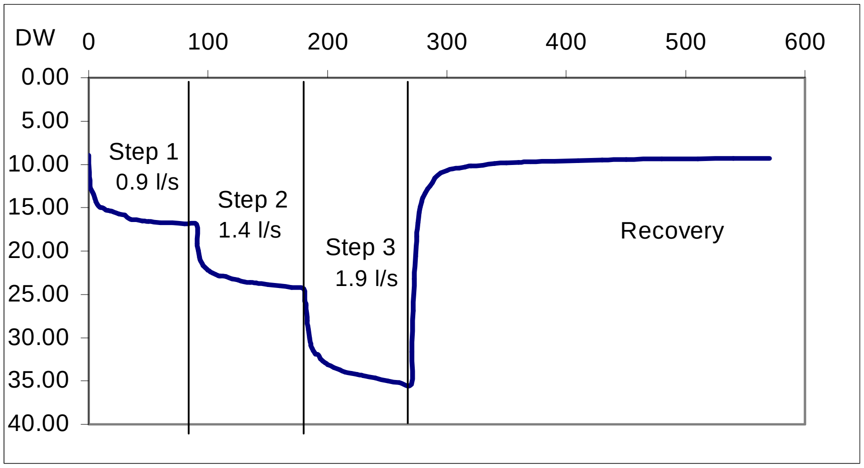
Transmissivity and Storativity
The dimension and the dynamic of the depression cone depends on the characteristic of the aquifer, and specifically:

Transmissivity (T): A measure of the amount of water that can be transmitted horizontally by the fully saturated thickness of the aquifer under a hydraulic gradient of 1. This is a product of the hydraulic conductivity and the saturated thickness of the aquifer.

Storativity (S) : The volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head. It is a dimensionless quantity.
.
There is practical reasons why pump tests are performed, and there are practical reasons why every well should be pump tested.
When a pump (even a hand pump) is started, the level of water in the well drops, initially very fast, and then slower and slower, with a logarithmic law. After constant pumping for some time the level of the water in the well stabilizes. If you increase the pumping rate the level drops again, with the same modalities. When you stop pumping, the water comes back to the Static Water Level (SWL) with the same modality: very fast at the beginning, than slower and slower, until the initial level is restored.

In practical terms, given the yield of the pump we install (i.e. hand pump) we want to know how much the level of water in the well will drop during pumping, and avoid the pump going dry by setting the pump lower than that depth. We also want to know how long the water table takes to come back to the original level when we stop pumping.

Step test (Multi Stage Pumping Test, MSPT)
We learnt that the DWL changes with time, and with the yield. So, if we start pumping to a certain yield (i.e. 0.5 l/s) for some time, the water will drop, initially very fast and then slower until certain stabilization occurs. If now we increase the yield, the DWL will drop again, and so on. When we stop the pump, the water will come back.



(RS)

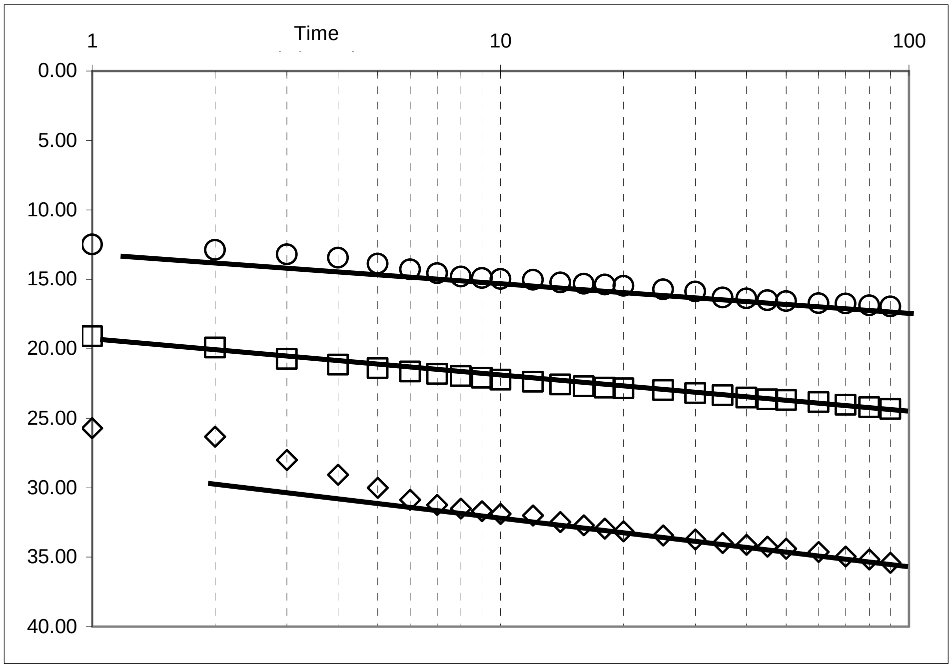
This is an example of a true pump test. This kind of test is called “Step Test”.
SWL was 8.97 m. The pump was started at 0.9 liters per second. The level of water dropped very fast and then slower and slower, with a logarithmic law. After 90 minutes the DWL was stabilized at 16.95 m, with a drawdown of 7.98 m (16.95-8.97). After 90 minutes the yield of the pump was incremented to 1.4 l/s. What was the DW after 180 m?
Then a last step was taken. Was the DWL stabilized? See the data below.
After 3 steps of 90 minutes, the pump was stopped and the residual DWL measured. It can be noticed that it took app. more 4.5 hours to come back to the original level.

When a well is pumped for some time, it takes approximately the same time to come back to original conditions after the pump is stopped.

This is only an approximate and general rule, with many exceptions: how long did it take in fact to come back to the SWL, in this example?

1 Step		**2 Step**		**3 Step**		**Recovery**	
Time (min)	DWL (m)	Time (min)	DWL (m)	Time (min)	DWL (m)	Time (min)	DWL (m)
0	8.97						
1	12.50	91	19.10	181	25.71	271	31.62
2	12.88	92	19.92	182	26.32	272	26.92
3	13.20	93	20.73	183	28.00	273	23.19
4	13.44	94	21.15	184	29.07	274	20.6
5	13.88	95	21.41	185	30.00	275	18.36
6	14.29	96	21.65	186	30.87	276	16.74
7	14.57	97	21.81	187	31.23	277	15.56
8	14.79	98	21.97	188	31.49	278	14.82
9	14.90	99	22.10	189	31.69	279	14.29
10	14.97	100	22.22	190	31.89	280	13.86
12	15.04	102	22.38	192	32.00	282	13.28
14	15.23	104	22.57	194	32.47	284	12.87
16	15.32	106	22.70	196	32.71	286	12.5
18	15.38	108	22.80	198	32.94	288	12.12
20	15.48	110	22.85	200	33.14	290	11.6
25	15.72	115	22.97	205	33.44	295	11
30	15.87	120	23.20	210	33.73	300	10.69
35	16.30	125	23.35	215	33.97	305	10.49
40	16.37	130	23.52	220	34.10	310	10.42
45	16.50	135	23.64	225	34.23	315	10.32
50	16.58	140	23.70	230	34.39	320	10.17
60	16.71	150	23.85	240	34.63	330	10.08
70	16.74	160	24.03	250	34.95	340	9.93
80	16.87	170	24.2	260	35.17	350	9.84
90	16.95	180	24.34	270	35.41	360	9.76
						370	9.7
						390	9.65
						410	9.54
						430	9.5
						450	9.46
						480	9.38
						510	9.34
						540	9.3
						570	9.28

We said that the water drops with logarithmic law: it means that if we make a chart with time in logarithmic coordinates, we should have a straight line. Is it true?
Let us try to plot the above data in a semi-logarithmic chart! (A semi-logarithmic chart has linear units in Y direction and logarithmic units in X direction)



The three steps have been plotted in a semi-logarithmic chart. We can notice some things:

- Points fit very well with a straight line
- The slopes of the lines are different. The higher the yield, the higher the slope
- There are some points, off the line or not exactly on the line: can you give an explanation to this?

The fact that the points fit a line tells us that, to <u>some extent</u>, given the yield we can predict the level of water in the well. The DWL appears to have stabilized, but continues to drop[18], just so slowly that we don't notice it.

The slope of the line is the rate at which the water drops in the well. It means that, if we increase the pumping rate, the DWL in the well will increase and drop faster. We can conclude that there is a limit to the yield that we can extract from a well.

Having this information is a practical reason why we perform step tests: to learn the maximum yield we can extract from a well? And at what depth should the pump be installed to safely extract this yield? We can call this information the "equation of the well".

Specific drawdown, specific capacity and well equation

We observed that the higher the yield, the higher and faster the DWL drops. In technical terms, we know that the Specific drawdown increases with the yield. We can also tell the same thing saying that the Specific capacity decreases with the yield.

Specific drawdown: How many meters does the water drop in the well if I pump out one cubic meter (1,000 liters) per second?

[18] Unless a recharge limit is reached

Specific capacity: it is the reciprocal of the specific drawdown. How many liters per second do I get with 1 m drawdown? In which units is it expressed?

As a general rule: high permeability, high specific capacity!

Well equation: it gives the drawdown a<u>fter a specific time</u>, (in our case: 90 minutes), for each yield. Well equation is:

$$DD= AQ + BQ^2$$

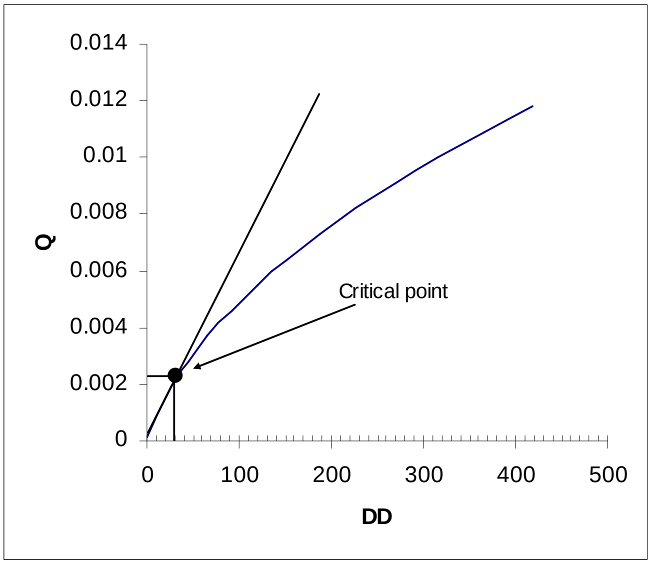
Being	DD	drawdown	(m)
	Q	yield	(m^3/s)
	A		(s/m^2)
	B		(s/m^5)

In our well, A= 9 806 (s/m^2) and B = 2 175 439 (s/m^5)

A depends on the formation (i.e. Transmissivity and Storativity), but B depends on how the well is constructed! Filters, gravel pack, etc. You can also calculate the efficiency of the well,. If a well is badly constructed, it can be discovered!

As seen below, the well curve is a parabolic curve. We can calculate the drawdown for each yield.

We can make some approximations.



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Practical conclusions

The calculation of the exact specific drawdown and well equation needs specific techniques that will be part of a further training in pump testing. For the time being let us try to understand what those things means.

We have seen that the well equation gives us drawdown for every yield. In the early stages it can be approximate to a straight line. <u>It means that for little yields (i.e. hand</u>

pump) we can consider the specific capacity as constant. The point at which this approximation is too big is called Critical point. In our case we have a critical point at 30 m of DD with a yield is app. 2.3 liters per second. Normally we should always pump maximum 80% of the critical point (for this well, 2 l/s). We also know what if we want to pump 2 l/s, we have to install the pump at least @ 30 m of depth (below SWL!). So, at what depth in our well?

We have a practical problem: when we drill say 100 wells in one area, we have to decide how deep those wells has to be to give enough water for our hand pumps. We saw that each well has its own characteristics that can be summarized in a simple well equation. But we don't have the well equation of each well; neither can we think to perform a pump test in each. But we know something: we install always the same kind of pump, the AFRIDEV hand pump. The yield of this pump is always the same19: 600 liters per hour (0.16 litre). We also can assume that in a certain area the conditions are similar, so we can estimate what is the average, approximate specific capacity of the wells. So we know that, to safely get our 0.16 l/s, we need the pump to be at least 10 m below the SWL.

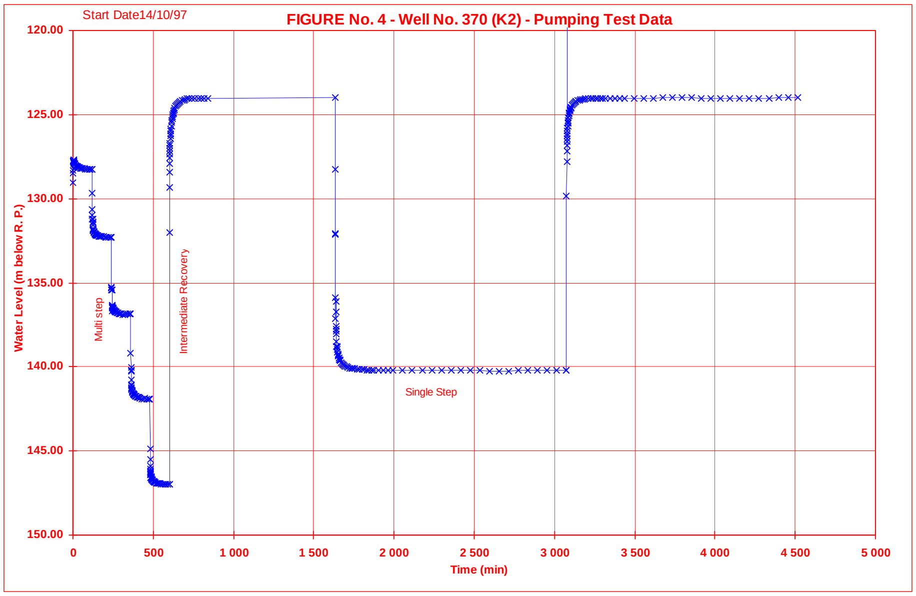
DACAAR standard for a silty terrain in Afghanistan is 10 m below the SWL. Now you know from where this number comes from.

What happens when the users of a well complain that, after a while, the pump goes dry, and they have to wait some time to get water back? It means that the specific capacity of the well is low, we don't have enough meters below SWL to feed the pump with 0.16 l/s, so the DWL reaches the pump, and we have to wait for recovery (how much?) before pumping again. It could be that the well is badly constructed (high B in the equation), but maybe also that the specific capacity of the area is lower than expected (A). If all other wells in the area are all right, the well is badly constructed. Otherwise, if it is a common problem, Drill the next wells deeper, even more than the 10 meters of the strategy! If you have a good drilling log, you should check to see if the conditions of this specific well are different, less sand, more clay to justify the lower specific capacity. If you encounter a good permeability layer (i.e. gravel), the specific capacity at that point will also be very good. That is why it is so important to keep a good drilling log, and put the filters just in front of good layers!

Duration test (Single Stage Pump Test, SSPT)
A duration test (also called single stage pumping test, SSPT) is a test that normally follows the step test, and is performed at 80% of the critical yield. A standard test is 72 hours, but can vary from 24 hours to some weeks.

The main purpose of this test is to determine the characteristics of the Aquifer (T,S) and the variation far from the well (if the depression cone is very big, and is influenced by variations that can be also be very far). Another reason why these very expensive tests are performed is to determine the recharge of the aquifer.
The analysis of these tests is quite long and it is far from the objective of this course. You can see an example of a complete pump test for a large production well. MSPT was 5 steps of 120 minutes, and single stage was performed @ 100 l/s.

[19] In fact we know that it depends on how strong the user pumps the handle. 600 l/hour it is the maximum value.



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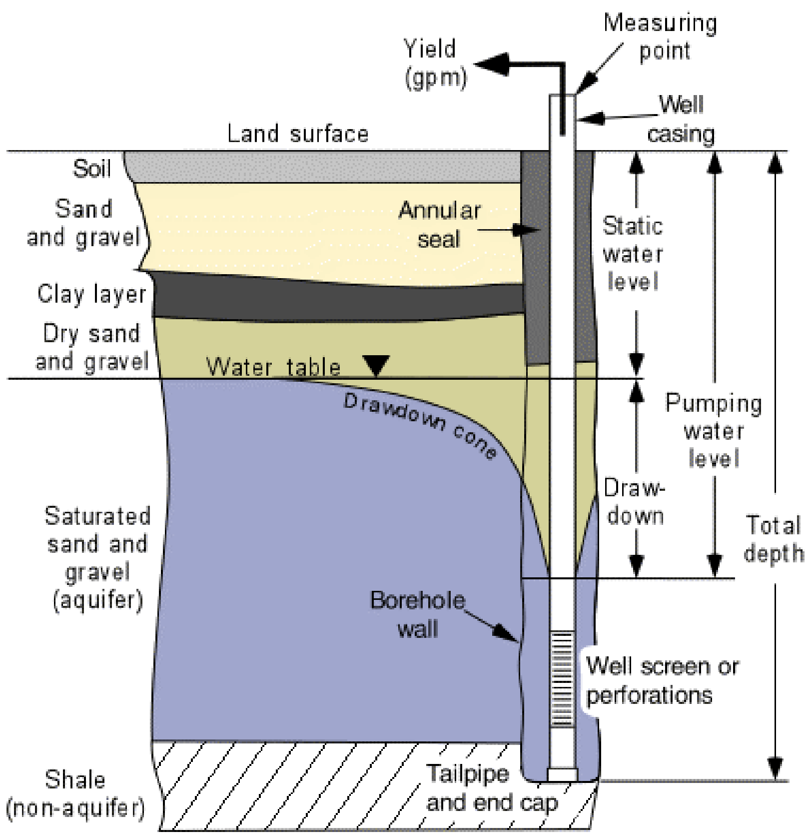

Fig. 05 – Sketch of a well being pumped.

Annex 4— Groundwater quality

DACAAR, Introduction to Basic Hydrogeology v l.l May 2003 Pages 13-16

We often think of water quality as a matter of taste, clarity and odour, and in terms of other properties which determine whether water is fit for drinking. Most of these properties depend on the kinds of substances that are dissolved or suspended in the water. Pure water is tasteless and odourless. A molecule of water contains only hydrogen and oxygen atoms. Water is never found in a pure state in nature. Both groundwater and surface water may contain many constituents, including microorganisms, gases, inorganic and organic materials.

The chemical nature of water continually evolves as it moves through the hydrologic cycle. The kinds of chemical constituents found in groundwater depend, in part, on the chemistry of the precipitation and recharge water.

One of the most important natural changes in groundwater chemistry occurs in the soil. In its passage from recharge to discharge area, groundwater may dissolve substances it encounters or it may deposit some of its constituents along the way. The eventual quality of the groundwater depends on temperature and pressure conditions, on the kinds of rock and soil formations through which the groundwater flows, and possibly on the residence time. In general, faster flowing water dissolves less material. Groundwater, of course, carries with it any soluble contaminants which it encounters.

Scientists assess water quality by measuring the amounts of the various constituents contained in the water. These amounts are often expressed as milligrams per liter (mg/l), which is equivalent to the number of grams of a substance per million grams of water.

As groundwater flows through an aquifer it is naturally filtered. This filtering, combined with the long residence time underground, means that groundwater is usually free from disease-causing microorganisms. A source of contamination close to a well, however, can defeat these natural safeguards. Natural filtering also means that groundwater usually contains less suspended material and undissolved solids than surface water.

Bacteriological quality

Abstract from :

"*WHO Guidelines for Drinking-Water Quality 3 – Preface – Chapter 1 DRAFT – 17 February 2003*"

The potential health consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised.

Coliforms are several different types of bacteria that exist in the intestines of warm blooded animals and are found in bodily waste, animal droppings, and naturally in soil. Coliform bacteria are described and grouped, based on their common origin or characteristics, as either total or faecal coliforms. The group of total coliforms includes faecal coliform bacteria, such as Escherichia coli (E.coli), as well as other types of coliform bacteria that can survive in soil and vegetation.

Total coliforms do not necessarily indicate recent water contamination by faecal waste; however the presence or absence of these bacteria in treated water is often used to determine whether water disinfection is working properly.

Faecal coliforms are bacteria that are present naturally within the bodily waste of all warm blooded animals and most species are not capable of survival outside the body of a warm blooded animal for a long period of time. The presence of faecal coliforms usually indicates recent contamination of groundwater by human sewage or animal droppings, which could contain other bacteria, viruses, or disease causing microorganisms. Other than a laboratory test, there is no way to tell if these microorganisms are present, as they do not change the appearance or taste of water.

Sources of total and faecal coliforms in groundwater can include:

- Agricultural run-off
- Effluent from septic systems or sewage discharges
- Infiltration of surface water contaminated with faecal matter from wildlife
- Poor well site selection, maintenance and construction (particularly shallow dug wells) can also increase the risk of bacteria and other harmful microorganisms getting into a well water supply.

Though generally not harmful themselves, the presence of faecal coliforms indicates contamination of water with faecal waste that may contain other harmful or disease causing microorganisms, including bacteria, viruses, protozoa or parasites such as Giardia. Drinking water contaminated with these organisms can cause stomach and intestinal illness including diarrhoea and nausea. These effects may be more severe and possibly life threatening for children, the elderly or people with immune deficiencies or other illnesses.

Disinfection

Disinfection is of unquestionable importance in the supply of safe drinking-water. The destruction of microbial pathogens is essential and very commonly involves the use of reactive chemical agents such as **chlorine**. Chlorine can be easily monitored and controlled as a drinking-water disinfectant, and frequent monitoring is recommended wherever chlorination is practiced.

The use of chemical disinfectants in water treatment usually results in the formation of chemical by-products. However, the risks to health from these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection should not be compromised in attempting to control such by-products.

High levels of **turbidity** can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria, and give rise to a significant chlorine demand. Turbidity is given by suspended matter, such as silt or clay, and this gives color to water.

Chemical quality

Abstract from:
"*WHO Guidelines for Drinking-Water Quality 3 – Preface – Chapter 1 DRAFT – 17 February 2003"*
As chemical contaminants are normally associated with adverse health effects only after long-term exposure, they are considered a lower priority category than microbial contaminants.

There are many chemicals that may occur in drinking-water; however only a few are of immediate health concern in any given circumstance. Chemical contaminants in drinking water should be prioritized both for monitoring and for remedial action to ensure scarce resources are not unnecessarily directed towards those of no health concern (See Chemical Safety of Drinking-water: Assessing Priorities for Risk Assessment).

- Exposure to high levels of naturally occurring **fluoride** can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
- Similarly, **arsenic** may occur naturally, and excess exposure to arsenic in drinking-water may result in a significant cancer risk.
- Other naturally occurring chemicals of health concern include **uranium and selenium**.
- The presence of **nitrate and nitrite** in water, causing methaemoglobinaemia in infants, may result from the excessive application of fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater.
- In areas with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated **lead** levels in drinking-water, which may cause adverse neurological effects in children.
- **Sodium** is often naturally found in groundwater. Sodium is a principal chemical in bodily fluids, and it is not considered harmful at normal levels of intake from combined food and drinking water sources. However, increased intake of sodium in drinking water may be problematic for people with hypertension, heart disease or kidney problems that require them to follow a low sodium diet
- **TDS (Salinity)** Total dissolved solids (TDS) can have an important effect on the taste of drinking-water. Drinking-water becomes increasingly unpalatable at TDS levels greater than 1200 mg/litre. The indicator for salinity is the Electroconductivity.
- **pH**: Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters.

Acceptability aspects

Water should be free of tastes and odours that would be objectionable to the majority of consumers.

In assessing the quality of drinking-water, consumers rely principally upon their senses. Microbial, chemical and physical water constituents may affect the appearance, odour, or taste of the water and the consumer will evaluate the quality and acceptability of the water on the basis of these criteria. Water that is highly turbid, is highly colored, or has an objectionable taste or odour may be regarded by consumers as unsafe and may be rejected for drinking purposes.

In extreme cases, consumers may avoid aesthetically unacceptable but otherwise safe supplies in favor of more pleasant but potentially unsafe sources of drinking water.

Annex 5--Earth's Water: (Hydrology)

The earth is mainly a planet of water. Oceans cover about three-fourth of the earth surface, and account for 97% of all the water on this planet.
But water in the oceans is very salty (33 g/l) and cannot be used by life on the surface.

Water available for human kind is the fresh water present in lakes, rivers and streams. The total of this water, from a global point of view, is only 0.18% of the total. But fresh water is also found underground (groundwater), and the total of water underground is 50 times more than the water on the surface!

	Quantity of water (Km^3)
Oceans	1340
Ice caps	24
Groundwater	10
Surface water	0.18

Total Salty water	1340
Total Fresh water	34.18

Table 01 – Distribution of water on earth

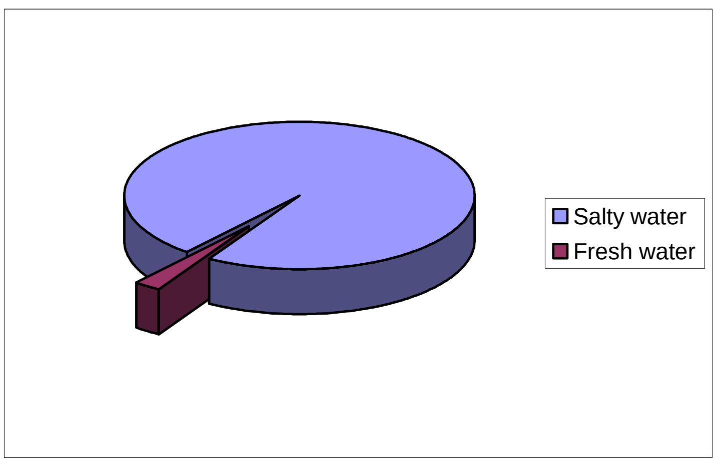

Chart 01 – Distribution of water on earth

Annex 6 -- Sealing and back filling of a tube-well:

When a tube well is being bored in a marshy area or stratum that contains salty water, to avoid mixing unpleasant or salty water with clean water the upper strata should be blocked.
The blocking of strata is done with pure clay. Pure clay is moistened sufficiently to roll into1 kg weight balls. The clay balls are dropped into the well to block the unwanted stratum.

The depth of the sealing depends on the depth of the undesirable stratum. During the clay packing operation the drilling casing should be drawn out slowly simultaneously with the clay packing procedure. When the clay packing procedure is finished the tube well should remain undisturbed for a maximum of 24 hours or at least 10 hours to settle the clay pack.

The back filling of the tube well is done with ordinary soil up to the ground level. When doing the back filling the drilling casing is drawn out gradually.

Basic Hydrogeology Training Course Handouts

Handout, A: Participants Profile

Handout, B: Schedule

Handout, C: Pre test

Handout, D: Course Evaluation Form

Handout, E: Introduction and Objectives

Handout, 1: Water Resources, Conservation and Development.

Handout, 1.1: Hydrogeology and Hydrologic Cycle.

Handout, 2: Wells, Aquifers, Rocks, Porosity and Permeability.

Handout, 2.1: Springs, Kareez and Pumping Tests

Handout, A

MRRD/DACAAR

Basic Hydrogeology Training Course

For Water and Sanitation Engineers
Date: / / 2005

Participants' Profile

Name:

Designation:

Qualification:

Age:

Sex: M F

Work Experience with MRRD etc

Areas of Specialization (Program/ Project)

Major Training Courses Attended

Signature

Handout C

Basic Hydrogeology Training Course
For
Water and Sanitation Engineers

After Training Pre-Test

اسم:__________ والایت:________ وظیفه:__________ موسسه:_______

تاریخ: ______/____/_______ تسهیل کننده : ___________________

سوالات

۱. اصطلاحات ذیل را تعریف نماید؟

a) هایدروجیولوجی (Hydrogeology)
b) بارنده گی (Precipitation)
c) جریان (Runoff)
d) (Evaporation) و (Transpiration)
e) نفوذ (Infiltration)

۲. طبقات آبده چیست و به چند نوع است ؟
۳. چند نوع چاه و چشمه را می شناسید نام ببرید ؟
۴.تخلخل (Porosity) و قابلیت نفوذ (Permeability) چیست ؟
۵ . زمانیکه پمپ فعال میشود چه اتفاق می افتد ؟

Schedule for Basic Hydrogeology Course

Day1	Day1	Day1	Day1
Trainers	**Objective**	**From**	**To**
AL and SShamal	**Course opening introduction And objectives**	**0830**	**1000**