WATER SOURCES AND THEIR PROTECTION

A guide to Community Water Source Protection

and

Designs for a Spring Protection and Well Digging Programme

by

Nick Rogers

based on the experiences of the OXFAM/ UNHCR South Sudan Water Team '83-'85

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For the successful protection of a water source and its subsequent maintenance the diseases and the paths through which the diseases are passed from one person to another need to be understood. Unless this occurs the physical protection will have difficulty succeeding due to lack of interest, and after the water source is physically protected diseases will still be spread due to the lack of awareness of the maintenance and care necessary.

Diseases passed by to water cause 8 out of every 10 diseases in man. They are passed mainly from the excreta of someone who is sick and then washed or somehow transported into water which is then drunk by numerous other people who get sick.

The causes of these diseases are so small that we cannot see them, but if the way they are passed from one person to another is understood then it is possible to prevent them.

Healthy living requires safe drinking water. Dirty and contaminated water can kill.

The very minimum requirements for living is 10 litres for each person every days (this is 1/2 jerrycan of water). For healthy living, drinking, and washing, 25 litres for each person every day is required (this is 1 1/4 jerrycans of water).

Therefore both quality and quantity are essential.

Contents:

Part 1.

The first 5 Chapters are for use where technical advice and assistance is not available.

These Chapters can be used to understand and to explain how diseases are passed by water and then gives a step by method for the protection of a spring or for digging a shallow well (down to a maximum of 8 metres).

These Chapters could be used by:

Community leaders
Community Health workers
Community Development officers
Teachers ....

Part 2.

The last 5 Chapters explain further techniques and designs for use in spring and well protection programmes and to train technicians. Part 1 though should also be understood in this case.

Chapter 1.

DISEASES

It is far easier, and prevents a lot of suffering, illness, and death, to prevent diseases, rather than having to cure them after they have occurred.

Prevention is better than cure

What is a disease?

Diseases are caused by very very small bacteria and organisms (living things) which together can be called germs. These germs are so small that they can only be seen by using a microscope (an instrument that makes very small objects look larger). Some germs can be seen, such as certain worms.

These germs attack a person's body making him or her ill. Once the germs are in a person's body there is a battle between the invading germs and the body's defenders which try to combat the attackers.

There are 3 possible outcomes of this battle:

1. The body's defenders attack the invading germs and after a sickness the invading germs are killed and the person gets better.

2. Additional body defenders in the form of specific medicines are added to the body, which may or may not be successful in killing the invading germs.

3. The body's defenders (perhaps including medicines) are outnumbered and the germs win, making the person constantly sick or causing death.

Whatever happens there is sickness, pain, a lack of energy and possible death.

Some diseases can be passed from a sick person to a healthy person - these are called Infectious Diseases. Other diseases cannot be passed, these are non-infectious diseases.

Here we are concerned with Infectious Diseases passed by water.

What we are trying to do is fight against something we cannot see and is hidden from view. If someone is attacked by a snake or a lion then they will defend themselves. Everyone is being attacked by these small germs and it is necessary to defend ourselves against these attacks.

Identifying Diseases

This is possible by identifying the changes which occur in the body when it is sick. These changes are called symptoms.

If someone is suffering from the diseases refered to in this Chapter then it is best to inform the local health worker. Maybe though there is not enough time, as is the case with dehydration.

Dehydration

If a person is losing a lot of liquid from his or her body because of diarrhoea (frequent watery faeces) or dysentery (faeces with mucus and blood in them) then dehydration is likely to occur.

Dehyd-ation is when a persons body does not have enough water in it to continue to work. Small children especially, die from dehydration. These deaths can be prevented by adding water to the body.

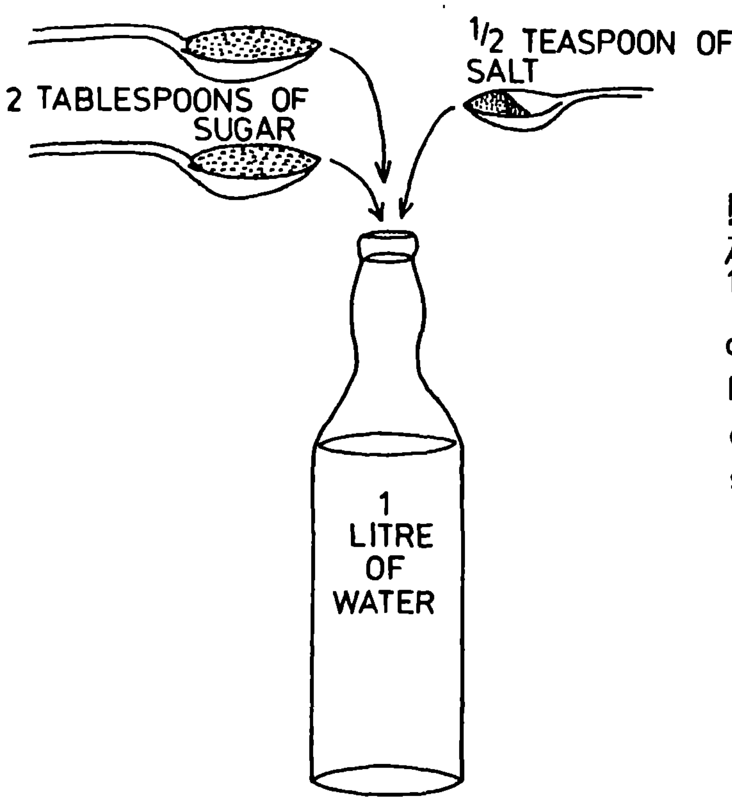
Symptoms of dehydration are:

1. Little or no urine, or urine is brown.
2. Sudden weight loss.
3. Dry mouth.
4. Sunken tearless eyes.
5. Sagging in of the 'soft spot' in very young children. The spot is just above the forehead.
6. The skin when lifted between two fingers does not fall back to normal.

Treatment of dehydration is:

Give the person large quantities of liquid to drink, such as : water, tea, soup ... and so on.

Give the person a rehydration drink (see below) every 5 minutes, day and night until he or she starts to urinate normally.



REHYDRATION DRINK

Add 2 tablespoons of sugar and 1/2 teaspoons of salt to 1 litre of water (boiled, if time allows). Before giving the drink taste it and be sure it is no more salty than tears.

How are diseases spread by unsafe water and what are the diseases?

There are 4 possibilities:

1. Diseases carried by water.
2. Diseases caused by a shortage of water.
3. Diseases passed by an animal which lives in water.
4. Diseases passed by insects which breed and live near water.

1. Diseases carried by water.

Examples: Cholera, Typhoid, Hepatitis, Giardia and all gut diseases giving diarrhoea, worms, amoebas.

Cholera

Can effect numerous people at once and should be reported to local health worker immediately.

Symptoms:

1. Diarrhoea like rice water
2. Vomiting
3. Dehydration

Typhoid

Symptoms:

1. Cold or flu with headache and sore throat
2. Body temperature rises each day
3. Diarrhoea
4. Weakness and loss of weight
5. Pink spots on body
6. Difficulty in controlling body movements
7. Mind wanders

Hepatitis

Symptoms:

1. Loss of appetite
2. Nausea (want to vomit)
3. Pain on right hand side of the body below the ribs
4. The eyes and skin turn yellow
5. Urine becomes orange or brown
6. Faeces become whitish

Giardia

Symptoms:

1. Yellow bad smelling, frothy (full of bubbles) diarrhoea
2. No blood, no mucus (thick slimy liquid), no fever
3. Swollen painful guts
4. Not regular diarrhoea

Worms

Threadworm (thin white and 1 cm long) and roundworm (white or pink and 20 to 30 cm long). Can sometimes be seen in the faeces.

Symptoms:

1. Itching around anus especially at night
2. Large swollen guts

Amoebas

Symptoms:

1. Diarrhoea with mucus and blood. Not all the time, sometimes with constipation
2. Pain in the guts
3. No fever
4. Lot of visits to latrine with no excreta passed

The germs causing these diseases are present in very large numbers in excreta, especially of someone that is sick. Excreta is therefore very dangerous.

These germs can get into a water source to then infect numerous other people, but to get into the water source they need to be transported there.

They can be transported by:

1. Rain which can wash excreta or small pieces of excreta carrying the germs over the surface of the ground or through the holes in the ground and into the water source. This is explained in the next Chapter.

2. People who accidentally stand in excreta and pick up germs on their feet and then stand in or near to a water source. Animals also carry diseases in this way.

3. People who do not wash their hands after excreting and then place their hands in a water source while collecting water. The germs can be passed from the hands onto a water container which is then put into a water source.

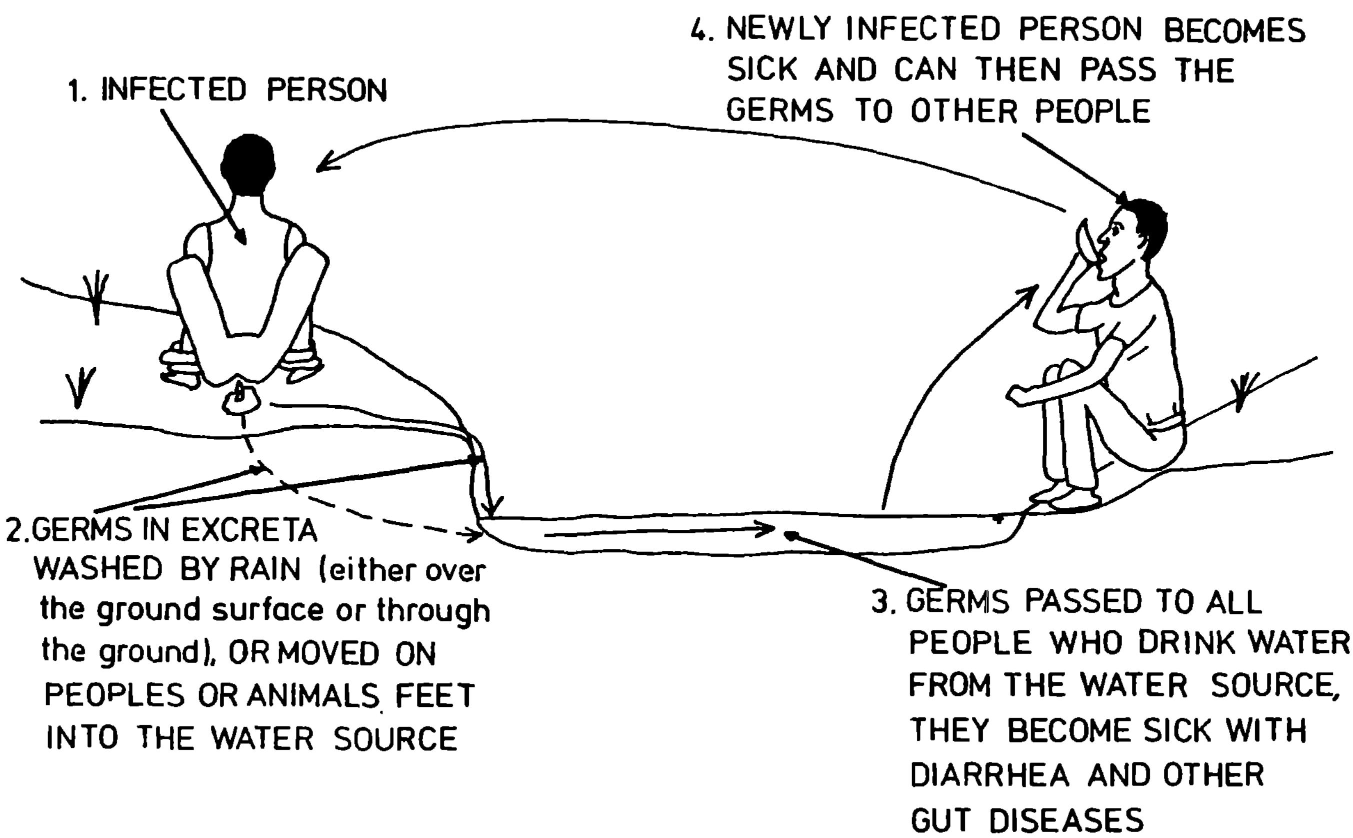


Diagram of how a Disease carried by water is passed

In broader terms these diseases spread due to poor sanitation (no pit latrines) and poor personal cleanliness. These diseases are easily caught and spread very quickly.

2. Diseases caused by a shortage of water.

Examples: Diarrhoeal diseases of amoebas, worms.

This can include all the diseases carried by water (group 1 as above) and is a result of the small organisms, worms and bacteria from the excreta being passed directly to the mouth on dirty hands, or from dirty hands onto food and then to the mouth. These diseases are passed due to not washing properly.

Not washing properly due to a shortage of water also causes the skin infections and eye diseases. These diseases remain in the dirt on the skin surface.

Examples: Scabies, trachoma, lice, typhus.

Scabies

Symptoms:

Itching bumps that appear all over the body,
especially: between the fingers
on the wrists
around the waist
between the legs

Trachoma

Symptoms:

1. Redness, pus and burning feeling in the eyues
2. Eyes stick together after sleep
3. Eventually blindness

<u>Lice</u>

Symptoms:

General body itching

<u>Typhus</u>

Spread by the bits from lice, ticks and rat fleas

Symptoms:

1. Bad cold
2. Fever chills and headache
3. Pains in the muscles and chest
4. Rash on the body and then on the arms and legs

These diseases are also caused where water is used again and again, to wash people and cooking utensils. This water does not clean properly.

<u>Diagram of how a Disease caused by a shortage of water is passed</u>

3. Diseases passed on by an animal which lives in water.

Examples: Bilharzia, Guinea worm.

Bilharzia

Symptoms:

1. Blood in faeces or urine
2. Pain in lower belly and between the legs
3. Low fever
4. General itching

Guinea Worm

Symptoms:

1. Very painful sore on the foot or leg
2. Sore becomes worse
3. Can make person unable to walk

These diseases can also pass from excreta into a water source, as above, or can be directly released into the water source. The organisms causing these diseases then pass into an animal which lives in the water, into a snail in the case of bilharzia and a flea in the case of guinea worm. In these animals the organisms multiply in numbers and are then released from the animal.

The bilharzia worms will attach themselves to the skin of someone washing or standing in infected water. They then make their way to the blood stream and are transported to the intestine. They can also be taken in when drinking, as is the guinea worm.

Care should be taken in stationary or slow moving water as this is where these animals tend to live and infection is most likely.

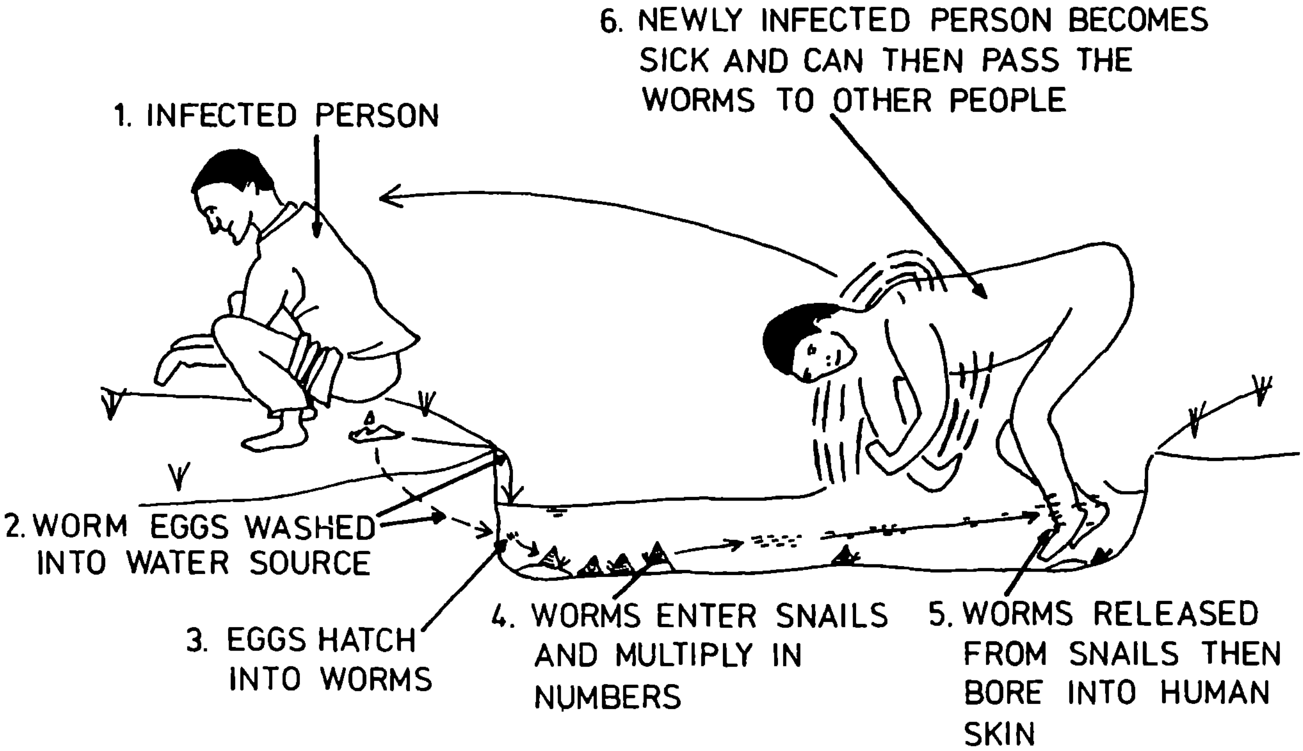


Diagram of how Bilharzia spreads

4. <u>Diseases passed by insects which breed in water and live near water.</u>

Examples: Malaria, Yellow fever, River blindness.

Malaria

Attacks of malaria last from a few hours every 2 to 3 days.

Symptoms:

1. Feel cold and have a headache
2. Shivering and shaking for 15 minutes to 1 hour
3. Fever, wandering mind, flushed red skin, body weak
4. Sweating and temperature goes down
5. Attack finishes.

Yellow Fever

Symptoms:

1. Fever with headache
2. Backache
3. Yellow skin and eyes
4. Diarrhoea

River Blindness

Symptoms:

1. In America, 3 to 6 lumps about 2 to 3 centimetres across on the upper body and head
   In Africa lumps on the lower body and thighs
2. Itching
3. Eyes become red and tearful
4. Difficulty in seeing clearly and painful eyes in bright light
5. Dry eyes, night blindness. Whites of the eyes become grey
6. Blindness.

These diseases are passed by insects, mainly mosquitos and flies.

The insects feed on the blood of an infected person and then feed on someone who is not infected. A small droplet of blood is then taken from the infected to the non-infected person, and it is in this blood that the disease is carried.

Mosquitos, which spread malaria, are most active near stagnant open water. Blackflies which spread river blindness are most active near fast flowing streams. The best way to prevent these diseases is to try to reduce the number of insects and so remove the carrier of the disease.

Mosquitos live part of their life as small worms called (larvae) floating just under the surface of stagnant water. At this stage they can be killed by putting a very small quantity of paraffin or soapy water on the stagnant water. This will prevent the larvae breathing. Or any stagnant water, even very small puddles, can be filled in or drained.

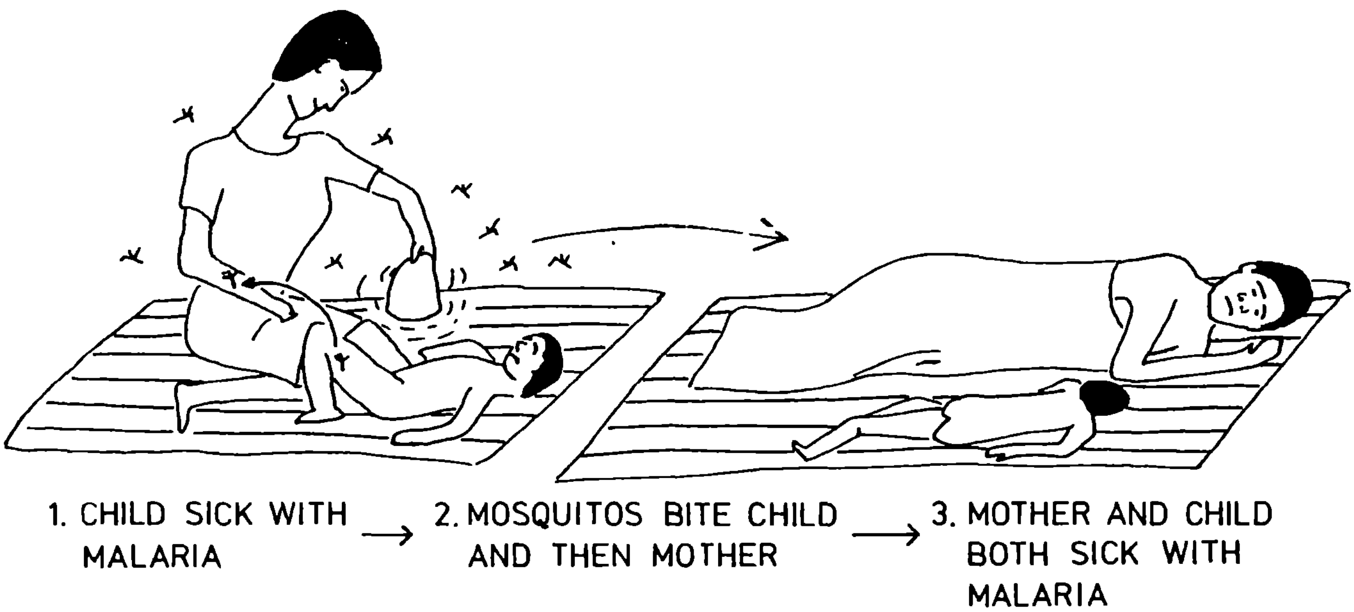


Diagram of how Malaria is spread

Blackflies which breed in fast flowing water can be reduced in numbers by clearing the bush and vegetation back from the river banks.

How can the spread of disease by water be prevented before technical advice and assistance is available?

1. Any excreting, pit latrines should be at least 50 metres from any water source.
2. Dig a diversion drainage channel to prevent any surface water from entering the water source.
3. Prevent animals from entering or getting near to a drinking water source. Put up a fence which preferably roots and grows.
4. Remove mud and vegetation from the water source. The mud can be banked 3-4 metres upslope and planted with grass.
5. Put logs across the water source so people do not have to stand in the water when collecting it. (And to prevent them doing so.)
6. Prevent water spilt while filling personal water containers from flowing back into the water source. The path from the source should lead downslope from the source for at least 10 metres.
7. Clean hands before collecting water. Not in the water source.
8. Put one container at the water source for use by everyone to fill their personal containers. This should be the only container ever to be put in the water. It should be hung up when not in use and not placed on the ground.
9. Wash clothes and bodies downslope of the water source.
10. Boil or filter water.
11. Read Chapters 2 and 3 and then protect the water source further.

Chapter 2.

WATER

Where does water come from?

The heat from the sun and the wind cause small droplets of water to be picked up into the air from any surface water such as: the sea, lakes, ponds, puddles; and from the soil surface and plants (this is called evaporation). The water rises at first as these small droplets which cannot be seen. These small droplets join together to form larger droplets which become visible as clouds. The clouds are moved by the wind and later release the water which falls as rain.

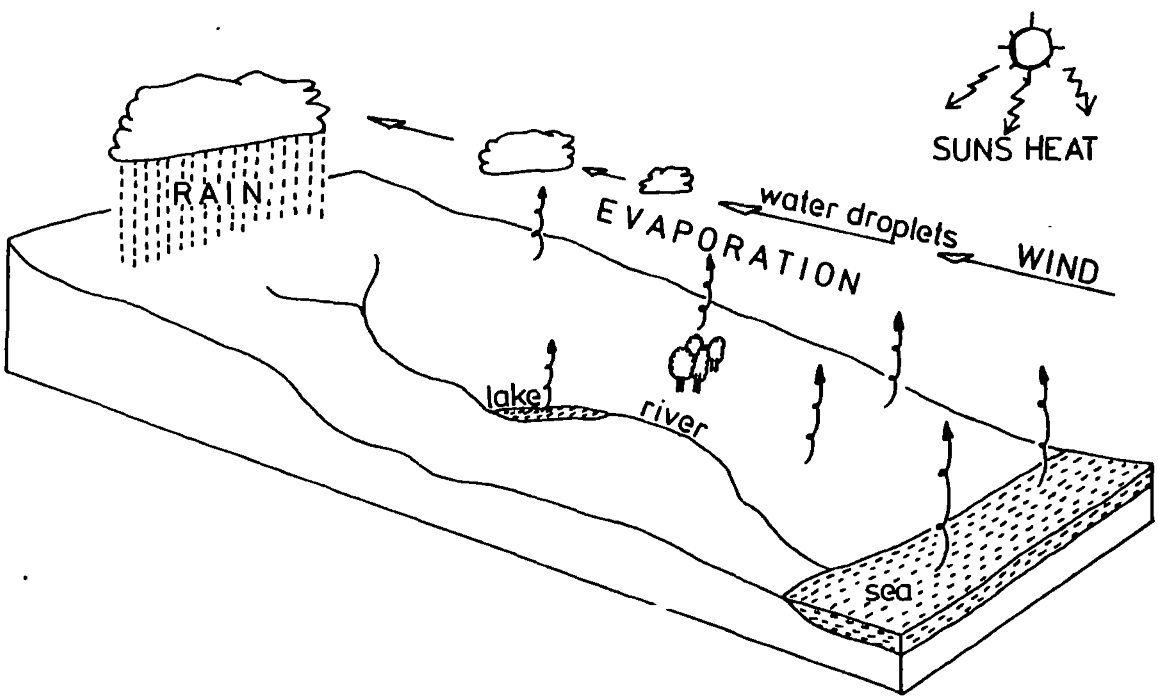


Diagram of where rain comes from

What happens to rain when it falls on the land?

There are 3 possibilities:

1. Evaporation. Water evaporates directly from the soil surface or from plants.

2. Run-off. Water flows over the surface of the land into small streams. These streams join together to form large rivers which flow into lakes or the sea or lakes.

3. Groundwater flow. Water seeps (infiltrates) into the ground and slowly flows through the ground as subsurface water (to be explained in this chapter). This subsurface water (sub means under) either comes to the surface again as a spring or it is held in the soil.

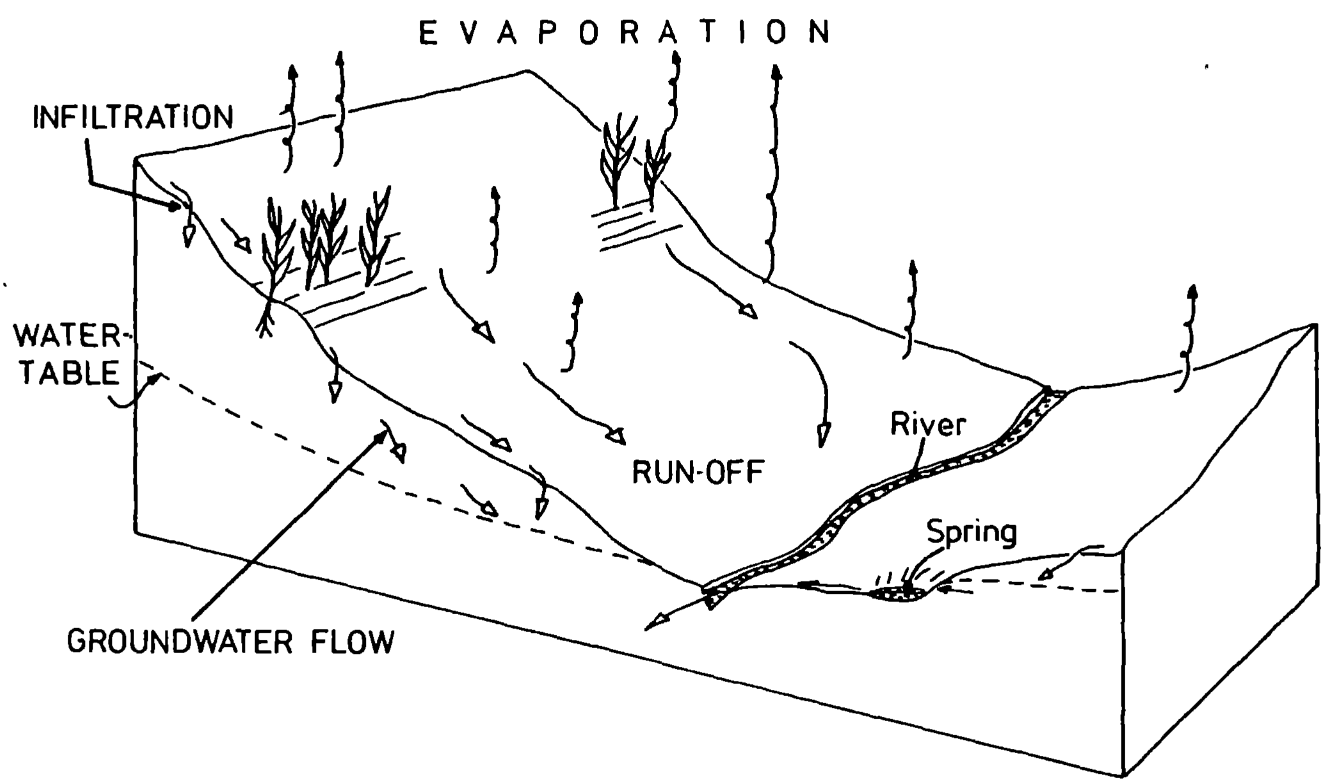


Diagram of what happens to rain when it falls on the land

How can water flow through the ground?

The ground is made up of very small pieces of clay, sand, stones, rocks and old and rotten plants.

In some parts of the ground all these pieces are loosely fitted together, so there are a lot of holes and spaces between the pieces which can be filled with air. These holes can also be filled with water. This water can be stationary or the water can flow through the holes. If water can flow through a soil it is called a permeable soil. A good example is sand.

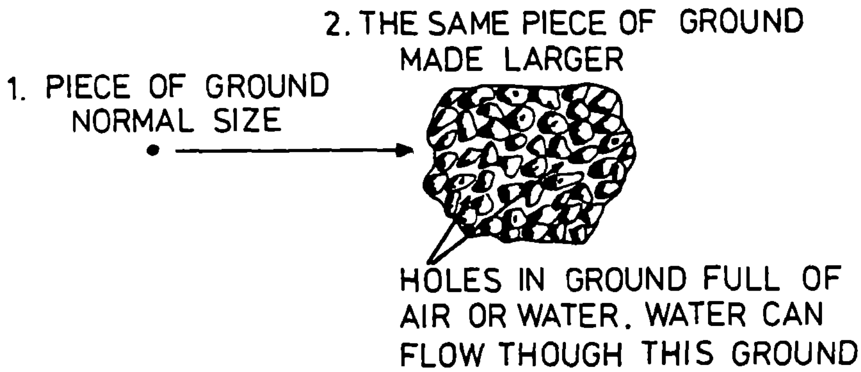


Diagram of small piece of permeable soil

In other parts of the ground the soil pieces are very closely packed so there are no air spaces. Water cannot get into or flow through these soils which are called impermeable soils, examples are clay or rock.

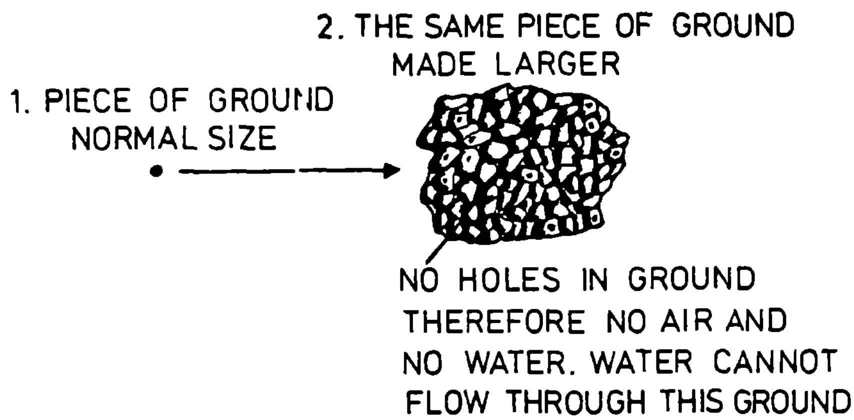


Diagram of small piece of impermeable soil

This gives an understanding of a small piece of soil over a very small area. If numerous of these small pieces are joined together it is possible to understand how the ground works over a larger area, and to see that water can pass through the ground.

As water flows through the ground it can wash out fine pieces of the soil and wear or erode a channel in the ground. These channels can run for many miles and come out as a spring.

The ground is made up of layers of permeable and impermeable soil, one on top of another.

At the ground surface and going down from a few centimetrs to about one metre there is the top soil. The top soil is where plants and trees root and grow and from which they extract most of the chemicals used to build a plant. This is the layer which is cultivated for food growing. This layer is permeable.

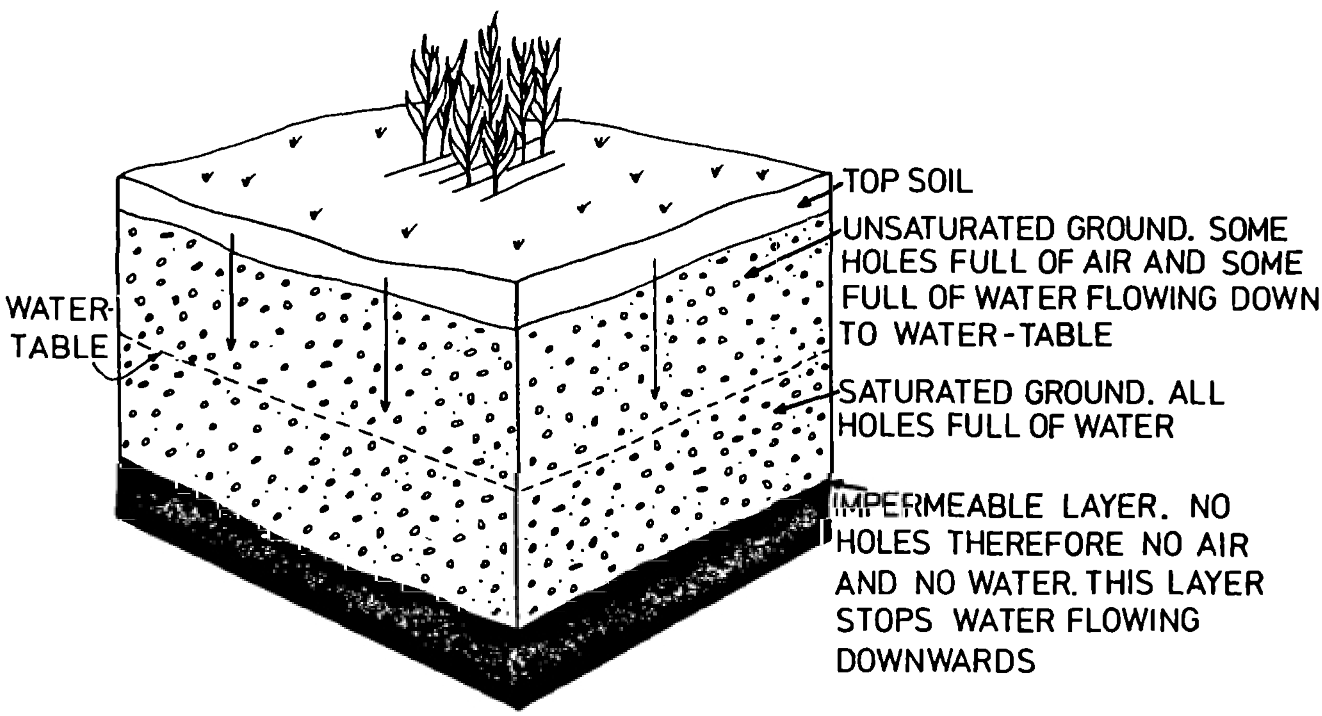
Below the top soil there is a layer called the subsoil. This layer is usually a few metres deep. It also is usually full of holes, and therefore permeable, and water is able to flow through it.

Underneath the subsoil there is a rock layer (called the bedrock) or a clay layer which is impermeable and will not allow water to pass through it.

Water (in this case the rainwater) always flows downwards or downhill from a higher level to a lower one. This can be seen by pouring water out of a bucket, the water will flow downwards out of the bucket onto the ground and will continue to flow downwards on the ground away from where it has been poured. Water if it does not flow downwards over the ground to a stream will flow downwards into the ground and into the holes in the permeable subsoil.

When the water reaches the bottom of the subsoil it cannot flow into the impermeable rock or clay layer as there are no holes so the water will do one of two things:

Water can collect in all the holes in the subsoil, above the impermeable layer. As more water infiltrates into the ground from the rain more and more of these holes fill up, until the whole area above the impermeable layer is full of water (if an area of ground is full up with water it is said to be saturated). The top of this saturated layer is called the water-table. Above the water-table there are still holes in the ground filled with air. Below the water-table all the holes are full of water.



<u>Diagram showing the top layers of the soil</u>

Water can flow away through the soil if the impermeable layer is not flat, in which case the water will continue to flow downwards. This water will eventually flow out onto the surface of the ground as a spring because the ground surface has dropped to the water-table, or the impermeable layer meets the surface of the ground and so the water naturally flows onto the surface as a spring.

On a larger scale, going down into the ground a few hundred metres, the ground can have numerous impermeable and permeable layers one on top of another.

The permeable layers are either confined (meaning trapped) below an impermeable layer, or unconfined, meaning there is no impermeable layer between this permeable layer and the ground surface.

Why does the water level in the ground change during the wet and dry season?

The water-table which marks the level of saturated ground changes because during the wet season rain is continually being added to the ground to maintain a higher water level. During the dry season there is no rain so the water-table level slowly drops to be at its lowest at the end of the dry season. Sumps/traditional sources which run dry in the dry season are therefore possible sites for digging for water.

The level will drop in the ground because the impermeable layer will not totally prevent water draining through it. There may be cracks in the water barrier, much as there can be cracks in water containers through which water can slowly pass.

What are the sources of water for humans?

There are 3 possible sources:

1. Rainwater.

Rainwater is safe to drink if collected from roofs. But it can become dirty and unsafe to drink because of dust, leaves and bird excreta on the roof, so the first few minutes of rain should be allowed to wash the roof clean before collection begins.

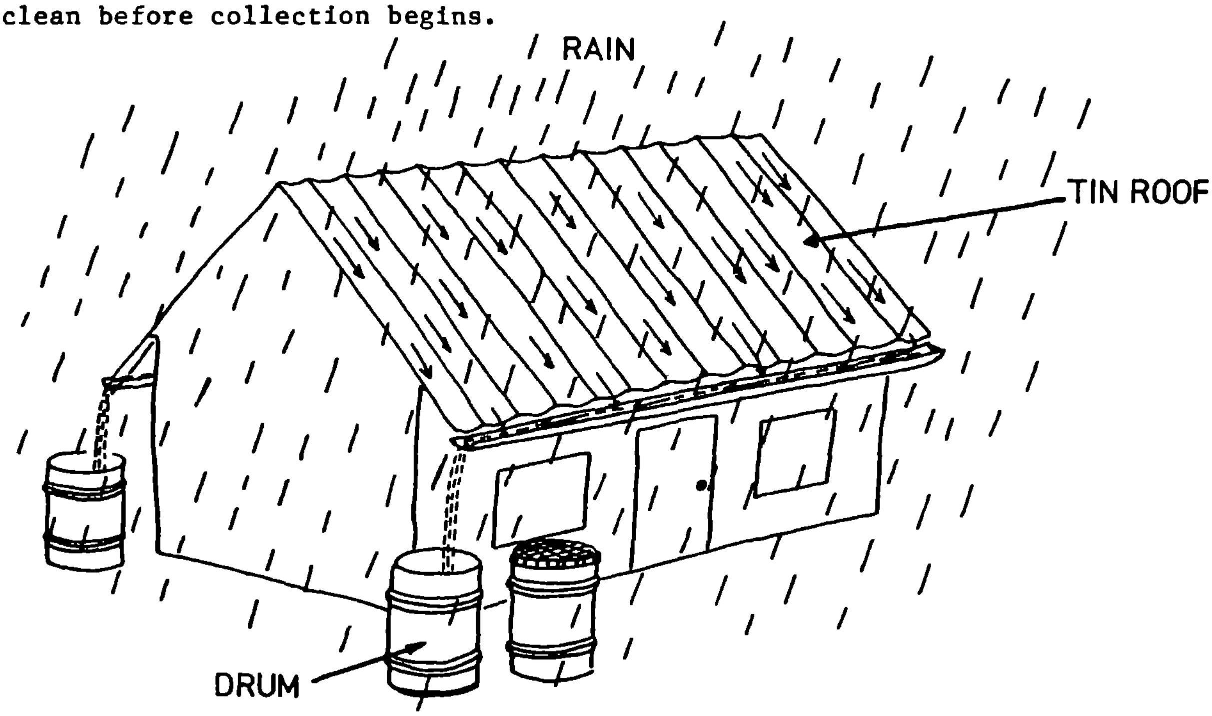


Diagram of rainwater collection

The rainwater can be piped to the point of use or collected in drums. The drums should remain clean and covered. There should be only one container used to get water from the drums and when not in use it should remain hung on a hook and not placed on any surface. Before fetching water the hands should be cleaned.

2. Surface water.

Examples: streams, rivers, ponds, lakes.

These sources are the most easily polluted by excreta from human beings and animals.

Great care should be taken if this water is used for drinking. Always collect water from upstream of any excreting areas, washing places or animal drinking sites.

If possible boil the water or filter it (there are instructions on how to build a water filter in chapter 4). The water can be treated with a chemical such as chlorine (follow the instructions carefully for chemical treatment).

3. Underground water.

Examples: wells, boreholes and springs.

Shallow wells draw water from the permeable layer above the top impermeable layer (unconfined) and the springs which flow from this permeable layer can be recognised by the fact that they are either:

* Holes in the ground with water in them with no flow or

* Flowing springs which have very little flow in the dry season.

Both of these types can dry up altogether in the dry season.

Deep wells and boreholes draw water from below the top impermeable layer. Springs can flow from this layer and can be recognised because:

There is very little or no difference in the amount of water flowing in the wet and dry seasons.

The water from the confined layers have some protection from surface pollution due to the impermeable layer, but the water from the top, unconfined, layer is easily polluted by dirty and infected surface water.

But all water is easily polluted where the water is collected. It is here that is particularly likely to spread disease.

Chapter 3

COMMUNITY WATER SOURCE PROTECTION

If correctly followed, the advice on the prevention of the spread of diseases in an unprotected water source can make a great improvement to the health of a community. However it is far better to protect the actual water source as far as possible.

In the case of a spring, it is possible to protect the source by making the water flow out of a pipe and covering over the spring itself with rocks. This prevents water containers, people and animals polluting the water source by direct contact with the water.

Where water is in short supply (especially during the dry season) and water is having to be collected from several kilometres walk away, there may be a nearer source of water which can be reached by digging a well.

This next section describes a step by step method for protecting a spring, digging a well, or building a combination of the two structures.

The work involved in any of these protective structures could take as little as 2 weeks (in the case of a spring that flows constantly all year), or 6-8 weeks (for a well of 6 metres depth). The speed of work is dependent on the number of people working, and the number of people working is dependent on the local understanding of the need for a safe drinking water source.

It will be hard work but will prevent unnecessary suffering, illness and deaths. The amount of work that people can do after the water source is safe will more than make up for the time taken up protecting a source, as they will no longer be getting constantly sick from worms and other diarrhoeal gut diseases making them permanently weak.

What is the first step necessary to protect a spring or dig a well?

It is first necessary to decide on the type of water source that is to be protected.

A. Springs that flow all year round with no difference in the amount of water flowing in the wet and dry season.

B. Springs that have a greatly reduced amount of water flowing in the dry season, or even no flow at all and may dry up.

C. Water sources that never flow, or sites which have been identified as having water near the ground surface.

If it is A or B then section 1 of this chapter should be followed.

Section 1 will explain how to install a pipe. In the case of type A this will have water flowing through it all the year. In the case of type B the water will flow only in the wet season.

If it is type C then a well will have to be dug and as there is never any flow, no pipe is necessary. Section 3 of this chapter should be followed.

If it is necessary to find a possible site for a well where water can be found a short distance below the ground then look:

1. In areas with green vegetation during the dry season. Water must be present to supply the plants with water to allow them to continue to grow.
2. Near to holes dug by animals who are looking for water.
3. In areas where there is a low ground mist early in the morning or during the evening.
4. In dried up water sources. This is a likely source as the water level in the soil may just have dropped lower.

For any water source read all the previous sections on diseases and how to stop them being passed, and those on water and how the ground is made up.

Study what is going to be involved by reading the relevant sections which follow and looking at the diagrams supplied.

Then:

1. Close any Pit latrines or casava pits within 50 metres of the water source.
2. Clear the area immediately surrounding the water source.
3. Collect together a large pile of rocks.

Then for Type A and B go to section 1.
and for Type C go to section 3.

Section 1

This section to be followed if the water source is type A or B.

1. Do not touch the drainage channel which leads away from the water source -it is important that it is left exactly as it is.

2. Either buy a 6 metre length of plastic or steel pipe about 5 centimetres across, or buy a length of tin sheeting and roll it into a pipe of the above size.

Place the pipe in the drainage channel. The top end of the pipe should extend into the water source about 1/4 metre and be only just below the surface of the water, so that water flows down the pipe. An alternative is to dig a temporary drainage channel for the spring, while positioning the pipe. This channel is later filled in with clay.

Support the pipe on Y-shaped sticks with the bottom end as high as possible .

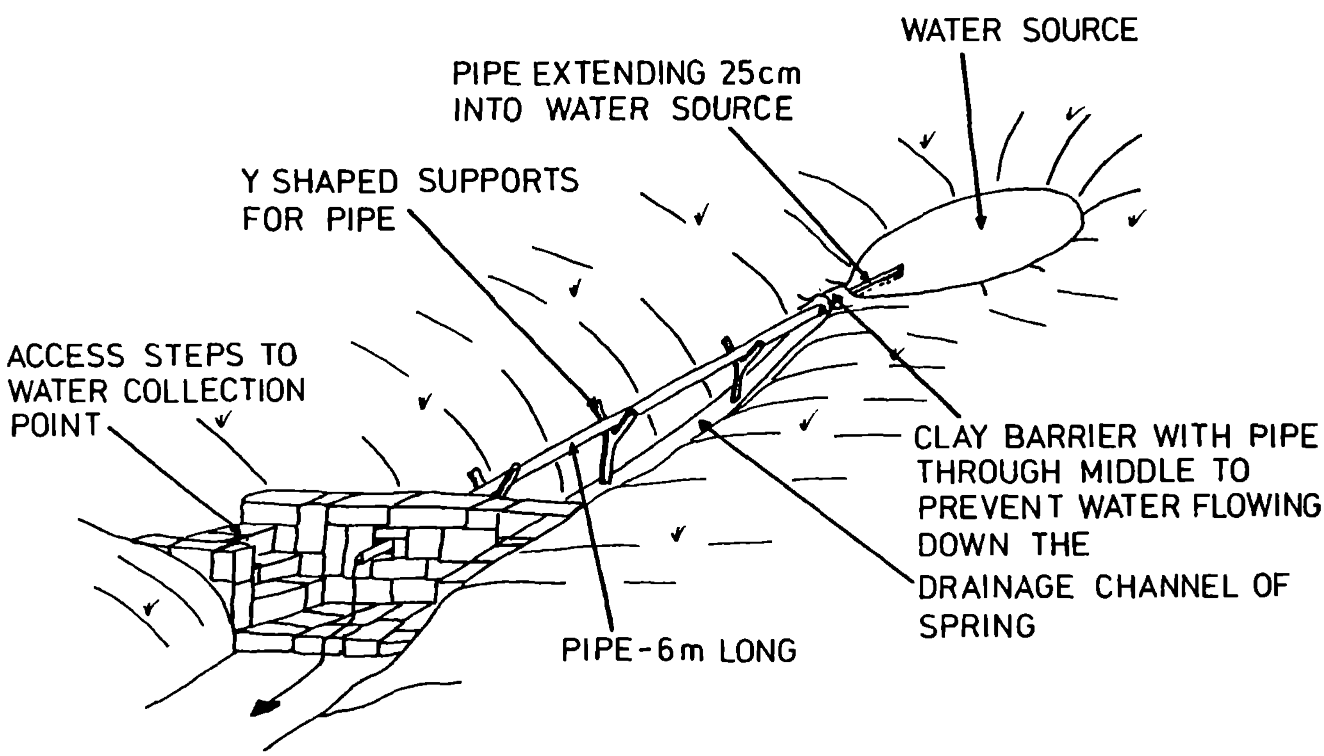


Diagram of the pipe, supports and water collection point

It is important not to dig the pipe more than 5 centimetres into the bottom of the drainage channel (and only do this at the top end of the pipe).

If water is not flowing because it is the dry season or the water in the sump is very low, place the pipe at the height where the water rises to in the wet season.

3. At the lower end of the pipe, build a wall using rocks (as in diagram above). This will support the pipe. The wall can be built using mortar if cement is available (mix one part of cement to six parts clean sharp sand - see Chapter 9 on cement).

Where the water flows out of the pipe place flat stones on which to place jerry cans and on which to stand.

4. Clear the mud out from the drainage channel to the sides and below the pipe.

5. Collect a large mound of clay (anthill clay is very good).

6. Place a very thin layer of clay (about 5 centimetres deep) in the bottom of the channel below the pipe.

Add a small quantity of water so that the clay becomes sticky. Do not add too much water. Tread on it and hit it with the ends of poles. Do this in exactly the same way as preparing clay (or mud) for mudding a house, as the clay wants to be in the form it would be when it is put on a wall. This process is called "puddling" clay. It is done as water cannot flow through puddled clay - it is impermeable - and this will force the water to flow through the pipe.

7. "Puddle" the clay in 5 centimetre layers, slowly filling the old drainage channel from the wall to 1/4 metre from the top end of the pipe.

Continue to puddle the clay until the pipe is buried at least 30 centimetres underneath.

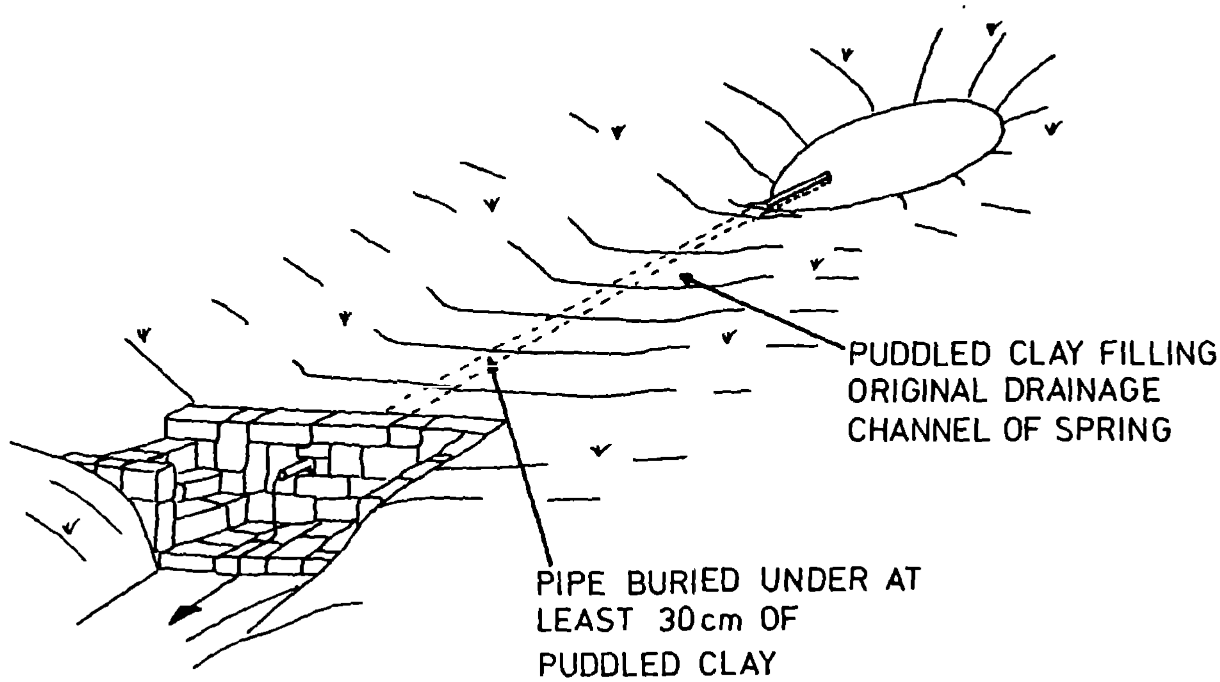


Diagram of spring site with "puddled" clay in drainage channel

Type A - follow Section 2.

Type B - follow Section 3.

Section 2

For water sources of Type A

The pipe is installed, the wall built, and puddled clay placed in the drainage ditch as far as the wall.

1. Clean out all the mud and vegetation from the water source. Dig back into the hillside about 1 metre following the spring "eyes".
Do not dig down into the source, just remove all the loose mud.

2. Fill the whole cleaned out area with rocks, from the spring "eyes" to the pipe and to at least 15 centimetres above the top of the pipe.
If there are not enough rocks then more should be collected.

3. 'Puddle' clay over all the rocks in 5 centimetre layers to a depth of at least 30 centimetres.
If plastic sheeting is available cover the rocks with the plastic before "puddling" clay.
This clay is impermeable and will prevent polluted surface water entering the spring water.

4. Put a layer of top soil 30 centimetres deep over all the "puddled" clay and extend it at the edges.

The top soil should make the ground surface over the spring higher than the ground to the sides of the spring.

5. Plant a fibrous grass over the whole area, and (where available) bushes whose roots do not grow downwards but spread sideways just below the ground surface.

6. Erect a fence, which preferably roots and grows, around the whole area that there is rockfill below the surface, and down to the water collection point.

7. Starting 15 paces up slope of the spring dig a ditch which runs the whole way round the spring. Dig the ditch so that it directs any surface water away from the spring area. It can be connected into the drainage ditch of the spring below the water collecting point.

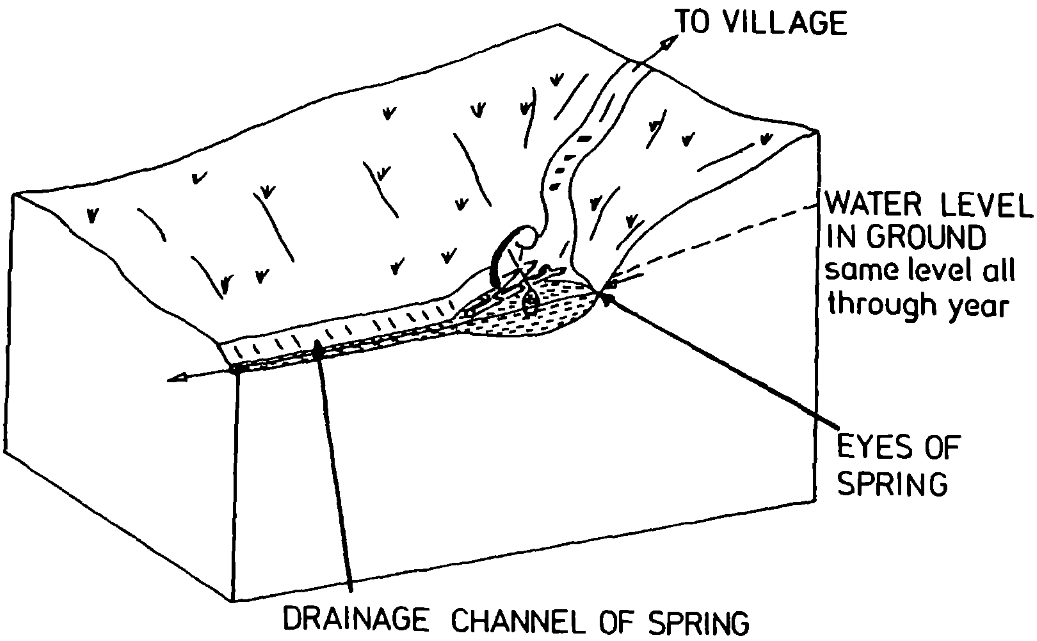


Diagram of Spring before protection

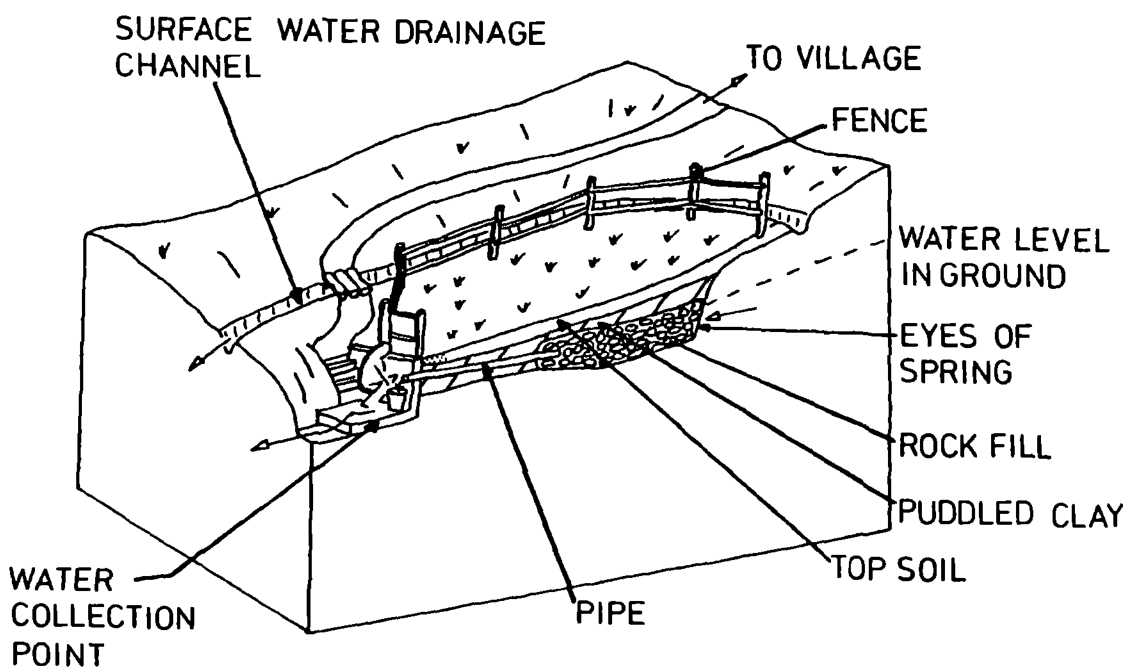


Diagram of Spring after protection

Section 3

For water sources of Type B and C

For Type B the pipe is installed, the wall built and puddled clay placed in the drainage ditch as far as the wall.

For Type C - no pipe is necessary.

When digging a well great care must be taken. In loose soil it is unlikely that any great depth can be obtained as the side walls will keep collapsing. To go deep side supports will be necessary. In firm soil it will be safer to dig a well.

Only dig a well during the dry season and preferably at the end of the dry season, when the water is a long way down in the ground. This time of year is safer to dig and will ensure that there is water available throughout the year and not just in the wet season.

1. Cut some large Y-shaped poles and fix them in the ground on each side of the water source (or proposed well site). These should be about 3 - 4 metres apart. The poles should be buried at least one metre in the ground and made firm by back filling the holes with rocks and soil. The poles can be set in concrete.

2. Cut a 5 metre pole and place it across the hole on the Y-shaped supports.

There are going to be areas where Y-shaped poles are not available, in which case alternative supports will have to be found - if none are available then even greater care must be taken.

3. A start on the well itself can now be made.

Mark out the site on the ground. It should be circular, as this is the most stable shape, and about 1 1/2 metres across. This will give room for a man to work inside the hole.

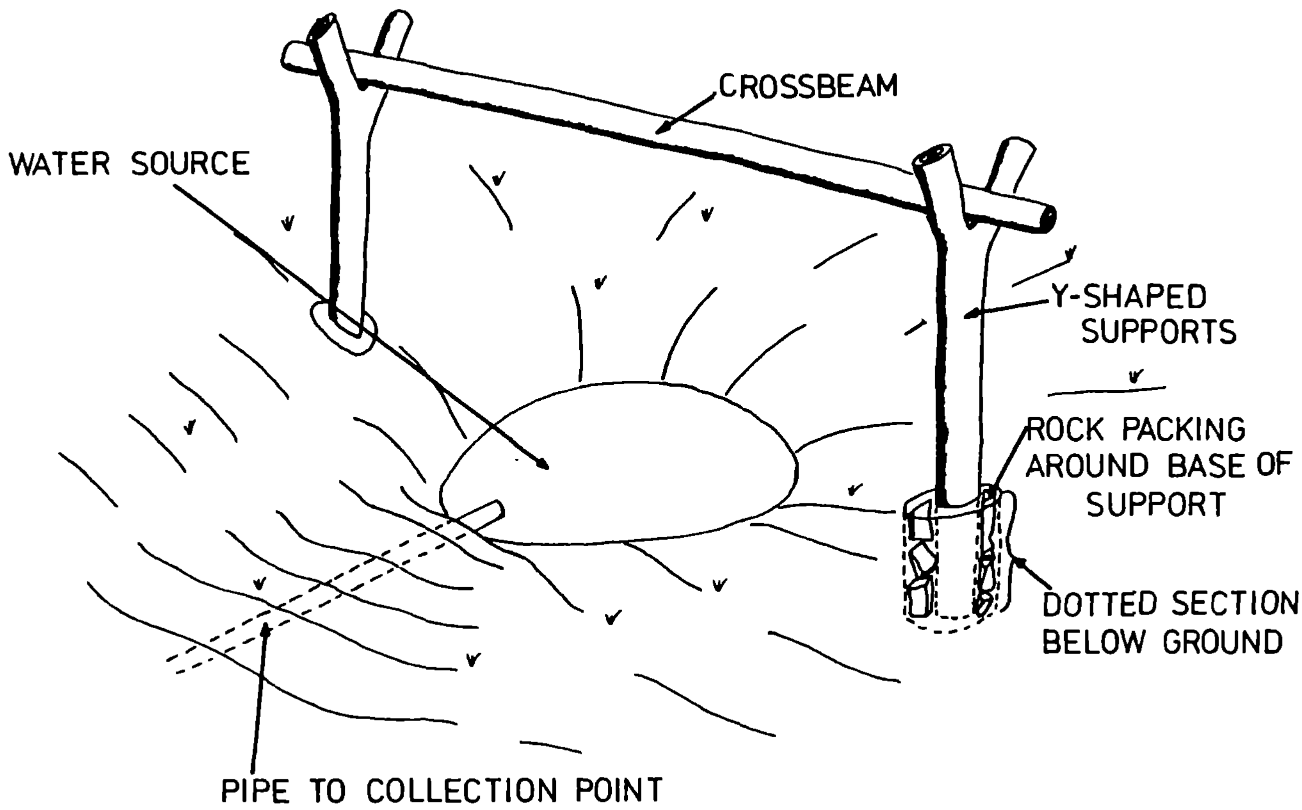


Diagram of Y-shaped supports

4. Dig out the inside of the marked area.

As the depth increases use buckets attached to thick ropes to lift the soil from the hole. Have one man in the well filling the buckets and one or two lifting the full containers. Change the workers in the well regularly.

Put the soil in a circle at least 2 metres from the edge of the well all the way round. (This will prevent surface water from flowing into the well).

As the depth increases - the danger increases.

* Care must be taken not to drop tools down the well especially when someone is working below. Keep all tools - hoes, spades - away from the well hole.

* Keep all children away.

* Cover the well at night with logs.

* Take care when climbing in and out of the well.

* The person in the well should at all times be secured to the surface by a rope. This rope must be held tight whenever someone is climbing in or out of the well.

* To help climbing in and out, another rope should be tied to the cross pole and foot holes dug up one side of the wall.

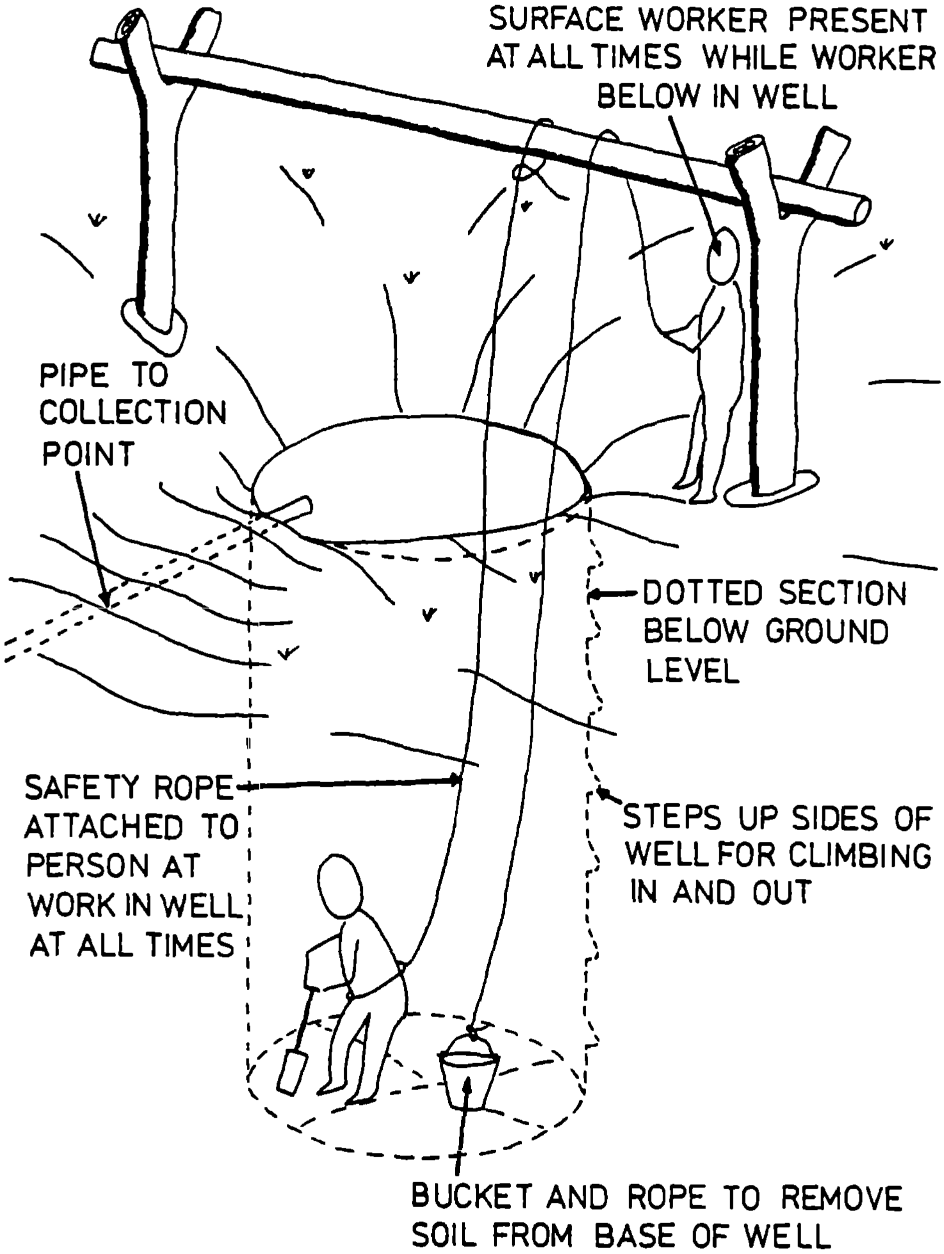


Diagram of safety ropes

5. At a certain depth water will begin to enter the well, either near the surface or at a few metres. Remove the water with buckets and ropes.

Whatever the depth, it is important to dig as deep as possible below where water begins to enter the well, at least 1 metre and preferably to rock. If there are shortages of water this will allow water to flow into the well during the night.

Don't give up once water is reached - dig deeper.

6. Once the well has been dug as deep as possible, make the bottom level and flat.

Start building up the sides of the well with rocks - these should be placed or stalked to make the well walls strong and stable. The bottom stones must be placed firmly to support the walls as they extend up the sides of the well.

The rock lining will make the well permanent and stable. If there are holes between the rock lining and the sides of the excavated hole then these should be filled with rocks at the same time as the walls are slowly being built up the sides of the well.

If cement is available then use mortar above the water level (not below). Mix one part cement to six parts of clean loose river sand.

7. Put 1/4 metre depth of the rocks in the bottom of the well.

8. When the rock lining gets to within 1/2 metre of the ground surface then puddle clay behind the rock lining as the rocks are built up. This will stop water spilt next to the well, when collecting water, from flowing back into the well and causing pollution.

9. In the case of Type B the pipe previously installed under section 1 should extend about 15 centimetres through the rock and into the well.

In the case of Type C no pipe is present.

10. Keep building the rock lining above the ground level by about 3/4 metre. This top lining can be built without cement but it is important to make a very solid wall.

11. Puddle clay all around the well to a depth of 30 centimetres above the ground surface.

Slope it away from the well lining to a collection channel for spilt water, which should extend all around the well and be drained away and downwards from the well.

12. Place flat rocks onto the 'puddled' clay over the whole surface to give a firm footing on which to walk and to prevent the well

surround becoming muddy. If cement is available the 'puddled' clay should be covered with concrete mixed at 1 part cement to 2 parts sand to 4 parts aggregate (clean small broken rocks). This covering should include all the drainage channels of the apron.

13. Cover the well when not in use to prevent dust and leaves from entering the well.

14. Build a fence around the whole well structure with a rock path leading downhill away from the well.

15. Attach one container to a rope and attach this rope to the cross pole. Leave the container suspended in the water when not in use. This container should never be placed on the ground. Only use this one container to collect water.

16. During the next season the water may flow through the pipe in the case of Type B and the well can be permanently covered. Water can then be collected from the pipe.

17. Starting 15 paces upslope of the well dig a ditch which runs the whole way round the water source. Dig the ditch so that it directs any surface water away from the water source area. It can be connected into the drainage ditch below the water collection point.

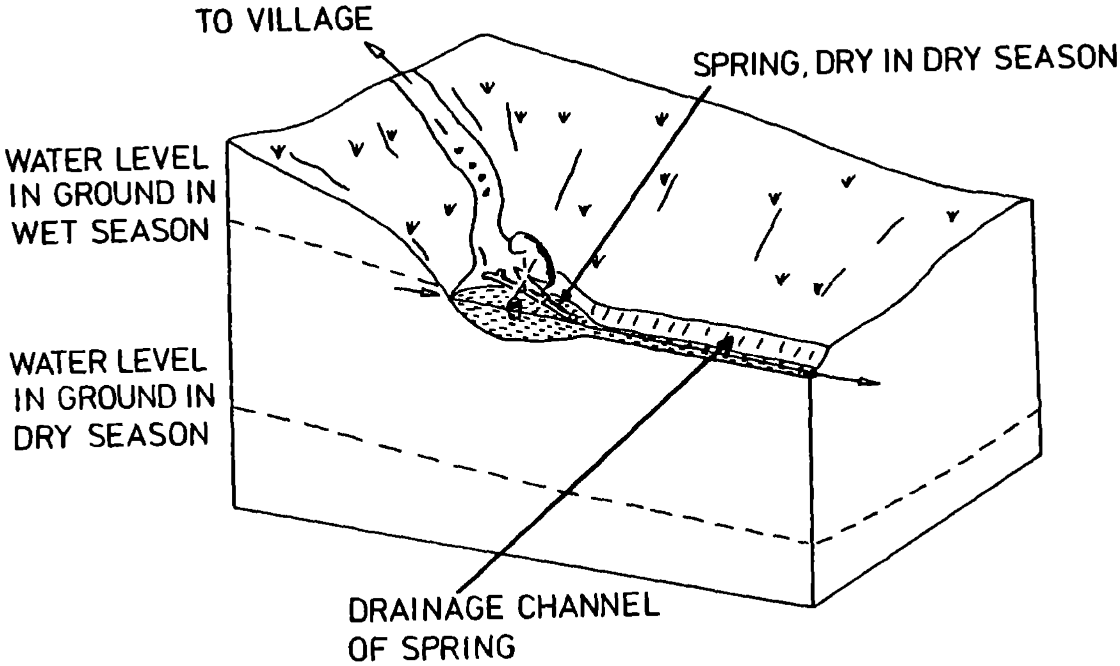


Diagram of well before protection

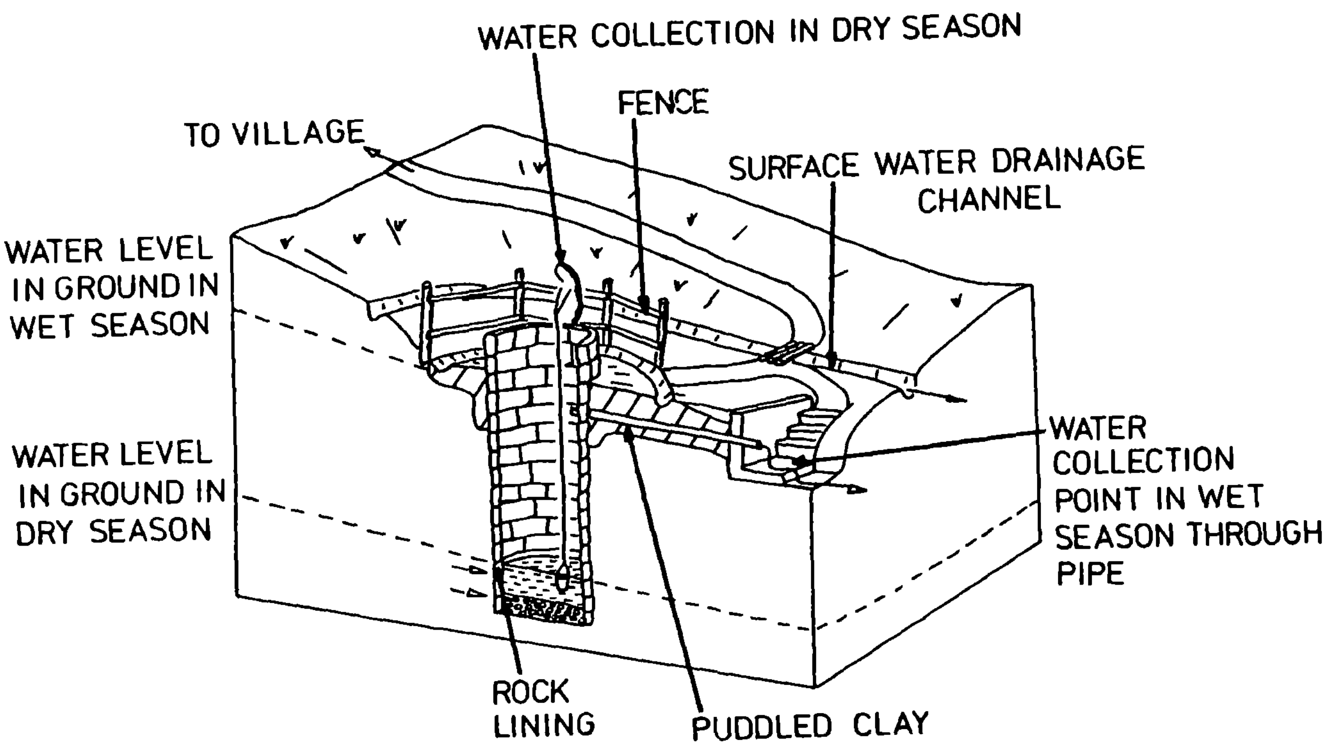


Diagram of well after protection

How should a watersource be maintained?

The following guidelines should be understood by all the members of a community - translate them into the local language and pin the guidelines in a clear waterproof piece of plastic near to the water source. It is the community's responsibility to keep their water sources clean and safe.

One person going against the following points can pollute the water source and cause illness and death throughout the whole community.

1. People should not excrete within 50 metres of the water source.

2. Keep the fence in good order to prevent access of children and animals into the area of ground on the surface above the water source.

3. In a well only one container should be used and one rope to collect water from the well. This container should never be placed on the ground.

4. A spring pipe should never be hooked. Blocking the flow does not increase the amount of water available. Instead the water will find another way out of the spring normally underneath and to the sides of the built structures. This will lead to the destruction of the spring structures.

5. Keep all drainage channels clear of vegetation and mud. If the channel leading from the spring becomes blocked then clean it or dig it out otherwise people have to stand in stagnant water when fetching safe water. This stagnant water can spread diseases and also give a breeding site for mosquitos and other flies.

6.Sticks and leaves should not be thrown into wells. This is especially important where children are concerned. All leaves, sticks should be removed immediately.

7. Wash clothes downhill from the water source - not upslope.

Chapter 4.

IMPROVING WATER QUALITY

1. Boil the water for 20 minutes and then allow to cool. This will destroy most germs.

2. Store the water in a clean closed container for 3 days (or as long as possible).

3. Treat the water with a chemical such as chlorine. Add the amount given in the instructions on the chemical container. Leave water to stand for approximately 30 minutes.

4. Filter the water - for drum water filter follow the directions below.

How can water be filtered using a drum?

1. Cut the top off a 200 litre drum.

2. Drill a hole 65 centimetres from the base of the drum. The hole needs to be 2 1/2 centimetres across.

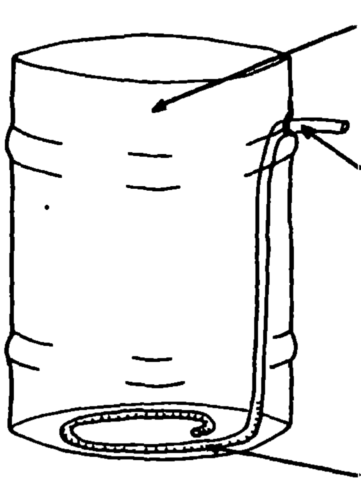
3. Paint the inside of the drum with bitomastic paint (if available).

4. Take a 2 metre length of hose pipe and cut slots with a knife in one side of the hose pipe every 5 cm for 100 cm from one end. The slots should be less than 1/2 way through the hose pipe.

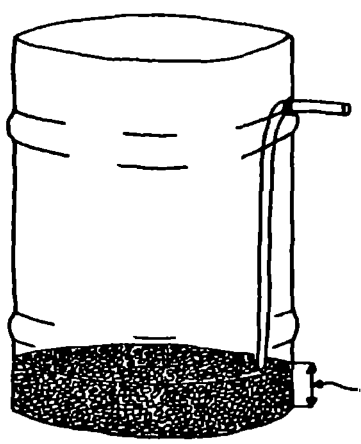
5. Coil the slotted end of the pipe on the bottom of the drum and push the other end of the pipe through the drilled hole so that it extends about 10 centimetres out of the side of the drum.

6. Fix the hose pipe in place where it passes out through the drilled hole in the drum with water resistant glue, or wind the inner tube of a

bicycle tyre around the pipe about 10 centimetres from the end and force it out through the hole to make a water-tight seal.

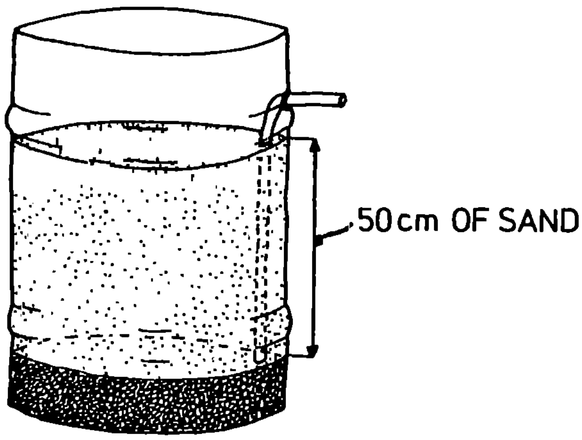


7. Wash some small stones thoroughly, put them in the base of the drum (adjusting the pipe in position, see diagram above) to a depth of 10 centimetres.



8. Wash some sharp river sand (not fine sand) and put it in the drum on top of the small stones to a depth of 60 centimetres from the base (this is 50 centimetres of sand on top of the small stones).

The sand layer then ends approximately 5 centimetres below the pipe outlet. What this means is that even if the hose pipe is left open there will still be a layer of water over the sand. This is important. The sand should never be allowed to dry out, because if it does the biologically active organisms which develop in the sand will die. These organisms are important as they clean the water. These are not the same organisms which cause diseases and they cannot pass through the sand to come out in the water through the pipe.



9. A cover should be placed over the top of the drum with a hole in the middle for adding water to the filter.

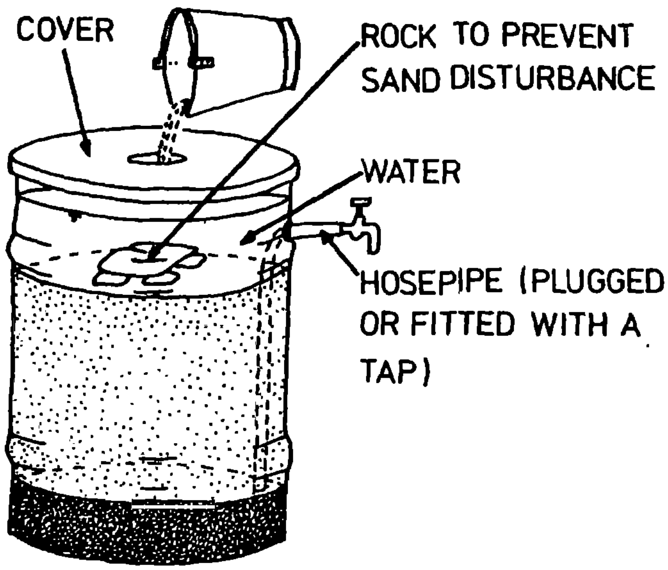
10. Underneath the hole place a flat stone which will prevent the sand being disturbed when the water is added. Raise the stone slightly above the sand by placing smaller stones underneath.

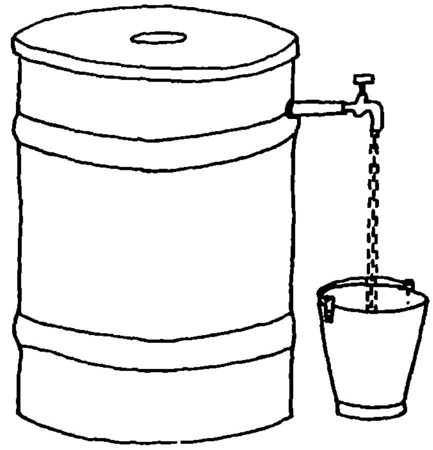
11. Add water through the lid and let the water flow through the hose pipe. The more water that is added, the faster the filter will start working.

12. Continue to add water, (about 20 litres), every day.

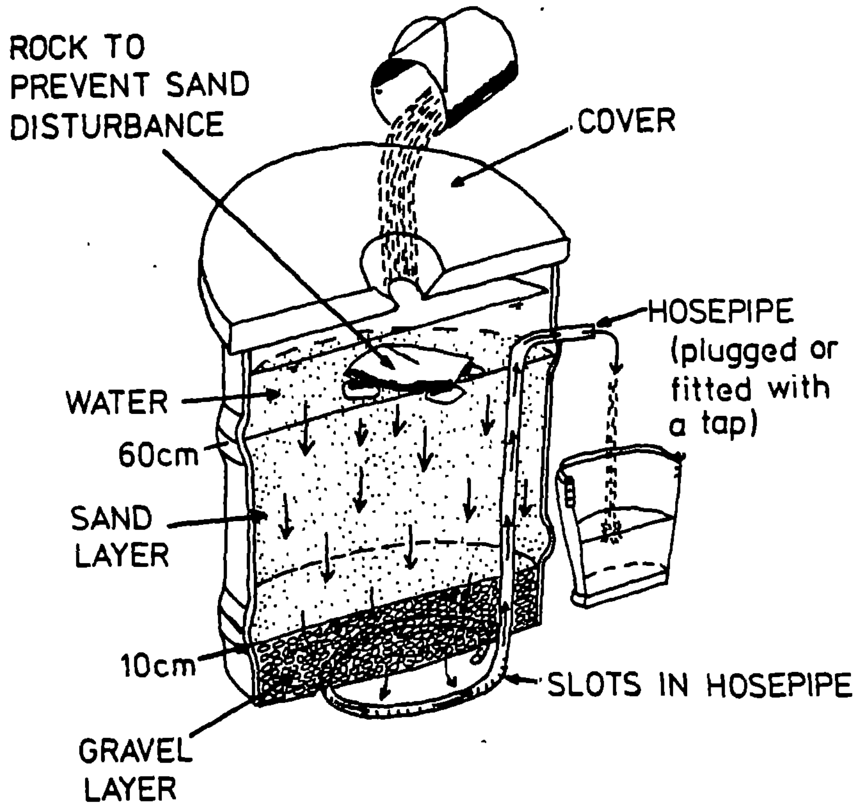
13. The sand filter will take a few weeks to start working. When it does there will be a noticeable improvement in the taste and colour of the water.

14. When the water has improved in quality a tap can be attached to the hose pipe or a wooden plug (piece of wood) can be pushed in the end.





15. Once a tap has been attached then a reservoir can be built up in the top 1/3 of the drum and water added as required.



<u>Diagram of how Drum filter works</u>

As the water added may be very dirty and contain mud it may block up the top layers of sand after a few months.This will be noticed as a slowing down of the speed of flow from the pipe.

To solve this either

Before adding water to the filter allow it to stand for 24 hours in another drum. The mud will then settle out on the bottom.

When dirty remove the top 15 centimetres of sand wash it and then replace it in the filter. The filter will then have a few days to start working again -start at No 11. above again.

How can a larger filter be built?

To build a larger filter the same system can be used. The filter can be built of bricks and mortar, or within corrugated tin roofing or a timber structure lined with plastic sheeting.

The following points should be remembered:

1. Fit the slotted pipe in place on the base of the filter with the supply pipe leading from the filter in place.

2. Cover the pipe with 10 centimetres of small stones

3. Put in clean sharp sand to 2/3 the way up the filter and 10-15 centimetres below the outlet pipe.

4. Flush the filter through, for 2-3 weeks, every day.

Chapter 5.

EXCRETA

Excreta is dangerous.

Excreta contains germs (bacteria and living organisms) which cause diarrhoea and other diseases which can kill.

Excreta should be put out of reach of:

* People (especially children)
* Animals
* Rain
* Water sources

Excreta should be put in a hole in the ground (a latrine). Even the use of a small protected hole in the ground is far safer than excreting on the surface.

However it is better to build proper latrines. These can be complex structures or relatively simple ones. They should be built down slope and 30 metres from any water source and close to living space (so they are used), but not closer than 5 metres. The pit should be 1 - 3 metres deep - the larger the latrine the longer it will last.

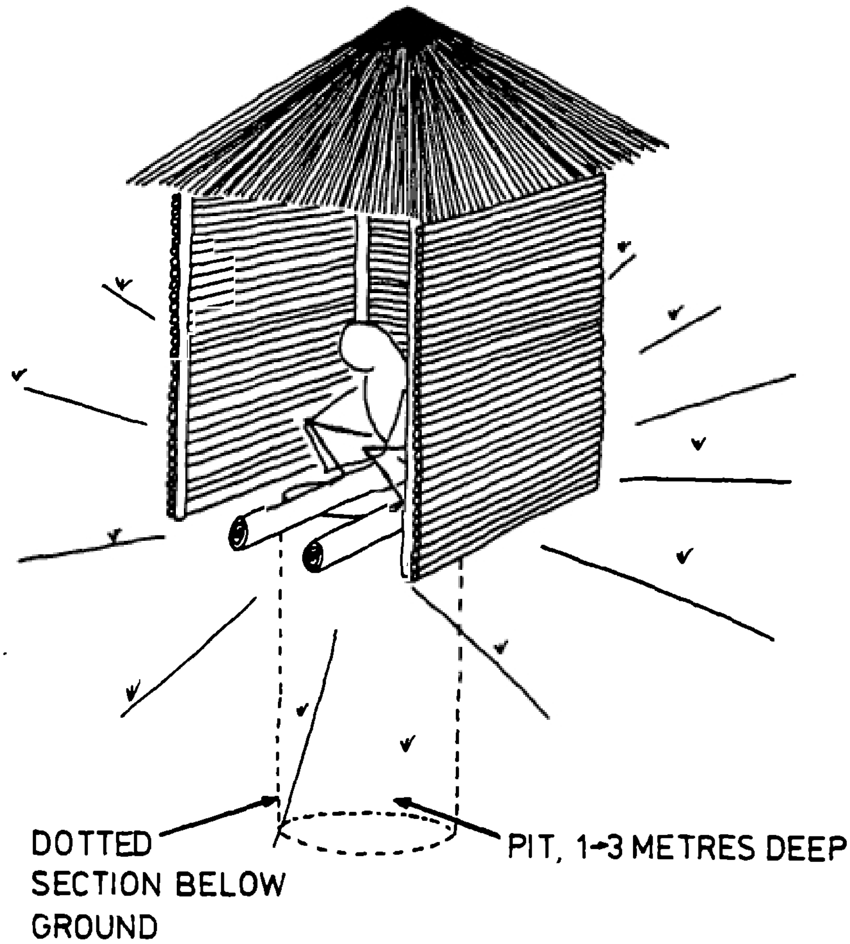
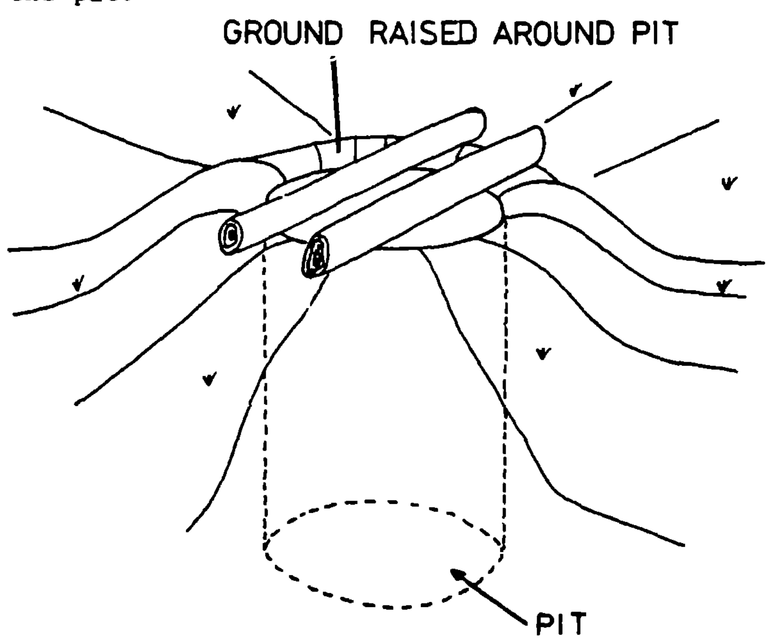


Diagram of simple Pit Latrine

If water is reached (ground water which flows into the pit) and there is a water source within 50 metres, then chose a different site (on slightly higher ground). If this is not done then germs in the excreta will be moved by the water and taken to pollute the water source. It is best also to bank the soil around the pit so that it is on slightly raised ground to prevent rain filling up the pit.



Where the pit (as above) is not sealed to reduce the problem of smell and flies throw some ashes or dirt down the pit after use to cover the excreta.

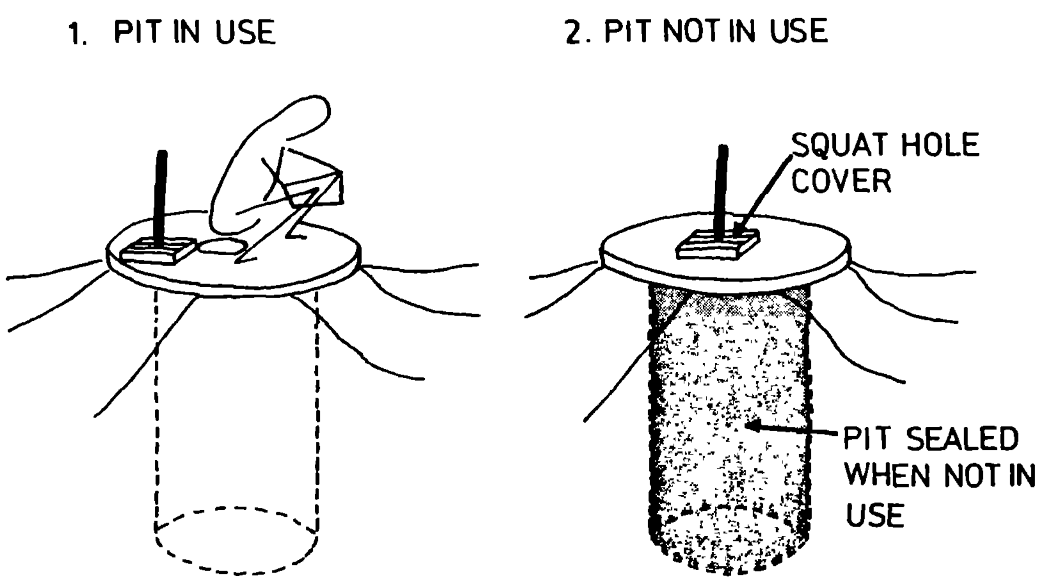
How to fight flies and smells.

The smell of excreta attracts flies. The flies lay eggs in the excreta. After laying the eggs the flies are likely to return to a food source, particularly prepared food or stored human food such as meat. In doing this the flies transport germs from the excreta, on their feet, to human food. This leads to the spread of infectious diseases. When flies first hatch from the excreta they will also carry diseases to human food.

Flies are an indication of bad sanitation and are unhygienic.

If the pit is sealed when not in use, flies cannot get into it except when someone is using it. This will greatly reduce the number of flies breeding. It will also reduce the smell and therefore less flies will be attracted.

To seal the pit the squat hole needs to be small and after use a wooden cover placed over the hole.



People who use the pit need to understand 'why' the cover should be in position over the hole. This is especially important for children.

Children need to be taught and to understand the reasons 'why' they should use a pit latrine in the first place.

The latrine needs to be kept clean with regular washing

The latrine can be built using logs to cover the pit - or wooden planks. The top can be built of tin sheeting or poles and mudded walls with a grass roof. If the soil is loose or unstable then the pit will need lining. This can be done using:

* timber, planks or poles, or
* open ended drums.

With the possibility that flies might still manage to get into the pit latrine and breed, due to bad maintenance and leaving the cover off the squat hole, a more complex structure can be built called a ventilated improved pit latrine (a VIP).

Ventilated Improved Pit Latrine

This has the addition of a screened ventilation pipe, and the inside of the latrine housing is as dark as possible.

The ventilation pipe removes the smell from the latrine, the air from the pit is sucked out of the ventilation pipe rather than coming through the squat hole.

The problem of flies is reduced. The flies lay eggs in the excreta. When these eggs hatch into flies, they move towards a source of light. In this case because the area around the squat hole is always dark, the only source of light is from the top of the ventilation pipe. The flies move towards this light and are also sucked up by air currents.

A fly screen at the top of the pipe traps the flies which will eventually die there and fall into the latrine.

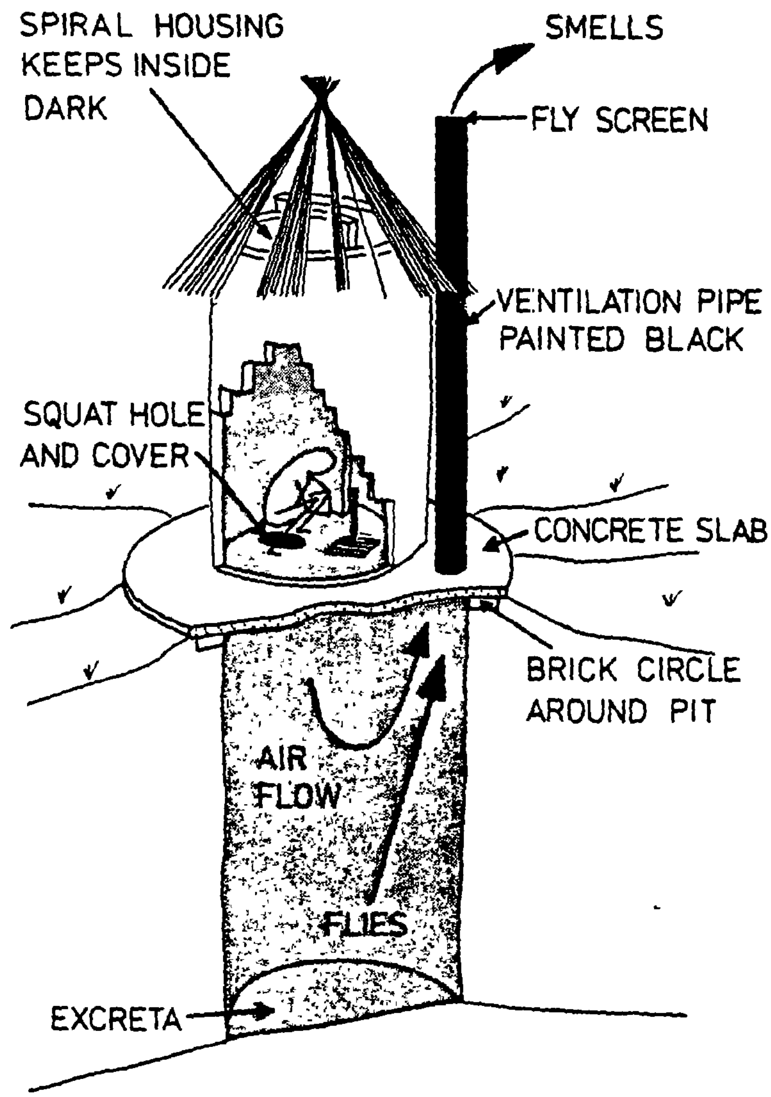


Diagram of a VIP

Part 2.

The chapter on community water protection (Chapter 3) is for situations where there is no technical assistance or advice. Water sources can be safely protected in this way, but with technical advice and assistance there is likely to be a programme of spring protection or well digging. This will include the use of cement for construction of impermeable barriers in the case of springs, and concrete rings, aprons and covers in the case of wells.

The remaining chapters in this book along with the preceeding chapters on water and diseases can be used as an educational source for water technicians, and to give further ideas on water source protection not included in the designs outlined in Chapter 3. Chapter 3, however, should still be understood.

Chapter 6.

SPRINGS

When protecting a spring then, as stated in Chapter 3, a decision must be taken on the type of spring involved. There are two types:

A. Springs that flow all the year round with no difference in the amount of water flowing in the wet and dry season. (Amount of water flowing is termed the flow-rate. For calculation of this rate see Chapter 10).

B. Springs that have a greatly reduced flow rate in the dry season, or have no flow, or dry up in the dry season.

Type A springs are likely to come from the confined layers in the soil, and are called artesian springs. These can supply the greatest quantity of water and due to the impermeable layer over the water bearing layer, the water is protected from surface contamination.

Type B springs are from the unconfined layer and easily polluted, and therefore require greater care. These springs tend to flow onto the surface over long distances along a hillside (termed also seepage springs), and it is necessary to connect all these sources together to one single point. This is done using infiltration trenches.

Infiltration trenches (as described below) can also be used to try to increase the amount of water flowing from a spring.

Infiltration trenches

Both spring types, A and B, may need the inclusion of infiltration trenches; either in order to lead the water to a single point for collection, or to try to increase the flow rate.

These trenches can be dug into the hillside, or along the hillside, so that a sufficient depth of the water bearing layer is contacted, even in the dry season when the ground water level here drops. The bottom of the areas should be filled with rocks, or with a slotted plastic pipe and rocks, short clay pipes and rocks, or even a concrete trench.

The idea is to give the water a direction of flow which is easier than through the ground. Water always flows downwards by the easiest path.

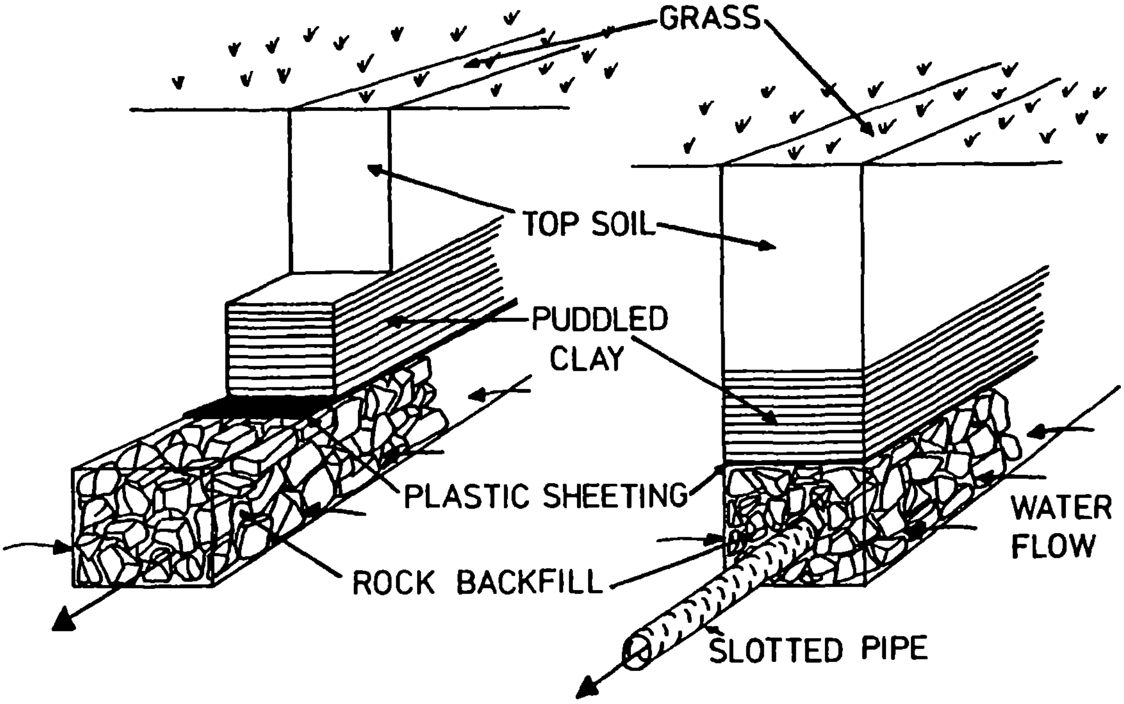


Diagram of possible Infiltration trenches

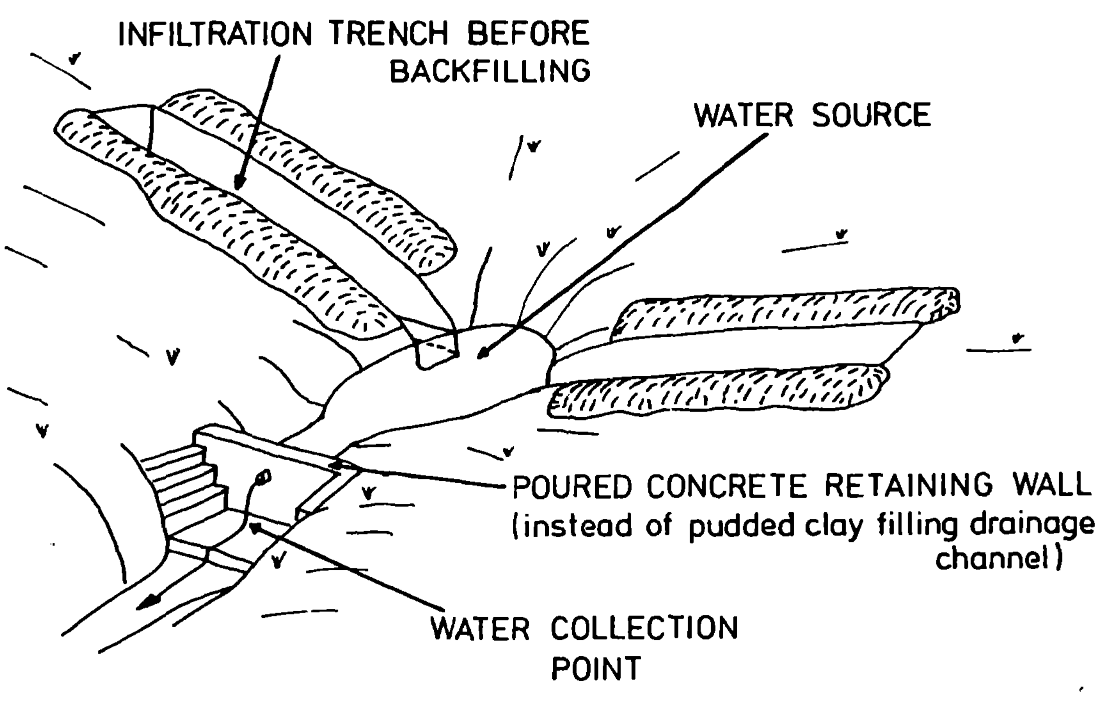


Diagram of positioning of infiltration trenches

The rocks should be covered with a sheet of plastic and/or an impermeable layer of 'puddled clay' to prevent surface contamination - the rocks extending to beyond the top end of the pipe.

The pipe, at the lower end, can be set in a concrete retaining wall. This can be used as an impermeable layer instead of the puddled clay discussed in the chapter on community water source protection.

The concrete wall should be set ("keyed") into impermeable layers to the sides and below the drainage channel, to prevent the seepage of water under and around the spring structures. This would lead to erosion and collapse of the spring structure.

The retaining wall can be built:

1. "Dry". As long as the trench behind is packed with impermeable clay.
2. Of poured concrete in shutters.
3. Of bricks with poured concrete in the middle, or a thick plastering on bricks.

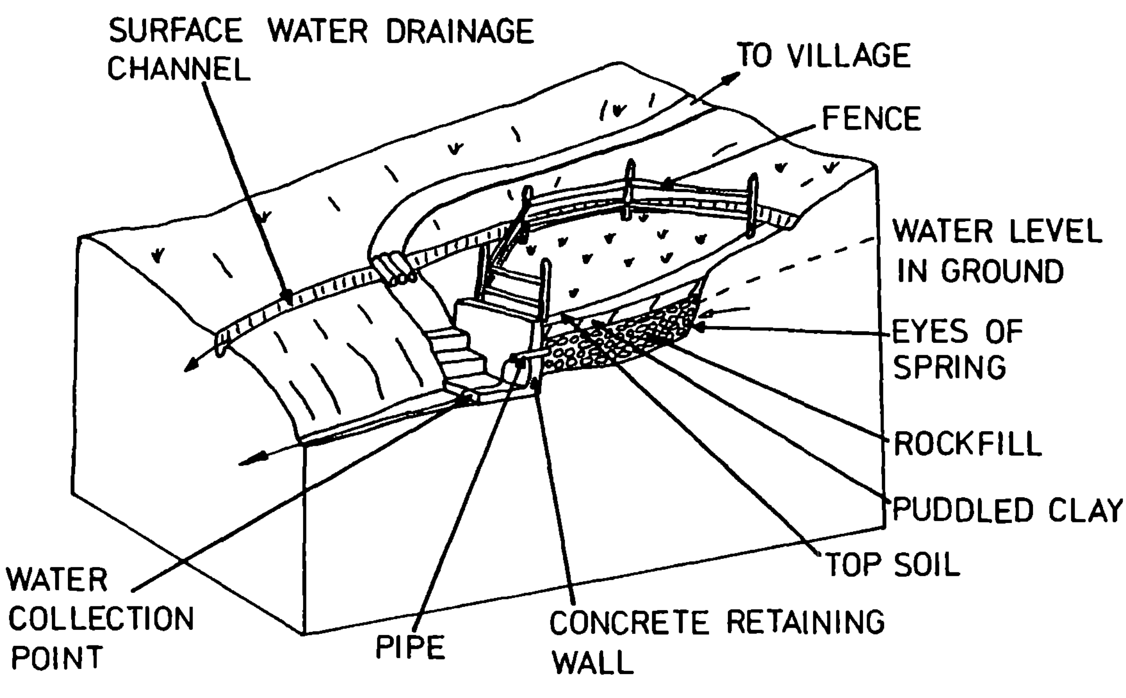
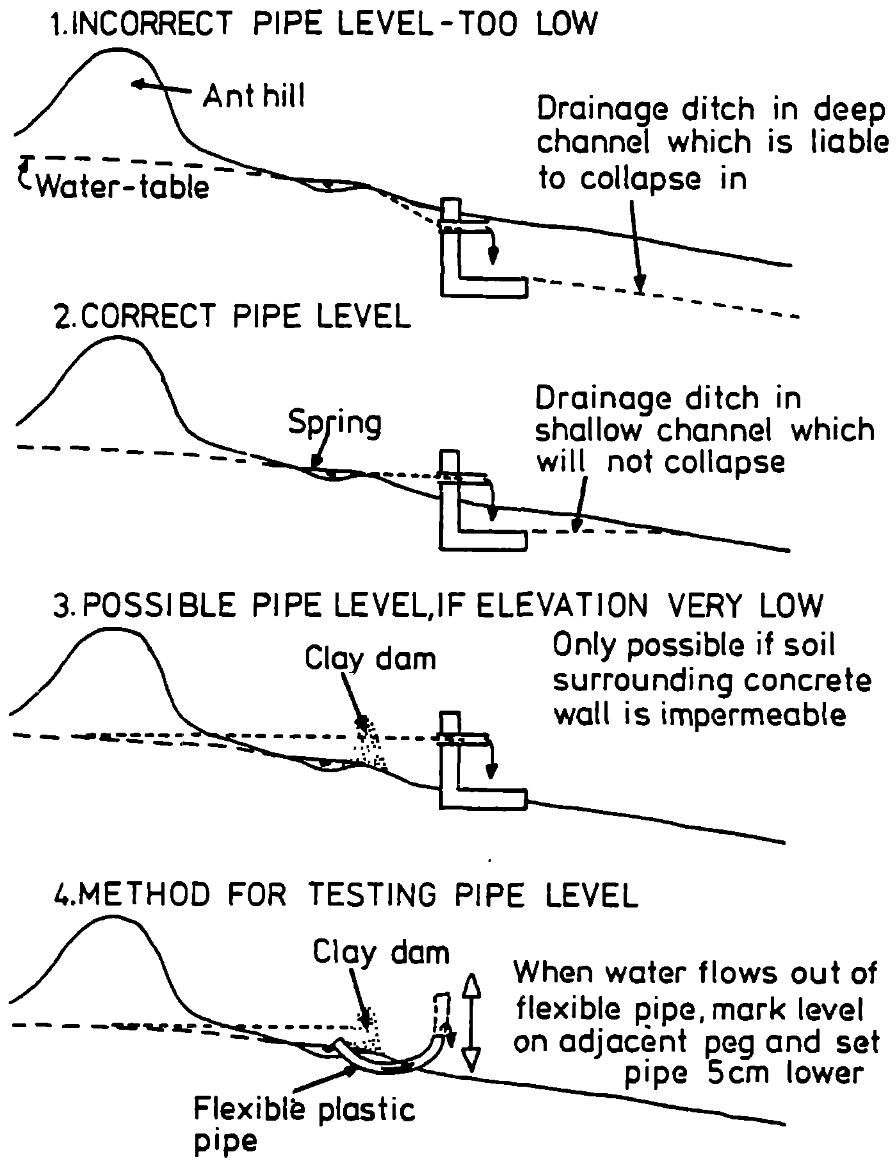


Diagram of "Spring box"

How to set the pipe level

The pipe level setting is important in areas of low elevation because if the pipe is set too low, it is necessary to dig a very deep drainage ditch from the water collection point. The depth is needed to allow the positioning of a jerry can below the pipe for filling.

If the drainage channel is deep the sides very quickly collapse into the channel. Grasses grow in the channel. This leads to a flooding of the water collection point and can lead to a situation where the spring pipe is under water. This not only allows dirty water to flow back into the spring and cause pollution, but also aids the spread of infectious diseases looked at in Chapter 1, especially those diseases passed by an animal which lives in water.



Diagrams of finding the highest possible pipe level

Whichever level is eventually chosen the first action at any spring site before construction begins should be the setting of the pipe level.

This pipe level should be marked by siting a large wooden peg driven into the ground outside the area to be excavated. This reference peg and the level of the pipe can be recorded in relation to the top of this peg. This reference peg should always remain undisturbed.

It is best to site the pipe as early as possible, as in chapter 3, to give the spring an outlet. If this is not possible because concrete shuttering is to be used then it is necessary to dig a diversion channel to allow the spring water to go around or away from the construction area. Alternatively, a narrower hose pipe can be fed through the pipe which is left in position, to carry the water through the shutters.

If the spring is of type B then unless infiltration trenches are successful, which can only be known at the end of the dry season, a well will need to be sunk, as in Chapter 3, with a wet season overflow pipe.

With the use of concrete the well apron can be concreted and a concrete cover with a basin included. These are described in detail in Chapter 8.

Tubular springs

If a spring is found to be flowing out of a singular circular hole then the best way to protect it is to dig back along the top half of the tube. Put the pipe directly into the hole and backfill the whole area with "puddled" clay to seal the pipe in place.

Fracture Springs

These are springs which usually flow out through rock and are due to a crack/fracture in the surface impermeable layer.

The water is usually coming out under pressure from a single opening. If obstacles are removed from the mouth of the spring then the flow may be increased.

This type of spring can be protected by building a raised "Spring Box". The water will rise above the level of the surrounding ground because of the pressure behind the water. The pressure occurring as the water is flowing from a confined permeable layer.

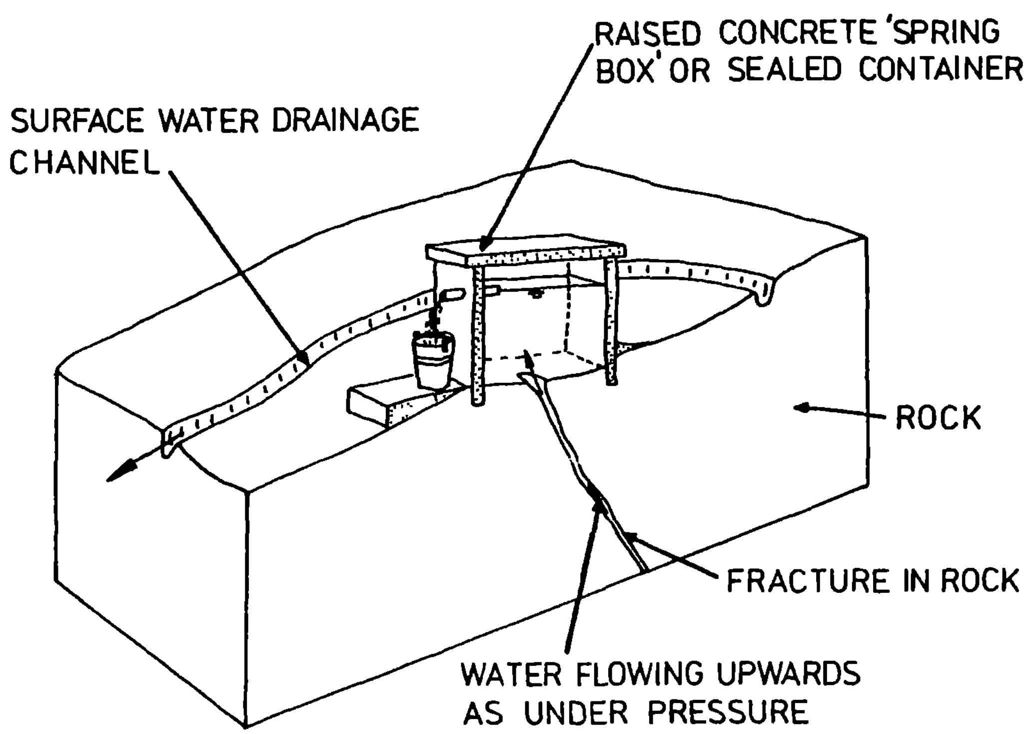


Diagram of Protected Fracture Spring

If water comes from rocks, and is not under pressure, then pit latrines should not be situated within 100 metres upslope of the water source.

Chapter 7.

WELLS

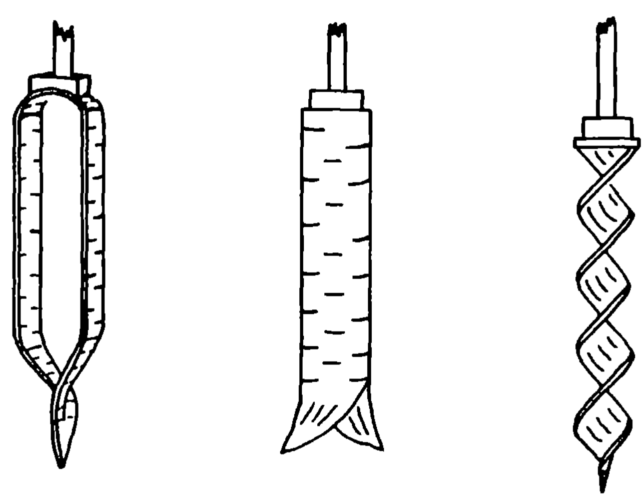
If looking for a possible well site, there are certain areas worth investigating as stated in Chapter 3. To save the time and effort of just digging a well and hoping for the best it is possible to use an auger to investigate what is below the ground.

Auger Surveys

An auger is an implement, usually manually operated, which can give a lot of valuable information on the composition of the ground.

The standard auger bits needed when surveying are:

1. Clay auger
2. Spiral auger
3. Sand auger



1. CLAY AUGER 2. SAND AUGER 3. SPIRAL AUGER

These are included with rods, a hand grip, and a bailer for testing recharge.

It is important to take great care of these kits.

The auger should not be forced if it does not turn with ease.

The correct spanners should be used to dismantle the rods.

Threads should always be cleaned and greased.

The information which can be gathered by augering is:

1. Whether there is ground water present or not.
2. The thickness of the water bearing layer.
3. Possible recharge rate.
4. The nature of the water-bearing layer, whether coarse grained or fine grained. Coarse grained material will release its water content more easily than fine grained material.
5. The nature of the material will also indicate how the well should be built. Whether a temporary lining may be necessary during construction, or whether caissoning (see below) is necessary
6. The depth to hard rock or the impermeable layer. This indicates the minimum depth of the well, and also the possible storage capacity of the well.
7. The colours of the augered material can indicate the movement of the water-table level (see below).

It is best to auger at the end of the dry season when the water-table is lowest. Auger surveys can involve numerous test holes so it is best to record accurately the information gathered.

The information from augering should be recorded (termed logging) for later study. It is likely that numerous auger holes will be drilled on the same day, so careful logging is important.

Whenever an auger hole is drilled:

1. Take a sample of every 1/2 metre for later inspection and at the time of sampling log, the colour of the soil.

- Reddish soils are well drained and well aired.
- Yellow soils indicate the soil is full of water for long periods, such as in the wet season.
- Black and dark grey soils are usually badly drained and indicate stagnant ground water.
- Bluish colours in a dark grey soil indicate the soils is waterlogged for most of the time and has a changing water level.

2. Record exactly at what depth water is first encountered and, when augering is completed, leave the hole for a few hours and then measure the water level again. This is termed the static water level.

3. Record the level of the rock or impermeable layer.

4. Bail out the auger hole, logging the number of times that it needs to be bailed, and therefore the number of litres in the hole. If the water can not be removed as fast as the auger hole is recharging it is a good sign. If the hole goes dry, measure the depth of water in the hole at 5 minutes intervals to gain the recharge rate.

Safety precautions when digging a well.

1. In loose uncompacted soil it will be necessary to line the well temporarily as the well is dug, or caisson it (see below). If neither of these are done then the walls may collapse whilst digging.

2. At the beginning of each days work check all the equipment, ropes, knots, pulleys, buckets, bosun's chair and so on.

3. Wear a hard hat at all times when in the well to prevent injury from tools, buckets, and loose soil falling from above.

4. Tools should be kept further than 2 metres from the well.

5. A fence or rope should be put up about 4 metres all the way around the well head to ensure that watchers, especially children, remain outside the rope.

6. Place logs and pipes across the well-head at night.

7. Combustion engines (such as pumps) should not be placed inside or near to the head of the well. Poisonous exhaust gas from the engines is heavier than air, and so it will fill the well, and is dangerous to workers. The gas does not smell, so at first its presence is not noticed.

8. Build a rigid superstructure which can be used for raising and lowering people, buckets, and rings in and out of the well in safety.

9. Ropes should never be adjusted, where they pass through pulleys or over the cross members, when the rope has a load on it.

10. If a heavy load, such as a ring, is being lowered into the well there should not be anyone inside the well.

Well linings.

A well can be lined with a variety of materials, even with open ended drums placed one on top of another.

It is better to build a more solid lining of bricks, rocks, precast concrete rolls, ferrocement rings, or precast reinforced concrete rings.

If only local materials, and no transport, are available then a rock lining or brick lining will have to be used as described in chapter 3.

If transport is available then for speed, (which maintains local interest, which is important if the project is self-help - local voluntary labour) safety and length of life of the finished well, precast reinforced concrete rings should be used. These rings can be either poured on site or at a central compound for later transport. A team trained in manufacturing the rings will ensure the development of a high level of quality.

The purpose of the lining is to prevent the collapsing of the sides of the well, this making the structure permanent.

The well lining needs to allow water to flow freely into the well, without allowing soil particles to be washed into the well from outside the lining, and filling the base of the well.

The linings should always be watertight (i.e. impermeable) above the water-table (this prevents pollution from the ground surface), and permeable below the water table (allowing the entry of water from the waterbearing layer).

To make the linings watertight it is necessary to mortar the joints between concrete rings, and with any other linings to backfill behind the lining and the excavated hole, with "puddled" clay.

How is a well lined?

In firm non-collapsing soils a well can be lined from the base upwards. Even in firm soils a maximum of 6 metres depth can be achieved without structural support. It is possible to line temporarily the top 1-2 metres to prevent the collapsing of the loose soil near to the surface, or to temporarily line the whole well down to the base.

Normally in loose soils the well is lined, as it is sunk, with a permanent lining of concrete poured in position using circular shutters, at a maximum of 5 metres each time. Each pour has reinforcing bars running through the concrete which extend from the top and bottom of each set of shutters, which are twisted and bound together. In this type of lining there is a gap left behind between concrete pours, to allow access to pour the concrete behind the shutters, which later need filling.

With precast reinforced concrete rings in loose soil, the rings are used as the support lining, which remains in place after completion of the well. The rings are stacked one on top of another as they are sunk into the ground under their own weight, the soil being removed from the centre of the well and from around the base of the bottom ring. This technique is called caissoning (see below).

Once the water-table is reached the well should be "punched" (sunk) into the water-table as far as possible and preferably to rock (sometimes "punched" into rock to increase the storage capacity of the well).

Precast reinforced concrete rings

These can be made of various diameters and depths. The measurements below are of a size enabling two men to work inside an unlined excavation and one man in the rings if caissoning. With a team of 8 men the rings can be moved relatively easily.

Concrete ring dimensions are:

1.5 internal diameter, thickness of 0.075m (7.5cm) making an external diameter of 1.65 m. within an excavated hole of 1.8 m. The ring is 0.85 m high.

The rings are reinforced with either 4 millimetre diameter weldmesh in a 50 millimetre grid, which is set centrally and adjusted as the ring is poured, or using short lengths approximately 4 centimetres long, of nylon string mixed with the wet concrete.

With 4 sets of shutters an output of two per day can be achieved with a rings team of 8 men. Each ring being given 36 hours to set in the shutters.

The steel shutters need to be pre-oiled and concrete poured in 15-20 centimetre layers. These layers should be forced into position using crowbars and by hammering the steel shutters with rubber hammers or wooden blocks to ensure the removal of air bubbles.

The concrete, mix at 1 : 2.5 : 4 (for explanation see Chapter 9) uses 1 1/2 bags of cement per ring.

The rings should be manufactured with joints allowing them to slot together.

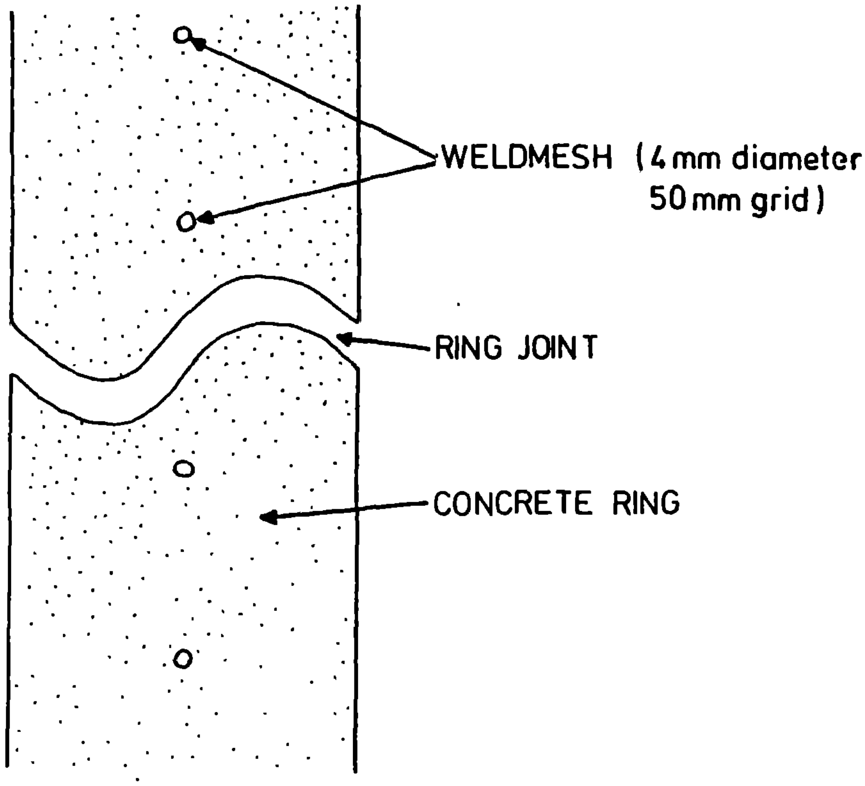


Diagram of ring joints

Construction of the well-head frame

When the position to dig a well has been decided upon either after augering or in a traditional source, then a solid head frame needs to be constructed.

After marking the 1.8 m circle which will be the well site on the ground, mark and dig out 4 further holes at 4 metre diagonal spacing (see diagram below). These need to be dug at least 1 metre in the ground and fit the base of the Y-shaped poles. These poles are set in concrete.

The poles need to be thick and approximately 3 metres long, and care should be taken to keep the top V of the Y poles which are opposite each other, facing each other and level, and 2 of the Y shaped poles a few inches lower than the other 2 (see diagram below).

The 2 cross poles can be wooden trunks, or 4" or 5" galvanised steel pipes (or borehole casing pipes).

As this structure is going to need to be able to support 450 kg of concrete ring, it has to be very rigid.

Moving concrete rings over the well.

Movement of the rings can be done by either rolling them (dependent on the quality) or by levering them onto two 5" steel pipes. They can then be pulled by ropes from the front (4 men) and levered with crow-bars at the balk of the ring itself (2 men).

To shift the rings into position over the well-head the same technique of two steel pipes is used. Moving of the rings easily comes with practice.

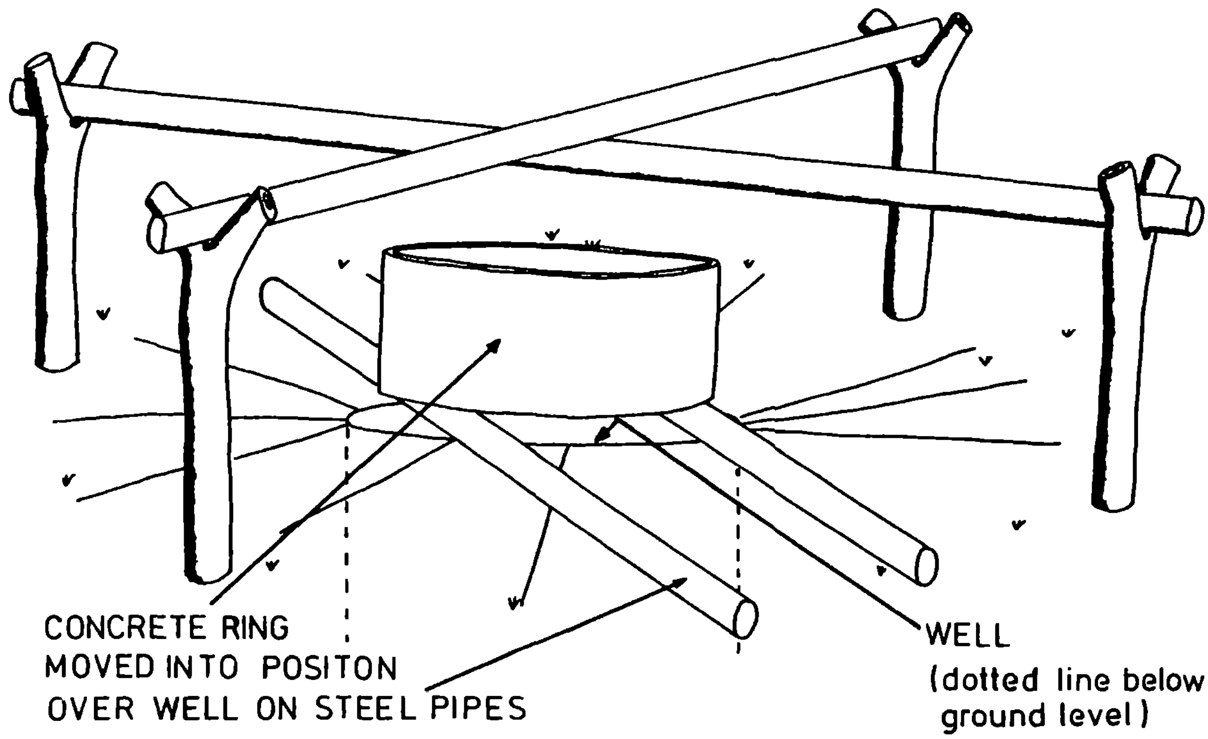


Diagram of ring position over well and well-head frame

Once the ring is centrally placed over the well, it is necessary to lift the ring up and to remove the two steel pipes. This allows the ring to be lowered into the well.

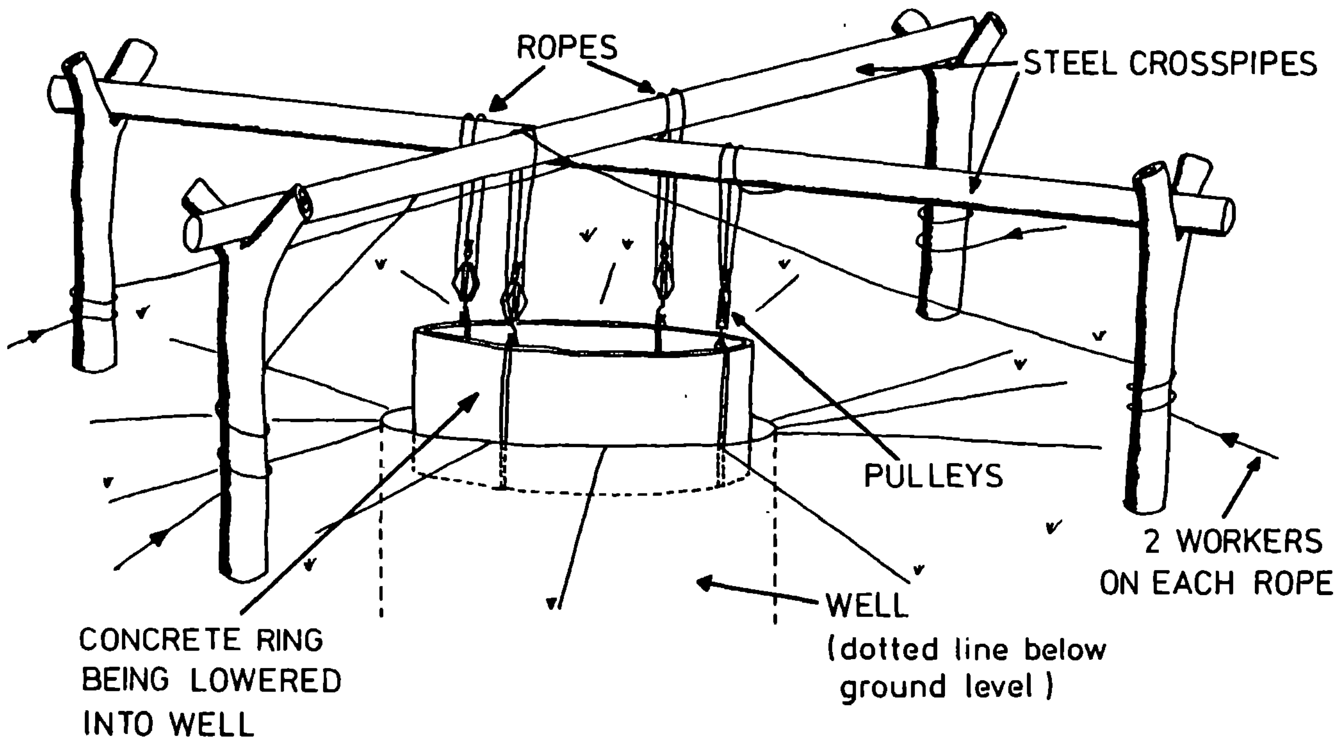


Diagram of ring lowering into well

This is done using 4 ropes, which are secured at equal distances around the ring, of approximate lengths 4 metres (doubled), and 4 ropes attached to pulleys (as in the diagram above), which are in turn attached to the ring ropes. These ropes need to be 10 metres long plus the depth of the well, and are wrapped around the adjacent upright Y shaped poles. Two men on each rope are then directed to lower the ring vertically down the well.

The bottom ring should be set centrally in the well on rocks and set level. The bottom 1/4 of this ring is later filled with broken rocks (aggregate).

This technique can be used in firm soil where the well is excavated first. In loose soil or below the water table sink a caisson.

Sinking a caisson.

Precast concrete rings are stacked one on top of another either:

* inside the upper lining, or

* added individually at the ground surface level, as the well depth increases.

Excavation takes place inside the rings. At first a hole is dug in the centre of the well, and then cut back in layers all around the sides below the ring. The following digging order should be followed.

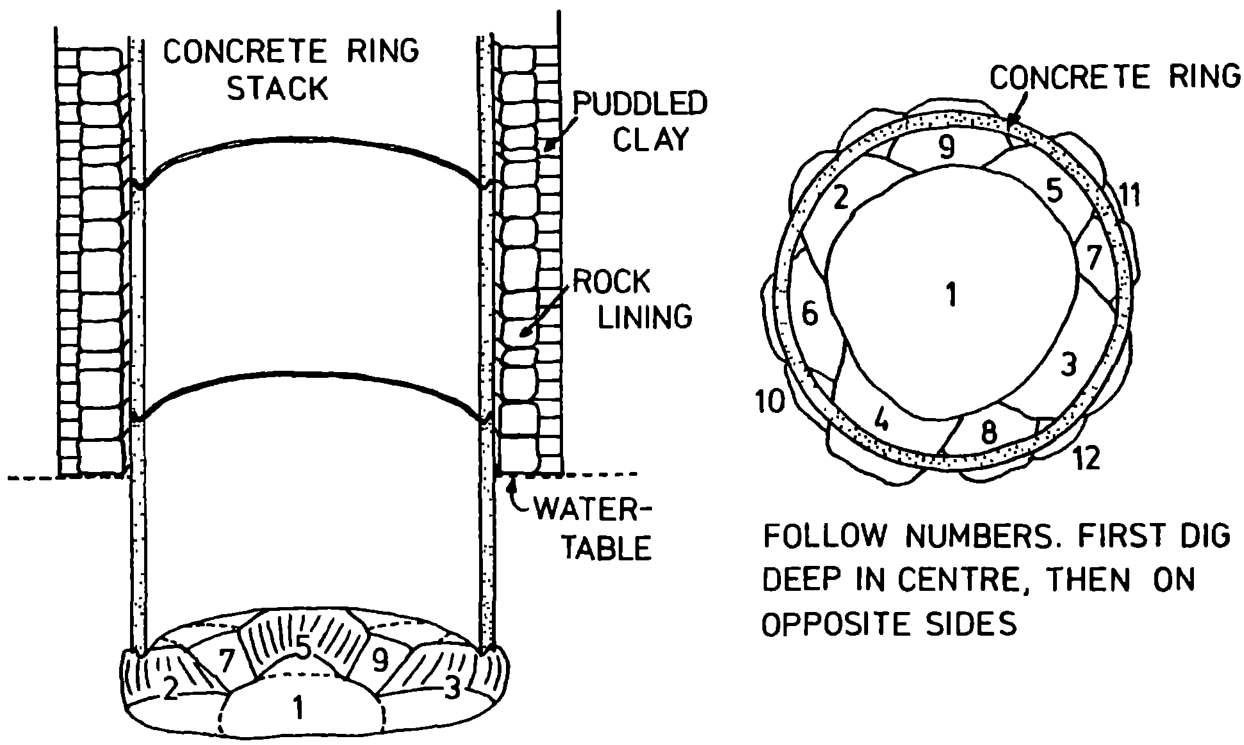


Diagram of cutting order inside a caisson

Care should be taken as digging away too much on one side may cause the rings to sink out of line, and the well must be sunk straight and vertically. When enough excavation has occurred the rings will sink under their own weight.

If the rings are not settling down straight it is important to correct the fault immediately. Concentrate on digging underneath the lowest side and dig upwards behind the rings into the side walls. This will give the rings space to move into as they sink straight. This should be understood by all the workforce as they will want to dig under the highest side, and this will make the situation worse and should not be done.

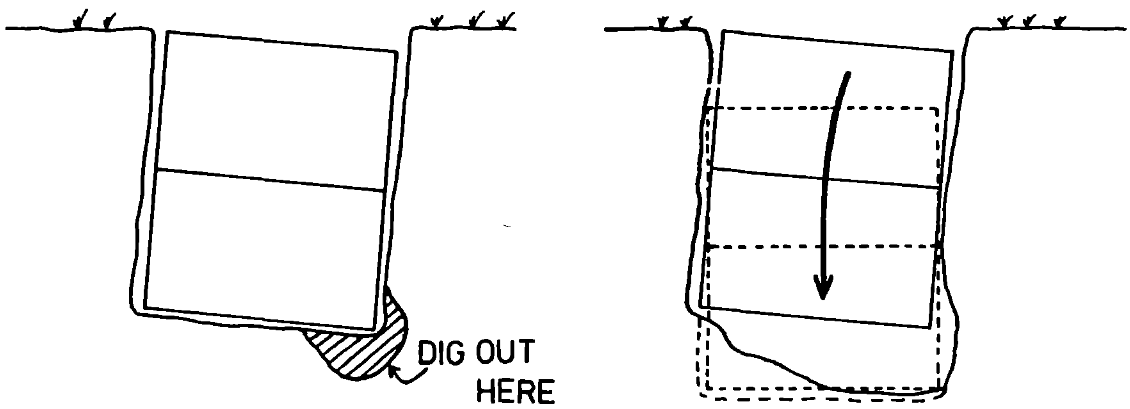


Diagram of correcting a well that is not straight

If the rings stick and do not sink after excavation, then "flush down" the rings by pumping water from the well down the outside of the rings. This will wash down any soil which may be holding the rings up.

How can the amount of water obtained from a well be increased?

There are two ways to increase the yield of a well:

1. Deepen the well. This can only be done with dewatering or sump pumps, and then only at the end of the dry season.

2. Widen the well. This not only increases the area in contact with the water bearing layer, but also the storage capacity of the well.

Widening the well using standard rings is impractical. One alternative is to dig infiltration trenches (described in chapter 6 on springs). These may need structural support while being constructed. Another is to 'punch' perforated pipes horizontally into the water-bearing layer.

Chapter 8.

DESIGNS FOR THE WELL-HEAD

For prevention of pollution, or contamination of the well occurring through the ground certain guidelines have already been mentioned, such as closing local pit latrines.

Preventing a well from becoming polluted through the well-head (where there is direct contact between the ground surface and the water, and between the users and the water), is particularly difficult and greater care needs to be taken.

Sticks, branches, leaves and dust can pollute a well. Children are particularly responsible for this kind of pollution.

Germs can get into the water source:

1. On dirty buckets, from being touched by dirty hands, or from the buckets being placed on the dirty ground.

2. Through spilt water either flowing back directly into the well, or seeping down the outside of the lining, carrying the pollution down to the source.

It is best to seal the well-head totally and fit a hand pump if available. This separates totally surface water and well users from the source, preventing contamination.

If no pumps are available it is necessary to physically protect the water source as far as possible. To do this a cover, windlass and basin should be installed along with the outward sloping well apron.

The cover

This can be made of wood or tin sheeting but is best made of reinforced concrete, which covers most of the well-head while still allowing access for the water container of the well. The cover should be fitted with grooves allowing it to slot onto the top ring of the well (see Chapter 7.)

The following design covers most of the well-head and can easily be adapted if a hand-pump becomes available.

The cover is approximately 5 centimetres thick in the centre and 7 centimetres around the outside. It is reinforced with either weldmesh or 4 centimetre strips of nylon string with a 10 mm twisted rebar around the circumference of the cover. The cover slopes at an angle of 15°. It has a mix the same as for the rings of 1:2.5:4 (see chapter 9), with a surface skim of mortar at a mix of 1:6.

To construct the cover it is necessary to build a concrete mould. After the mould is built up (best above the ground level otherwise drainage of rainwater is a problem) then the metal moulding used for the top of the ring mould needs to be worked into the still wet concrete,to give the correct join for the cover to the top ring.

Once the mould is set then cut the weldmesh to shape and include:

1. A circular bevelled opening (made from a hammered out drum) as the man-hole cover. This can be poured at the same time as the cover - it should be reinforced with weldmesh and include two 10mm lengths of rebar twisted, as a locking device and as a handle for opening the man-hole.

2. Two large loops of rebar set into the concrete and under the weldmesh as lifting handles (for insertion of poles) for the whole cover.

3. Union for the possible later inclusion of a hand-pump on the well, at which time the top ring can be removed and the manhole cover sealed.

4. Locking device - without keys of two T angles of pipe with central, slightly smaller piping threaded at each end with a joining union.

The cover can then be poured, the mould first being covered with oiled plastic sheeting.

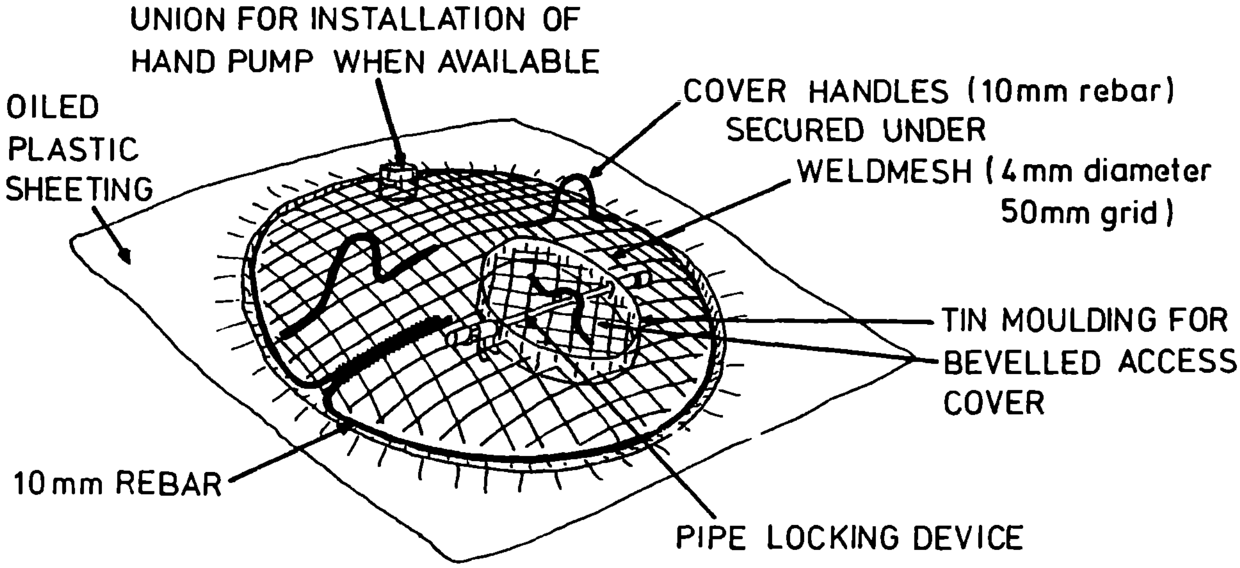
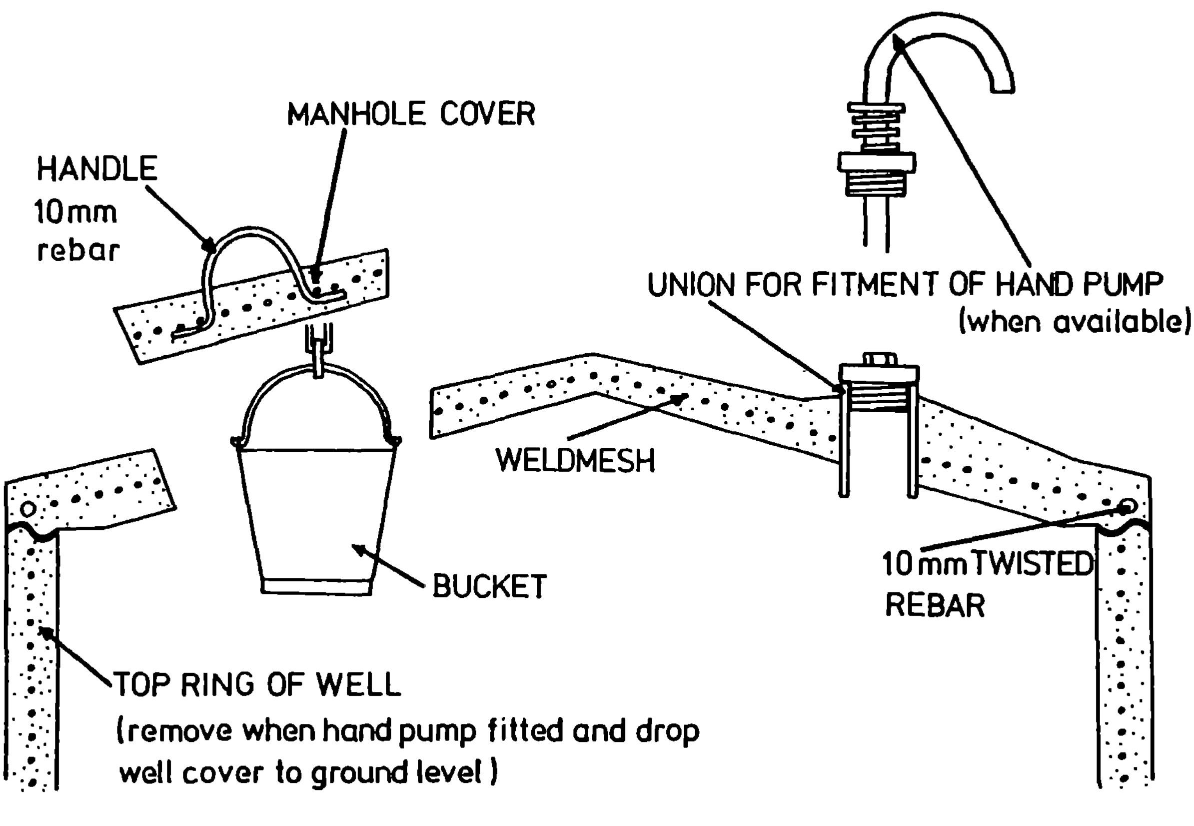


Diagram of mould ready for pouring cover



Cross-sectional diagram of well cover

The correct top angle is obtained by using a wooden template.

If rope is being used rather than chain to lift the cement or water container from the well, then rebar set across the manhole at the top and bottom prevents the wearing away of the rope on the concrete.

The Windlass

To overcome the problem of wearing of the wood on wood or metal on wood bearing, reducing the length of life of the windlass, the bearing surface should be made as large as possible. Also the torque developed whilst lifting the full bucket of water - possibly weighing 20 kg - needs a very rigid structure which cannot twist when in use. The following windlass design overcomes these two problems.

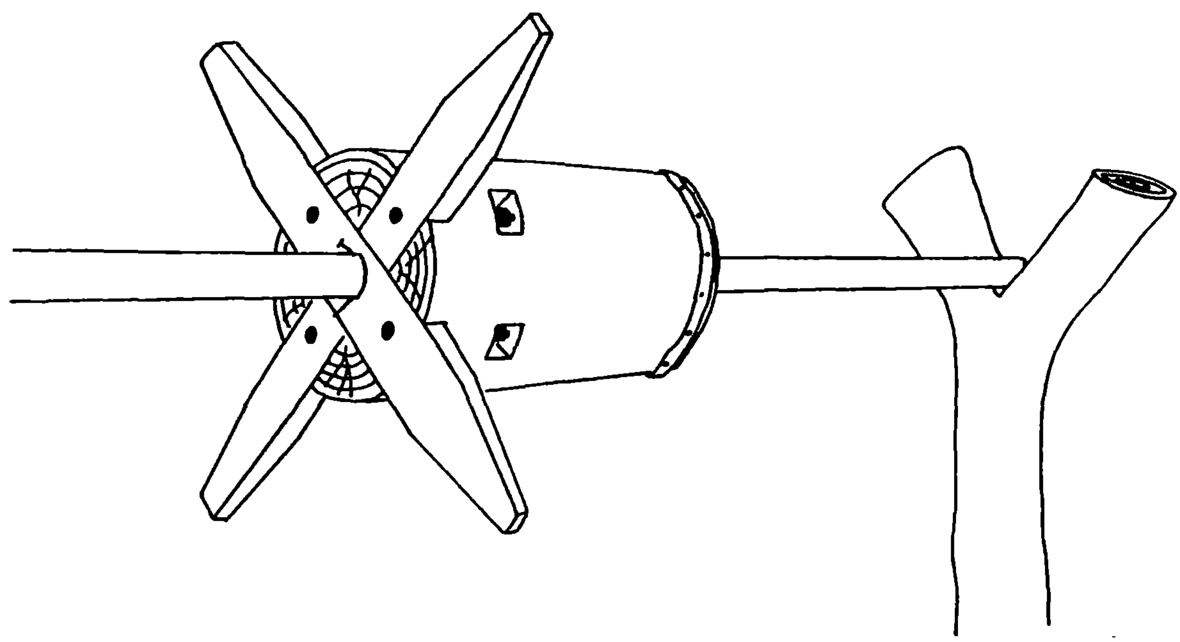


Diagram of Log-Windlass

1. Cut a 50 centimetre length of hardwood log, 20cm to 30cm in diameter (mahogany and preferably well-seasoned).

2. Using a 60 millimetre hand auger, drill a hole down the centre of the log. This needs a specialised tool. A smaller auger can be used, and the remainder removed using chisles.

3. Cut two 90 centimetre lengths of 5cm x 7.5cm mahogany.

4. Shape the handles - as in diagram below.

5. Half-lap the centres of the mahogany at right-angles.

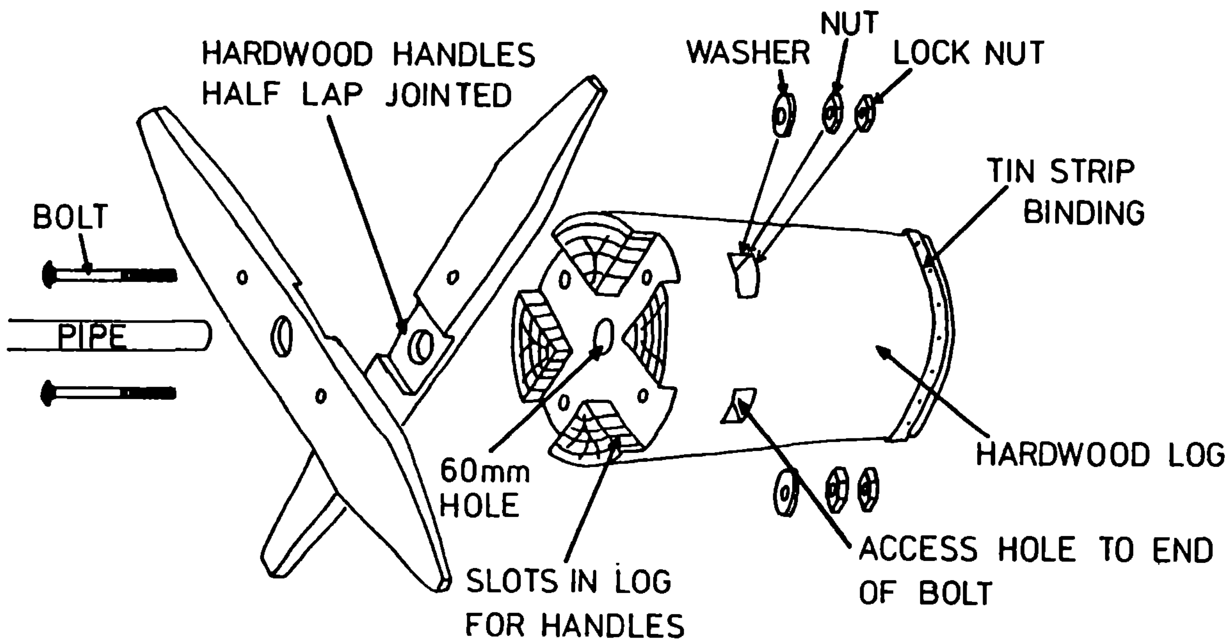


Diagram of components of windlass

6. Drill 60 mm hole in the dead centre of the half-laps. (The mahogany handles first having been joined together.)

7. Place the handle over end of log, centering on the drilled holes, and mark the handles onto the end of the log with a pencil.

8. Cut out where the handles are marked to allow the handle to slot into end of the log.

9. Fit the handle onto end of log and drill four 1cm holes 15cm long for the four end bolts.

10. Mark how far the bolts go into the log and cut out an access hole to insert the nuts and washers. Two nuts need to be screwed on the end of the bolts to allow locking of the retaining nut. The end of the access hole nearest the handles needs to be flat to allow the washer to fit flush. The bolt wants to run from one side of this access hole into the wood at the other side.

11. The end link of the chain,for lifting the water bucker, can be slotted over one of these bolts.

12. A 1.5cm strip of metal (again from a drum) needs to be hammered onto the other end of the log from the handles, to hold the log together if splitting occurs.

13. Drill six holes in a 1.85 metre long 60mm external diameter pipe at 5cm, 72cm, 126cm, 170cm, 175cm and 180cm from one end. The diameter of these holes should allow a 15cm nail to pass through the pipe.

14. Fill the pipe with concrete, with the nails in position.

15. Set two Y-shaped poles (previously used in the well head frame) and reset in concrete apron, as in diagram below. From the central line of the access man-hole mark the edge of the cover. Measure 75cm in one direction and 100cm in the other direction around the edge of the top ring from this mark. These are the positions for the Y-shaped poles.

16. Put windlass onto pipe and centralise windlass using 2 bent-over nails as in diagram below, with nails through holes at 72cm and 126cm.

17. Nail to Y-shaped supports

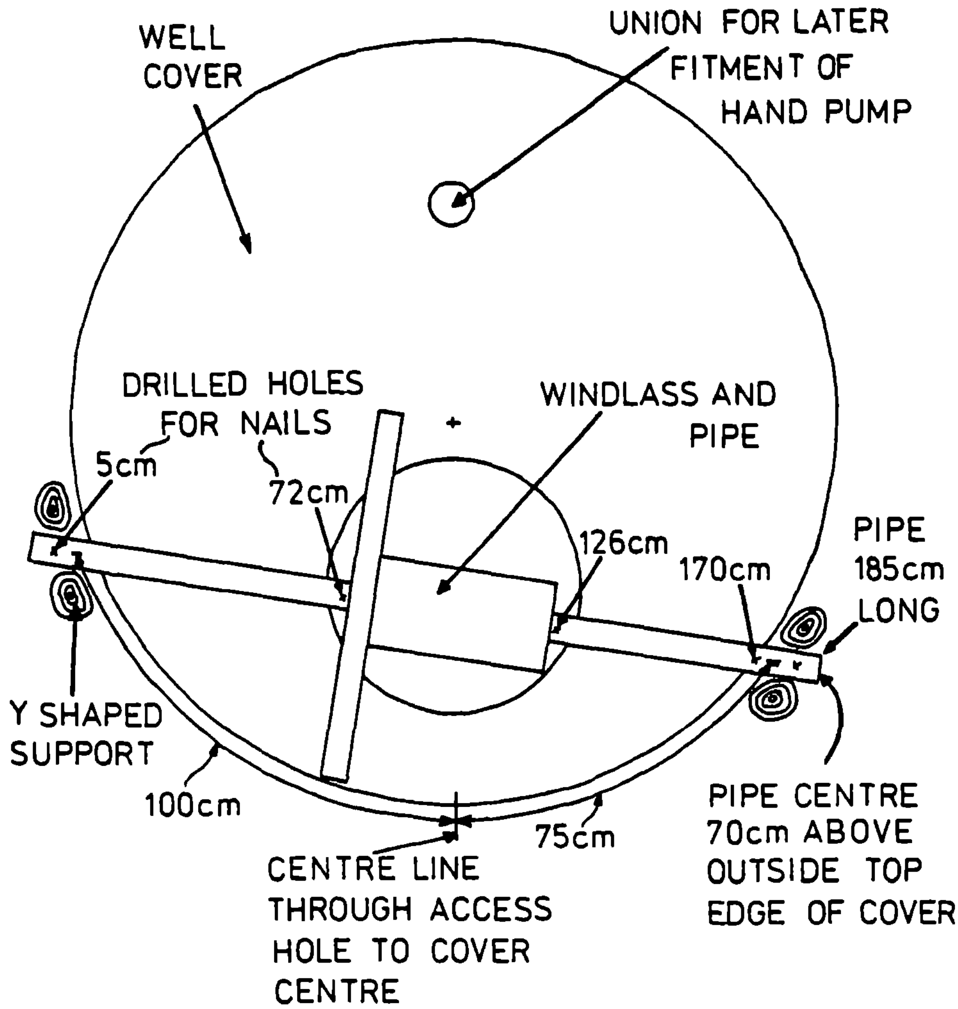


Diagram of windlass setting with supports

If a hand-pump is fitted the whole windlass structure of windlass, bucket and chain should be left erected, and the chain and bucket sealed inside the man-hole cover, for use if the pump breaks down and immediate maintenance is not possible.

The basin.

Pollution of the well is possible where the bucket, which is used to collect water from the well, is placed on the ground outside the well. On the ground the bucket can pick up germs and dirt, especially germs washed off people's feet and clothes.

A basin attached to the side of the well, allowing the water to be poured straight from the bucket into the basin, means that the bucket can be returned immediately into the well without ever being placed on the ground. The water flows in the sloping basin to an outlet pipe which directs the water into a jerry can.

The basin is built separately so that if the top ring should be removed, the basin can be left intact.

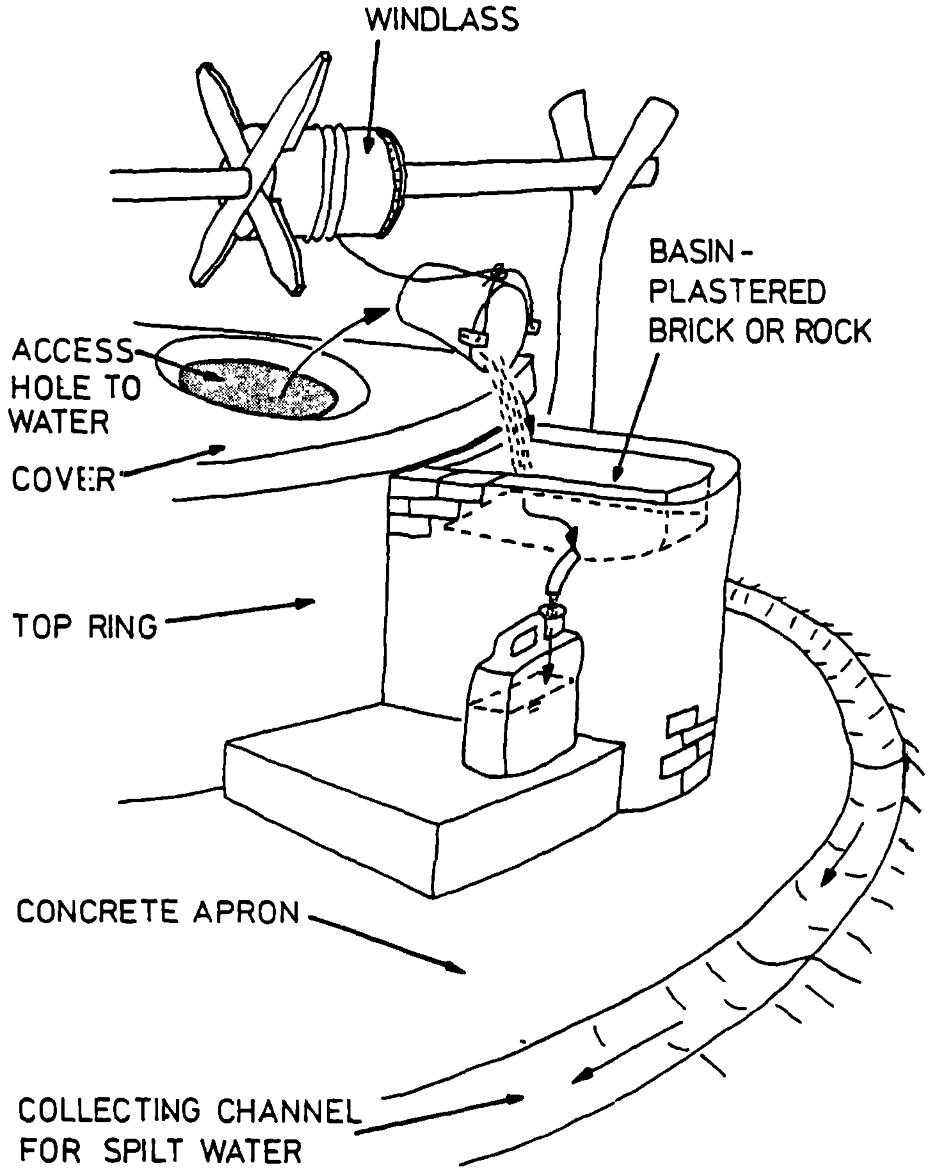


Diagram of Basin

The jerry can, in turn, is placed on a platform built up level from the sloping apron.

The basin is built of bricks or rocks on 4 sides and back filled with rocks in the centre to the required height.

The basin should be set slightly to the side of the centre of the cover's man-hole, to allow physical access to the windlass to collect water.

Chapter 9.

CEMENT

What does 1:4:6 or 1:3:7 and so on mean?

This means that the mixture contains 1 part cement, 4 parts sand and 6 parts aggregate, or 1 part cement, 3 parts sand and 7 parts aggregate and so on.

So	1	: 2	: 4
indicates	1 cement	: 2 sand	: 4 aggregate

If there are only 2 numbers then this indicates just cement and sand.

These amounts can be measured as numbers of buckets, numbers of shovelfuls, and so on.

The sand should be clean and sharp with no clay, earth, mould or roots. The stone should be angular (with sharp edges) and also clean.

What mixes of cement, sand and aggregate should be used for concrete, mortar and plaster?-

1. Strong concrete for dams, houses, rings, watertight foundation and floors	1 : 2 : 4
2. Ordinary concrete - backfilling	1 ; 3 : 6
3. Mortar	1 : 6
4. Plaster	1 : 4

How should concrete be mixed?

Good concrete cannot be mixed on the bare ground, because dirt and earth will mix with it and make it weak. It must be mixed either on boards, in a wheelbarrow, or in a concrete mixing trough.

If the proportions of the mix are to be 1:3:6 and this is being measured in buckets, then 6 buckets of stone should be mixed first with the 3 buckets of sand before adding the 1 bucket of cement.

The whole mixture - aggregate, cement and sand - should be turned over "dry" three times - that is without water. Only after this mixing has been completed should water be added. The wet mix should then be turned over several times until the mix is plastic, evenly mixed, and the same colour throughout.

Only enough water should be added to make concrete plastic. Too much water reduces the strength of concrete.

How should concrete be laid?

Concrete should be used as soon as it is mixed. It must never be allowed to set before use.

Lay the concrete in 15 cm layers and ram with crowbars or wooden poles before adding the next layer. This ensures that the concrete is compact and any air bubbles are removed.

If new concrete is put on old, the surface of the old concrete must be thoroughly cleaned and wetted with water, and if it is smooth it must be chipped to form a good key.

Why are steel bars and rods sometimes used in concrete?

Concrete is very good at resisting compression (being squeezed) but is weak at resisting being pulled apart. Steel is therefore added to concrete to make good this weakness. It is used in such situations as concrete bridges, rings, and beams (mainly in situations where there will be parts of the concrete not supported underneath, as in a bridge).

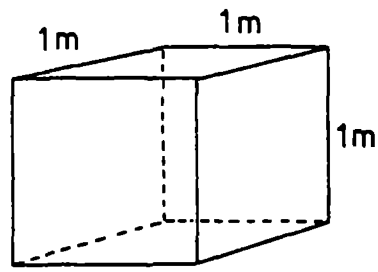
Chapter 10

MEASUREMENTS

Why does 1 tonne = 1000kg = 1000 litres = 1 cubic metre of water?

The above is the basis of all the metric system of measurements. It was devised so that all measurements are standardised.

A length was decided upon to equal 1 metre. When this length is measured as a container with all the sides equalling 1 metre as:



and this container is filled with water, then the water weighs 1 tonne. And the Volume is 1 cubic metre.

1 tonne was divided into 1000 equal parts. The weight of each part was called 1 kilogram (Kg).

Therefore 1 tonne = 1000Kg

If the volume of the 1 cubic metre is divided at the same time into 1000 equal parts and each volume is called 1 litre (l), then:

1 cubic metre = 1000 l
and 1 Kg = 1l
as 1000 Kg = 1000 l

This can be further extended:

If 1 Kg is divided into 1000 equal parts and the weight of each part called 1 gram (gm).

Then 1 Kg = 1000 gm

and 1 litre is divided up into 1000 equal parts and the volume of each part called 1 cubic centimetre (cc).

Then 1 l = 1000 cc

From all this therefore:

1 gm of water has a volume of 1 cc
1 Kg of water has a volume of 1 l
1 tonne of water has a volume of 1 m^3

And:

1 tonne = 1000 Kg = 1,000,000 gm = 1,000,000 cc = 1000 l = 1 m 3

The density of water is therefore 1 gm per cc. The density is the compaction or mass of a substance.

Now 1 cc of rock does not equal 1 gm, that is the same volume of rock and water do not weigh the same. All gases, liquids, and solids weigh a different amount per cc.

The weights of all materials per cc can be seen as an amount greater than or less than 1 cc of water, or as a multiple of this weight, so:

1 cc of rock weighs a lot more than 1 cc of water (depending on the type of rock, it weighs between 1.5 and 2.5 times as much). That is, lcc of water weighs 1 gm, and 1 cc of rock weighs between 1.5 and 2.5 gms, and similarly $1m^3$ of rock weighs between 1.5 and 2.5 tonnes.

This is why a rock sinks in water. It is more dense than water, whereas a piece of wood floats, because it has a density of approximately 0.7 gm per cc.

What are the basic units of measurements?

1. Lengths :

1 kilometre (Km) = 1000 metres (m)
1 m = 100 centimetres (cm)
1 cm = 10 millimetres (mm)

From this: 1 m = 1000 mm

and ½ m = 50 cm = 500 mm. This is also = 0.5 m

¼ m = 25 cm = 250 mm. This is also = 0.25 m

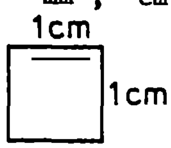
As an example :

425 mm = 10 cm = 42.5 cm = 42½ cm = 0.425 m

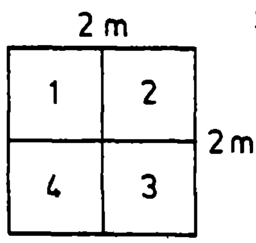
2. <u>Areas</u> :

If metres are multiplied by metres, this gives square metres. The same is true for cm and mm so:

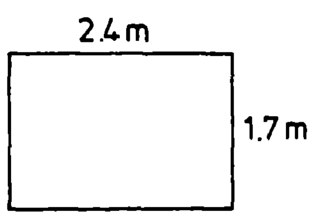
$mm \times mm = mm^2$, $cm \times cm = cm^2$, $m \times m = m^2$.

$1\ cm^2$ = 

$1\ cm \times 1\ cm = 1\ cm^2$

$4\ m^2$ = 

$2\ m \times 2\ m = 4\ m^2$



As an example :

	1.7×2.4	$= 4.08$
and	$m \times m$	$= m^2$
therefore		$= 4.08\ m^2$

You cannot multiply cm x m as they are not in the same units. If it is necessary to multiply cm x m, then one of these units must be converted to the same as the other.

As an example :

5.7 cm needs to be multiplied by 3.2 m. Either :

5.7 cm = 0.057 m

therefore 0.057 m x 3.2 m = 0.1824 m^2

or

3.2 m = 320 cm^2

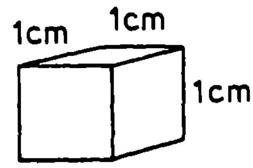
therefore 5.7 x 320 = 1824 cm

1 hectare (ha) = 10.000 m^2 = 100 m x 100 m

1 square kilometre = 100 ha = 10 ha x 10 ha = 1000 m x 1000 m = 1 Km^2

3. <u>Volumes</u> :

1 cubic centimetre = 1 cm x 1 cm x 1 cm = 1 cm^3 or 1 cc

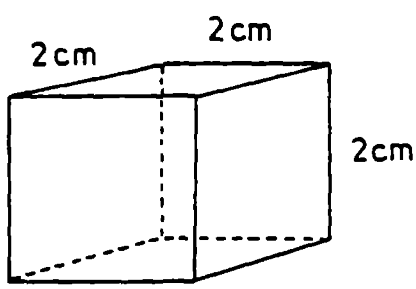


and so

2 cubic centimetres = 2 cm x 2 cm x 2 cm

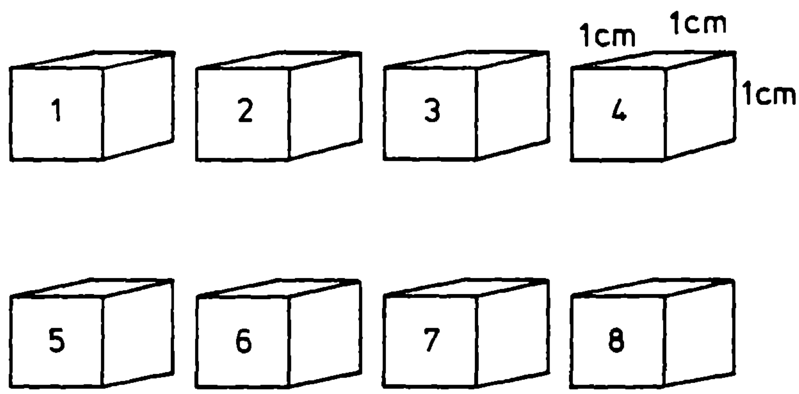
= 2 x 2 x 2 = 8

cm x cm x cm = cm^3



= 8 cm^3

This is the same as



The same is true for cubic millimetres, cubic metres,and so on.

In addition 1 litre = 10,000 cm^3 = 10 cm x 10 cm x 10 cm

and 1 m^3 = 1000 litres

4. Weights

1 tonne = 1000 Kgs.
1 kilogram = 1000 gms.

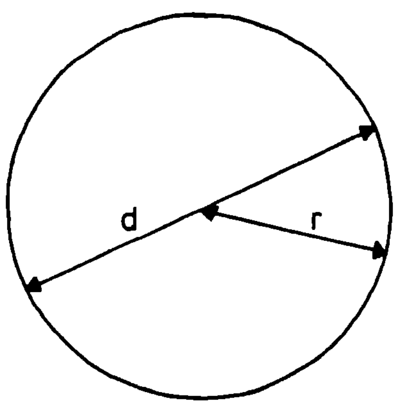
Now 1 cc of water weighs 1 gram, as stated above and
1000 cc = 1000 gms = 1 Kg = 1 litre

This implies that 20 Kg of water = 20 litres (1 jerry can)

How can the area of a circle be calculated?

The size of a circle can be described as the length of a straight line from the exact centre of the circle to the outside edge. This length is called the radius (r). Or the circle can be described by a straight line through the centre of the circle from opposite sides called the diameter (d).

So this circle



has r = 2 m
and d = 2 x r = 4 m

To calculate the area of a circle then multiply :

$$\frac{22}{7} r^2 \quad (r^2 = r \times r)$$

As an example:

if $r = 3.2$ m

then area of circle $= \frac{22}{7} \times 3.2 \times 3.2 = 32.18$

$m \times m = m^2$

$= 32.18 \ m^2$

How can the volume of a cylinder be calculated

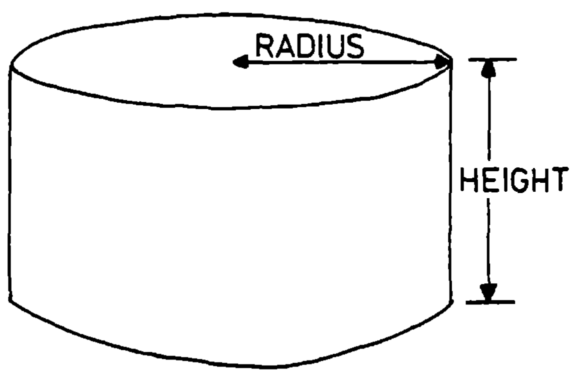
This can be done by using the formula for a circle (one end of the cylinder and multiplying this by the height of the cylinder.

$\frac{22}{7} r^2 \times h$ (where h = height of the cylinder)

As an example :

if $r = 0.75$ m

and $h = 0.85$ m



then volume $= \frac{22}{7} \times 0.75 \times 0.75 \times 0.85 = 1.50$

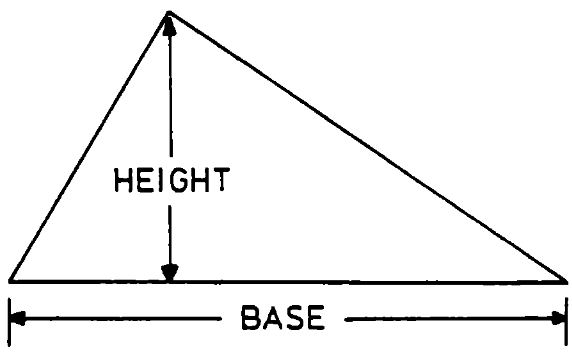
and $m \times m \times m = 1.50 \ m^3$

Also, from the above, as $1 \ m^3 = 1000^1$

then $1.5 \ m^3 = 1500^1$

How can the area of a triangle be calculated?

By multiplying ½ the base length by the height



How are flow rates calculated?

The flow rate is a measure of a volume for a certain length of time.

Therefore 1 litre flowing in 1 second is described as 1 l/sec.

This means that in one minute there will be:

1 l x 60 seconds = 60 l/min

= 3 jerry cans per minute

and as 1 hour = 60 minutes then at a flow rate of 60 l/min per hour the flow rate will be:

60 l x 60 minutes = 3600 l/hr

= 180 jerry cans per hour

and per day = 24 hours. Therefore

3600 l x 24 hrs = 86,400 l/day

= 4320 jerry cans per day

= 21-3/4 drums (200 litre drum).

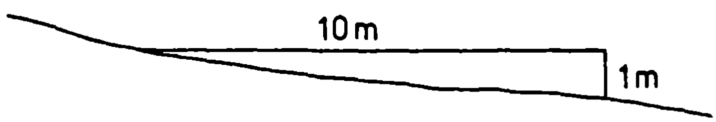
How is a gradient calculated?

A gradient is a measure of slope or steepness, and is expressed in one of three ways :

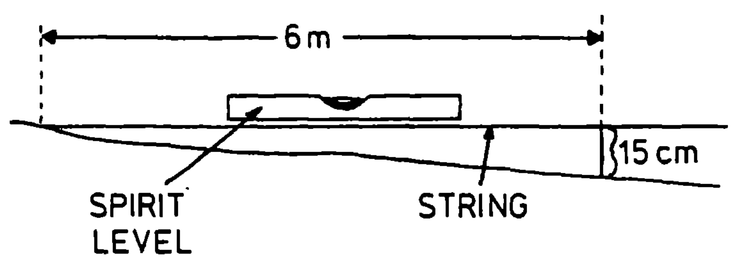
1. As a ratio........... 1 in 10, 1 : 10
2. As a percentage 10%
3. As a fraction........ $\frac{1}{10}$

These all mean that for every 10 m horizontal distance there is a vertical drop of 1 m.

As



and if a gradient has to be measured and the slope is like this:



Then as a ratio = $\frac{6}{0.15}$ = 40 and so 1 : 40

as a percentage = $\frac{6}{0.15}$ x 100 = 2.5%

as a fraction = $\frac{0.15}{6} = \frac{1}{40}$

In the field, if a length of string is pulled tight and adjusted to be level by placing a spirit level on the string, then any length of the rope can be chosen as the horizontal length. The vertical height can be measured straight down from this chosen length.

REFERENCES :

Feacham, R. et al, Water Wastes and Health in Hot Climates, John Wiley and Sons Ltd. (1977).

Hudson, N.K. Field Engineering for Agricultural Development, Clarendon Press. (1975)

International Reference Centre for Community Water Supply and Sanitation Small Community Water Supplies, Technical paper 18. (1981)

Nissen-Petersen, E. Rain Catchment and Water Supply in Rural Africa; a Manual, Publ. Hodder and Stoughton (1982).

Prodorite Bulletin. Harare, Zimbabwe.

Skat, Swiss Centre for Appropriate Technology. Manual for Rural Water Supply. (1980).

Stern, P. et al, Field Engineering: An Introduction to Development Work and Construction in Rural Areas, Intermediate Technology Publications (1983).

Wagner, E.G. and Lanoix, J.N. Water Supply for Rural Areas and Small Communities, World Health Organisation (1959).

Watt, S.B. and Wood, W.E., Hand Dug Wells and their construction, Intermediate Technology Publications. (1979).

Werner, D., Where there is no doctor: A Village Health Care Handbook, Macmillan Press. (1981).

United Republic of Tanzania, Shinyanga project, Shallow wells, DHV Netherlands.

REFERENCES :

Feacham, R. et al, Water Wastes and Health in Hot Climates, John Wiley and Sons Ltd. (1977).

Hudson, N.K. Field Engineering for Agricultural Development, Clarendon Press. (1975)

International Reference Centre for Community Water Supply and Sanitation Small Community Water Supplies, Technical paper 18. (1981)

Nissen-Petersen, E. Rain Catchment and Water Supply in Rural Africa; a Manual, Publ. Hodder and Stoughton (1982).

Prodorite Bulletin. Harare, Zimbabwe.

Skat, Swiss Centre for Appropriate Technology. Manual for Rural Water Supply. (1980).

Stern, P. et al, Field Engineering: An Introduction to Development Work and Construction in Rural Areas, Intermediate Technology Publications (1983).

Wagner, E.G. and Lanoix, J.N. Water Supply for Rural Areas and Small Communities, World Health Organisation (1959).

Watt, S.B. and Wood, W.E., Hand Dug Wells and their construction, Intermediate Technology Publications. (1979).

Werner, D., Where there is no doctor: A Village Health Care Handbook, Macmillan Press. (1981).

United Republic of Tanzania, Shinyanga project, Shallow wells, DHV Netherlands.