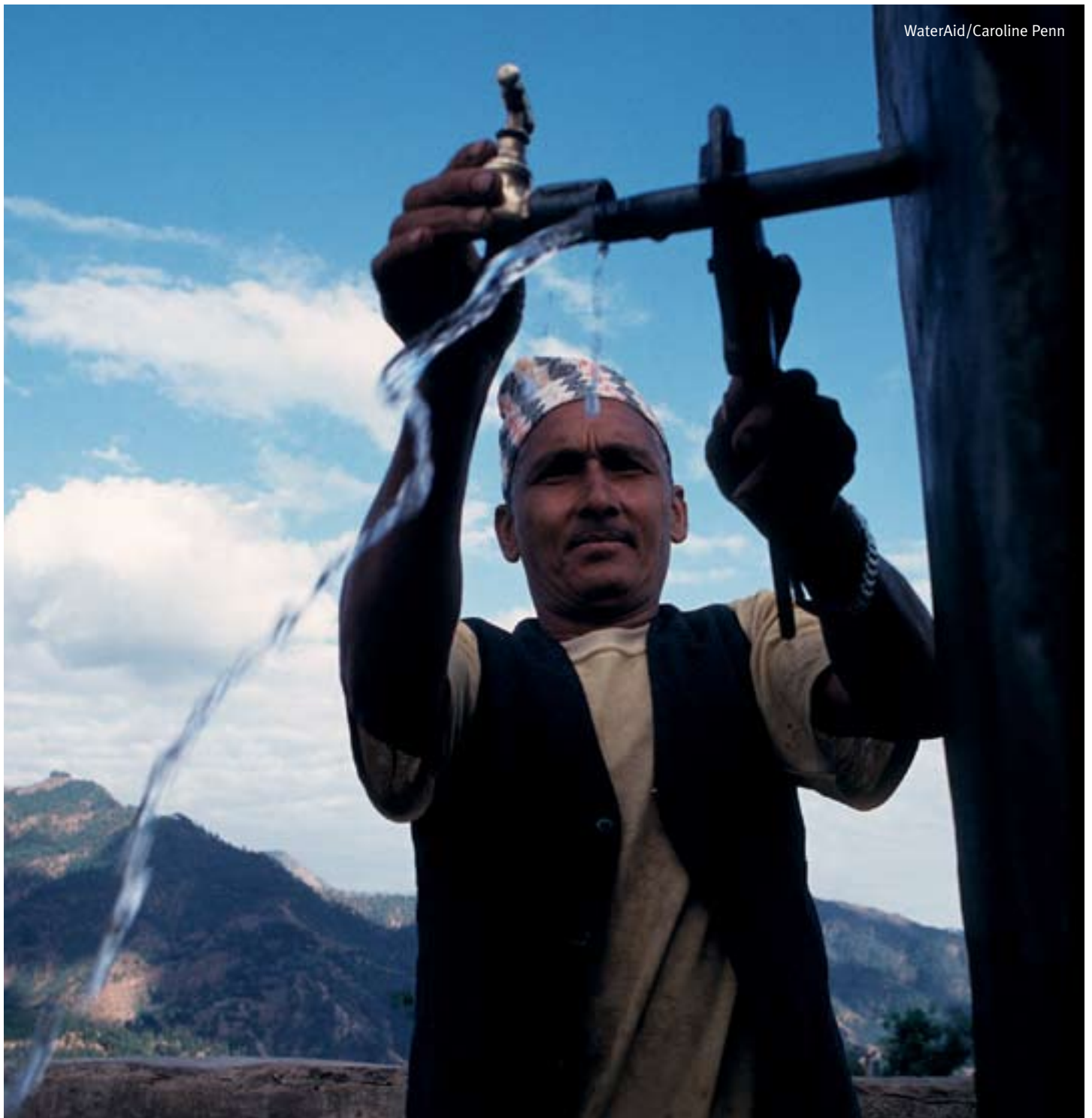


Technology notes



TECHNOLOGY NOTES

Section 1	Introduction
Section 2	Considerations before design
Section 3	Hygiene education
Section 4	Water resource development
Section 5	Gravity schemes
Section 6	Hand-dug wells
Section 7	Tubewells and boreholes
Section 8	Handpumps
Section 9	Spring protection
Section 10	Rainwater harvesting
Section 11	Sub-surface dams
Section 12	Sanitation
Section 13	Disinfection
Section 14	Treatment of water



WaterAid – water for life – The UK's only major charity dedicated exclusively to the provision of safe domestic water, sanitation and hygiene education to the world's poorest people.

Charity registration number 288701

INTRODUCTION

Technology notes

These Technology Notes have been prepared following many general enquiries for technical information having been received by WaterAid over the years.

Their purpose is to give an outline of the technologies used by WaterAid on long-term development projects in Africa and Asia, and to show alternatives which might be appropriate in different circumstances. It may be possible to determine from the notes the technology which would be appropriate in a particular location.

If it is proposed to proceed with the design and construction of a project using any of the principles set out in these notes, it is strongly recommended that further details be obtained from a specialist or from the reference books which are listed at the end of the relevant section.

Acknowledgements

These notes have been prepared within WaterAid for use by its own staff and by those organisations which have requested technical help from WaterAid.

In order to illustrate the points raised in the text, drawings, sketches and charts have been collected from various sources. It is not always possible to locate the original source of the illustrations, but WaterAid wishes to acknowledge that some have been taken from publications listed in the references at the end of sections.

WaterAid thanks the relevant authors and organisations and trusts that mutual cooperation will continue.

CONSIDERATIONS BEFORE DESIGN

Introduction

There are many non-technical points which should be considered fully by the supporting agency and the community before any scheme proceeds, in order to ensure long term sustainability and maximum benefit of the scheme to the health and quality of life of the community.

The involvement, by supporting agencies, of communities in the design, implementation, monitoring, review and evaluation of a project enhances their sense of ownership. In turn, this empowers people to make decisions, relevant to their perceptions and needs, concerning the work which will help to safeguard the long-term sustainability of the project.

A commitment by the local community to participate fully in the scheme is now considered by WaterAid to be essential in all the projects which it supports. This means commitment at all stages. The stages can be considered to be: appraising the project, including the setting up of a baseline survey from which to measure improvements; setting its aims and objectives; designing it with the involvement of all the stakeholders; and setting up a monitoring system.

During the first stage, before any construction begins, consideration must be given to the final ownership; the management of day to day operations, however small; the method of payment for any repairs and maintenance; and the possibility of future extensions when neighbours see the benefits of the project.

Unless the scheme is to supply a formal institution such as a school or hospital, or a refugee or resettlement camp, the final owners should be the community which it serves.

Early formation of a committee

It is essential that the community is involved in decision making at an early stage and that local people determine the type of scheme, as far as it is technically possible, which they feel will serve them best.

This is best achieved by the formation of a committee, in which the whole community, whether a small town or just a group of homes around a spring, must be involved. Every effort should be made to make this committee truly representative of all the interests in the community, with men and women being equally represented on it. This committee will make decisions regarding all aspects of the project; these are likely to include such matters as:

- The type of scheme
- The location of water supply points, wells, boreholes, tapstands, etc
- The method of construction
- Whether the initial contribution should consist of cash or labour
- The method of payment to accumulate funds for eventual repairs
- The daily maintenance and cleanliness of the system

Hygiene education

Whether it is a water supply and/or a sanitation scheme that is proposed, the ultimate aim is to improve the health and quality of life of the community. Technical developments or improvements will give maximum benefit only if they are part of a wider hygiene education programme. This may involve the changing of long held attitudes and practices and may well take considerably longer to achieve than the actual construction of the scheme.

Hygiene education must be a community activity so that everyone goes forward together without any group being left behind. It is usual for the women to be the ones who are primarily concerned with the health of the family, and education will normally concentrate on them. However, it is often the children who are the easiest to educate regarding the benefits of hygiene education, and then they insist on changes being made within the family unit.

The community's contribution to the scheme

Decisions will have to be made by the supporting agency, in cooperation with the community's committee, regarding the nature of the community's contribution to the setting up of the scheme. This could, and probably should, include the provision of labour for construction, under the supervision of a suitably qualified person. A financial contribution may be required towards the initial capital cost, or to set up a fund for future maintenance.

Costs of operation and maintenance

The cost of operating the project when it is finished must be considered at an early stage. This may be little more than the cost of payment for the occasional services of a caretaker to clean the apron and steps at a protected spring, handpump or borehole. However, it might be considerably more, such as the cost of maintenance, and possible replacement of parts, for a handpump, or the operation of a diesel driven pump, including the provision of fuel or even the provision and dosing of chemicals for water treatment.

The following list of headings to be considered was used in the preparation of a maintenance budget for self sufficiency for a gravity scheme, from a spring source, supplying 50,000 people in rural Ethiopia.

- Salaries
 - Office staff and caretakers
- Maintenance
 - Labour costs
 - Materials for repairs
- Office costs
 - Maintenance – structure and equipment
 - Stationery and printing
- Transport cost
 - Truck hire to carry out repairs
 - Caretakers attending the office
- Protective clothing
- Hand tools
- Meter replacements
- Consultants – (to advise on management and engineering)
- Training
- Motor bikes
 - Replacement costs
 - Running cost

Two other items to consider (not applicable in this particular example project) are diesel fuel and electricity.

Payment for water

It is essential that a community understands that it is necessary to make some payment for the water that is used. The method of payment will vary according to the type of system and the nature of the users.

It may be payment to a caretaker for each jerry can collected, probably the most equitable way. However, this requires honesty and integrity from both the caretaker in handling cash and the user in offering payment. A monthly charge per household is easier to collect, but visitors, nomads or travellers will not contribute. Also, excess water used for irrigation or cattle watering is not covered by this method of charging, and there is no incentive to prevent wastage.

All accounts should be managed by some person who is respected within the community and should regularly be made available for public scrutiny. The community must decide what method, or combination of methods, it will use to build up funds for future maintenance.

Monitoring and evaluation

Monitoring of the project is a continual process: to check whether or not it is progressing in accordance with its aims and objectives; to identify problems as they develop; and to maintain a continual reporting system to all involved.

Provision should be made to carry out a final evaluation of the project on completion. This process will examine its performance, to find out whether or not its aims and objectives have been achieved, and what effect and impact it has had on the local people and their environment.

REFERENCES:

- 1 **Scinivasan L** (1990) *Tools for Community Participation*
PROWESS/UNDP
- 2 **Davis, Garvey and Wood** (1993) *Developing and Managing Community Water Supplies*
Oxfam
- 3 **Petty et al** (1995) *Participatory Learning and Action: A Trainer's Guide*
IIED

HYGIENE EDUCATION

Introduction

Hygiene education is about helping people to understand, firstly, what causes some of their health problems and, secondly, what preventative measures might be possible. It needs to be approached in a very sensitive way, with a great deal of respect being shown to local beliefs and practices.

It is estimated that diarrhoea kills about two million children each year in the developing world. Diarrhoea is frequently caused by pathogens from human faeces entering a person's mouth. Much, but not all, of hygiene education is concerned with explaining this route, which is called the faecal-oral route, and suggesting ways in which it can be blocked.

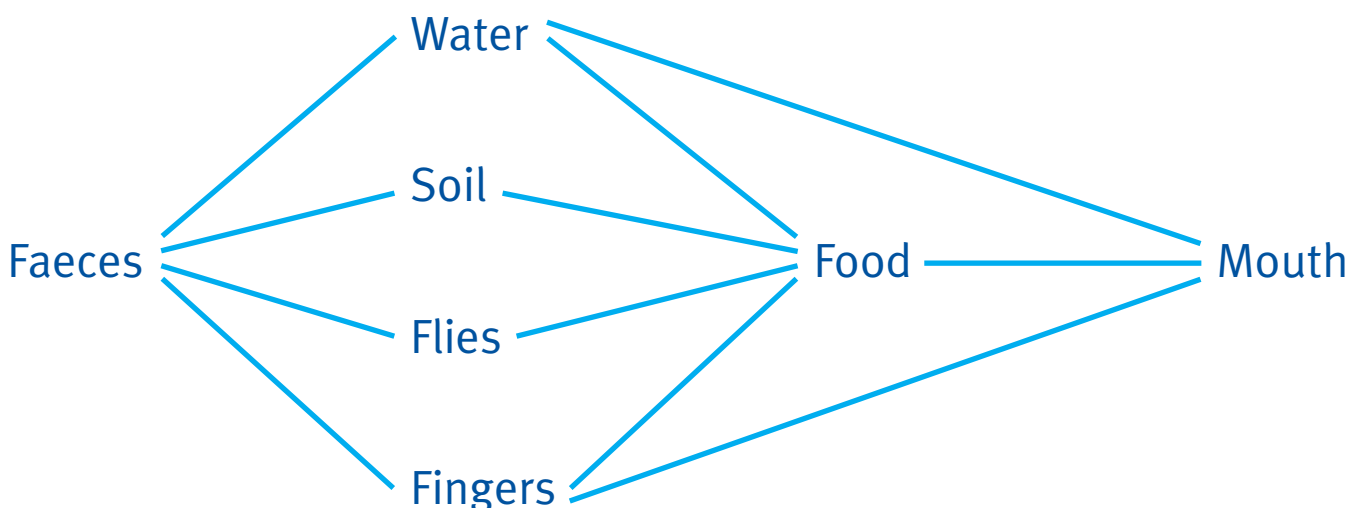
These notes do not attempt to tackle the whole range of topics in hygiene education; they concentrate on providing information about the faecal-oral transmission route and how it might be blocked.

The faecal-oral transmission route, which causes diarrhoea

If pathogens from human faeces enter a person's mouth and are swallowed, they will cause diarrhoea. If proper treatment is not given, this can prove fatal, particularly to children. The pathogens can enter the mouth in a number of ways; these include:

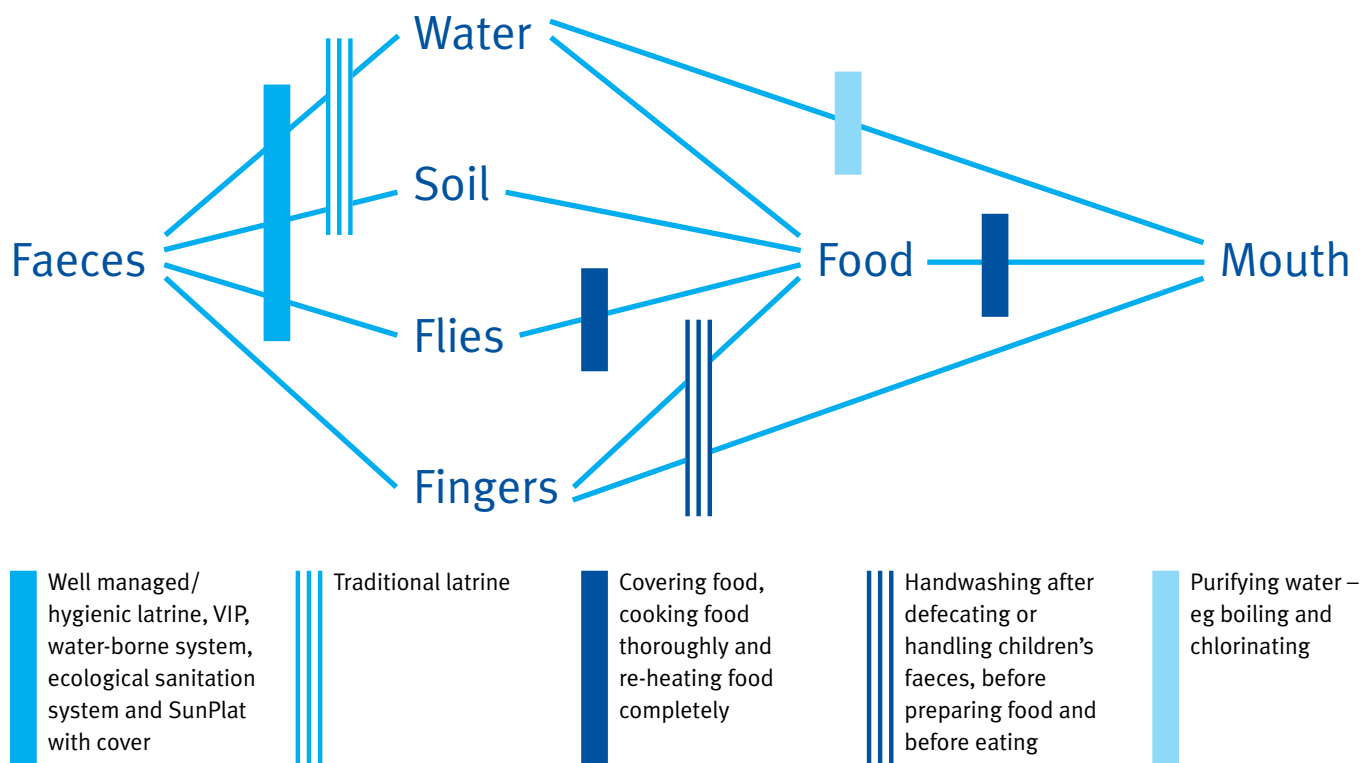
- Directly from a person's hands or fingers; pathogens get onto the hands or fingers if:
 - hands are not washed after a person has defecated, or
 - hands come into contact with someone else's faeces on the ground (such as when small children are crawling or playing on the ground or when adults clear up a child's faeces)
- Indirectly from a person's hands, if not washed after defecation:
 - from food which has been prepared by them
 - from food which is eaten with dirty hands
 - from cups or other utensils, handled by dirty hands
- From food: If this has been contaminated by flies which settle first on excreta, in a latrine or on the ground, then transfer faeces to food by settling on it
- From water: If it has been contaminated by faeces
- From soil: If this contains faeces, they can be transferred:
 - by hands which are not washed before eating, or
 - by crops which are not cleaned properly before cooking, or not cooked properly

These routes are shown in the following diagram:



Blocking the faecal-oral transmission route

The likelihood of diarrhoea can be greatly reduced by blocking the various faecal-oral transmission routes. This can be achieved by a combination of building latrines which incorporate blocking mechanisms and hygiene education which is designed to result in changes to people's personal behaviour. The process can be illustrated by using the same diagram as before, but adding vertical bars to represent the different blocking actions, as follows:



Measures required in addition to building latrines

Building latrines in a community is desirable, but will not be sufficient to prevent the occurrence of diarrhoea. It must be combined with hygiene education which is designed to encourage the changes in people's patterns of personal behaviour which are necessary in order to block the faecal-oral transmission route and reduce the spread of disease.

Therefore a sanitation project without accompanying hygiene education will have little impact on community health unless:

- Most (preferably all) of the people use the new latrines
- Children's faeces are properly disposed of
- Latrines are properly maintained and cleaned
- Hands are washed by everyone at critical times; these are:
 - after defecation
 - after clearing a child's stools
 - before eating
 - before preparing food
- Water sources are protected, or water is purified before consumption
- Food is prepared properly. This means:
 - cooked thoroughly
 - re-heated thoroughly
 - stored in a way that does not allow it to be contaminated by insects or small animals
 - cleaned thoroughly before being eaten raw

WATER RESOURCE DEVELOPMENT

Supplies of drinking water can be developed from a variety of different sources, and by a variety of different methods. The table below summarises the main types of source, with some brief comments. Fuller information about each type of source is given in the individual sections of these technology notes.

A brief guide to water resource development:

Water Source	Capital Cost	Running Cost	Comments / Requirements
Rainwater catchment	Medium Storage tanks needed.	Low	Needs two wet seasons a year, preferably. Water quality is poor.
Spring protection	Low Medium, if piped to community.	Low	Needs a reliable spring flow throughout the year.
Gravity supply	High Pipelines and local storage.	Low	Needs a stream or spring source at a higher elevation. Major advantage is that tapstands can be near houses.
Hand-dug wells	Low (local labour) Hand pump needed.	Low	Abstraction can be by bucket and windlass, but handpump is preferred.
Tubewells or boreholes	Medium Well drilling equipment needed. Borehole to be lined.	Medium Mechanical pumping	Suits deep underground aquifer. Needs maintenance of mechanical pumps.
River / lake abstraction	High Design and construction of intake.	High Treatment and pumping usually needed	Last resort. Filtration essential. Maintenance required for filtration and dosing plant.

GRAVITY SCHEMES

Introduction

In considering the sustainability of a water supply project in the developing world, the choice of technology to be used should favour the use of unpolluted sources; this eliminates the need for treatment which may require chemicals, energy or skilled manpower.

A gravity-fed supply from a small upland river, stream or spring, impounded within a protected catchment, is an example of such a choice. An additional benefit is that, using the force of gravity, water can be transported by pipework to tapstands placed near to homes, thus reducing the drudgery involved in carrying water a long way.

The capital costs of gravity schemes are, on average, higher than the costs of schemes which obtain water from underground sources. This is due mainly to the cost of long pipelines from the upland sources down to the villages and partly to the cost of providing storage tanks. Running costs are usually low, with regular maintenance needed only for replacing tap washers, cleaning screens, etc. Reliability is usually high and consequently the level of service provided is good.

The usual components of a gravity scheme are the source (stream, spring, catchment, dam or intake), main pipeline, storage and break-pressure tanks, distribution pipelines and tapstands. The communities which benefit from the scheme are usually involved in large commitments of time and effort in the construction work associated with these components. Considering the components in turn:

Source

A source may have several elements:

A Spring/stream

If a spring or stream is to be the source, it must be unpolluted and must be one which flows throughout the year; the flow must be measured in the dry season in order to know what yield can safely be relied upon. When a spring is used, the springhead must be protected as detailed in Section 9. The water must be piped directly from the eye of the spring to prevent any pollution affecting the supply.

B Catchment:

The catchment area of a spring or stream must be free of animals and cultivation; if only a small area is involved it may be fenced off completely. Communities often enforce bylaws to exclude people and animals from the area.

C Dams and intakes:

Dams in streams are generally small; their purpose is to provide a small pond so that a controllable draw-off pipe can be built into the wall of the dam at a level higher than the bed of the stream. Unlike larger dams, which impound water to provide storage over a dry season, these small dams overflow for most of the time. The crest of the dam acts as an overflow weir, except at the sides, where it is raised to prevent scouring of the banks.

A dam is usually constructed of concrete, blockwork or masonry, preferably founded on rock. Rock, or some other impermeable material, should also form the basin of the impoundment. Twin intake pipes (one in use, one in reserve) are built into the wall of the dam; on the upstream side of the dam they have strainers or screens; on the downstream side they are fitted with control valves. A scour pipe is also built into the dam, at low level, with a stop valve on the downstream side, and is used periodically to drain the pond and to clear accumulated silt etc.

Main pipeline

The route of the pipeline from the intake to the storage tank must be surveyed and a drawing made of the optimum hydraulic gradient line, in order to determine the pipe size needed to deliver the design flow. In rocky areas the pipeline will probably be laid above ground and will be galvanised mild steel tubing, anchored on saddles. Elsewhere, the pipeline will be laid in trenches, to protect it from damage, and will usually be plastic pipe (MDPE – medium density polyethylene).

Storage and break-pressure tanks

To reduce operating pressures, it is sometime necessary to introduce break-pressure tanks, which are usually made of concrete or ferrocement. If such tanks are used, the hydraulic gradient starts again at tank water level. If suitably sized, these tanks can be used within the system as storage tanks to meet peak demand.

Storage tanks are usually constructed within the system to provide a total volume of storage equivalent to one day's consumption. The tanks may also be sited so as either to limit the maximum pressure in distribution pipelines or to sustain a pressure of at least 3 metres head at each tapstand whilst meeting the peak demands in the morning and evening.

Capacities of tanks range from 10 to 100 cubic metres, depending upon the size of the population to be served. Various materials have been used to construct them: masonry, reinforced concrete, concrete blockwork, ferrocement, galvanised mild steel and GRP panels. In flat areas, tanks may have to be elevated on blockwork support structures. Tanks are roofed and, typically, are provided with a float controlled inlet valve, twin outlet pipes with stop valves, a scour pipe at low level for emptying and cleaning out, and an overflow pipe led well away from the tank.

The roof of the tank should have a sealed access manhole, and ventilators, covered in mesh fly screen, to allow air to be exhausted or admitted air when raising or lowering the water level in the tank.

Distribution pipelines and tapstands

A distribution system of small diameter MPDE pipes, laid in trenches, feeds tapstands around the village. Each tapstand should serve about 150 people and should be positioned so as to reduce uniformly the maximum distance people have to carry water.

Tapstands have several components: a concrete post supporting a 15mm mild steel riser pipe from the pipeline up to a bib-cock which should discharge at least 0.1 litres per second; a concrete stand on which to place a bucket; a concrete apron to collect spillage; and a gutter and drainage to a soakaway, in order to prevent the breeding of mosquitoes and the development of a muddy mess.

Tapstands should have a fence around them to keep animals away and each one should have a nominated person, or caretaker, to keep the area clean and tidy.

REFERENCE:

1. **Jordan T D Jnr.** (1984) *A handbook of gravity-flow water systems*
IT Publications
2. **Watt S B** (1978) *Ferrocement Water Tanks and their construction*
IT Publications

HAND-DUG WELLS

Introduction

The traditional method of obtaining groundwater in rural areas of the developing world, and still the most common, is by means of hand-dug wells. However, because they are dug by hand their use is restricted to suitable types of ground, such as clays, sands, gravels and mixed soils where only small boulders are encountered. Some communities use the skill and knowledge of local well-diggers, but often the excavation is carried out, under supervision, by the villagers themselves.

The volume of the water in the well below the standing water table acts as a reservoir, which can meet demands on it during the day and should replenish itself during periods when there is no abstraction.

Dimensions

Depths of hand-dug wells range from shallow wells, about 5 metres deep, to deep wells over 20 metres deep. Wells with depths of over 30 metres are sometimes constructed to exploit a known aquifer. It is impractical to excavate a well which is less than a metre in diameter; an excavation of about 1.5 metres in diameter provides adequate working space for the diggers and will allow a final internal diameter of about 1.2 metres after the well has been lined.

Digging with the sides of the excavation supported

There are several methods of supporting the sides of the excavation while digging proceeds:

- 1** The safest method, and the one preferred by WaterAid, is to excavate within pre-cast concrete rings which later become the permanent lining to the sides of the well. The first ring has a cutting edge, and additional rings are placed on it as excavation proceeds. As material is excavated within the ring, it sinks progressively under its own weight and that of the rings on top of it. This method should always be used in unstable ground. When construction has finished, the joints between the rings which are above the water table should be sealed with cement mortar.
- 2** In suitable ground, excavation may proceed for a short distance without support to the sides; these are then supported by means of concrete poured in situ from the top, between the sides of the excavation and temporary formwork, which becomes the permanent lining to the well. This process is repeated until the water table is reached.
- 3** In suitably stable ground, excavation may proceed within the protection of vertical close-fitting timber boards, supported by horizontal steel rings. The timbers are hammered down as excavation proceeds and additional timbers are added progressively at ground level. The steel rings must be hinged, or in two parts bolted together, so that lower ones can be added as the excavation progresses. The vertical spacing between the rings will depend on the instability of the ground. The well is lined with bricks, or concrete blocks, from the water table upwards, within the timbers as they are withdrawn.

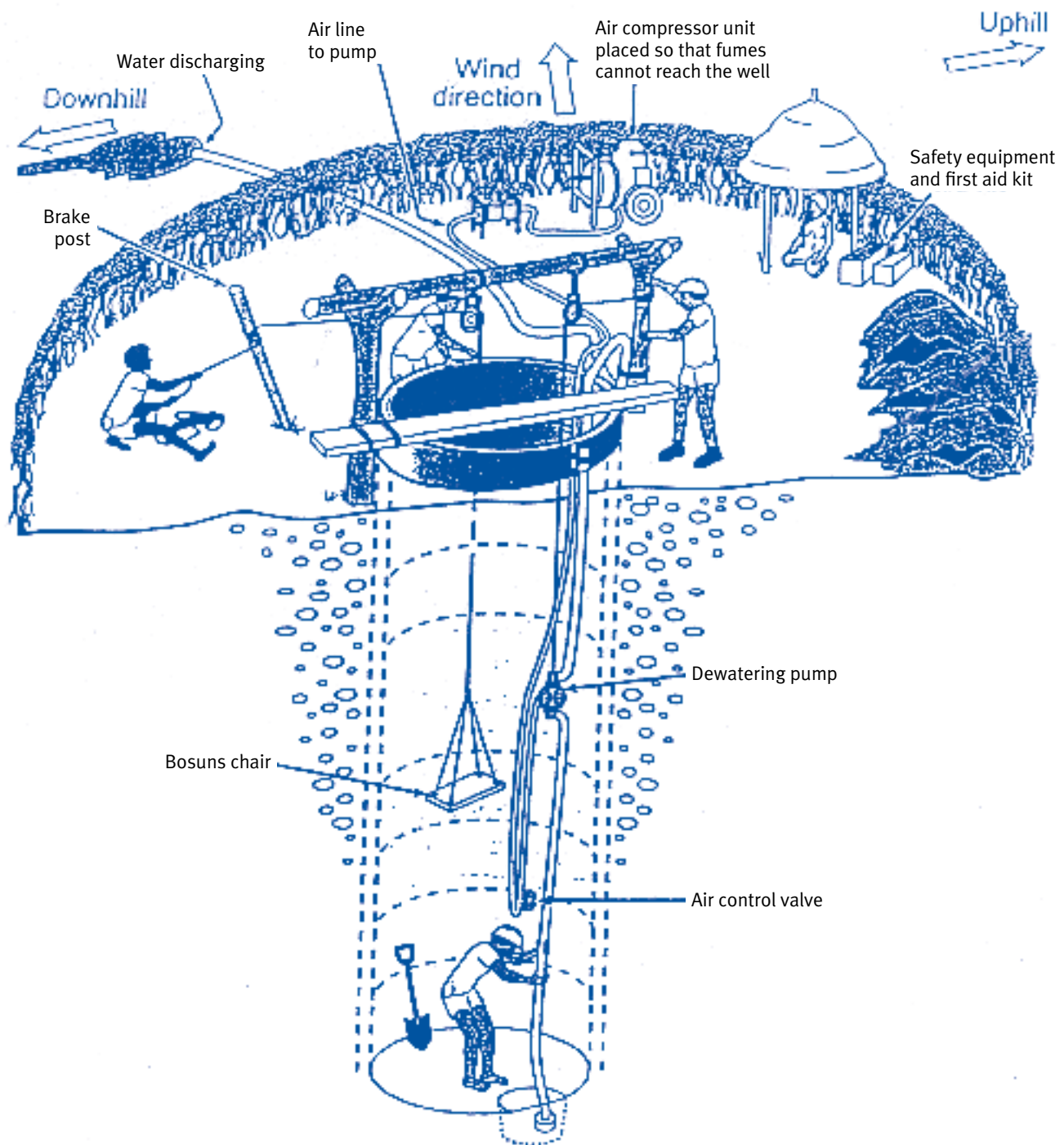
Digging with the sides of the excavation unsupported

In stable ground, wells are often excavated down to water level without a lining, and are lined with in situ concrete, or with pre-cast concrete rings, from this level upwards.

Wells safely dug during the dry season may become unstable when the water level rises in the wet season and therefore must be lined before this occurs to prevent a collapse.

Although in firm stable ground unlined wells may be safely excavated and may give long service in operation, it is prudent, and in most cases essential, to provide a permanent supporting lining which will support the sides of the excavation and prevent them from collapsing; suitable lining materials are concrete, reinforced concrete, ferrocement, masonry, brickwork, etc.

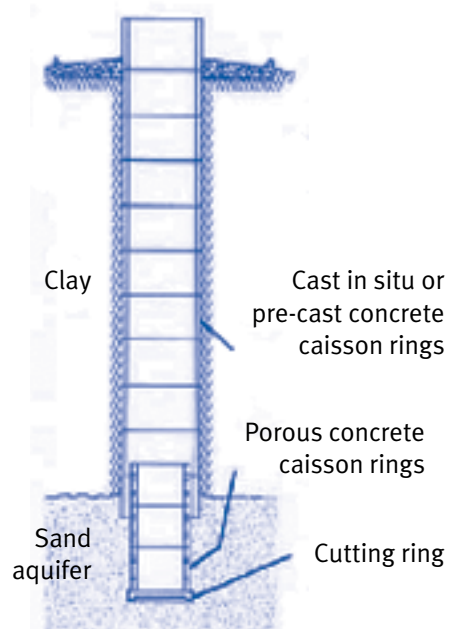
A safe well digging operation



Excavation below the water level

Regardless of which method has been used to excavate the well to the water table, excavation below this level should never be attempted until the sides of the excavation have received the support of their permanent lining, from water table to ground level.

Excavation below the water table should be carried out within pre-cast concrete caisson rings of a smaller diameter than the rest of the well. The initial caisson ring is provided with a cutting edge and additional rings are placed on top of it; as the material within is excavated, the rings sink progressively under their own weight. To facilitate the ingress of water, these lower rings are often constructed with porous, or no-fines, concrete and their joints are left unpainted. See the opposite diagram:

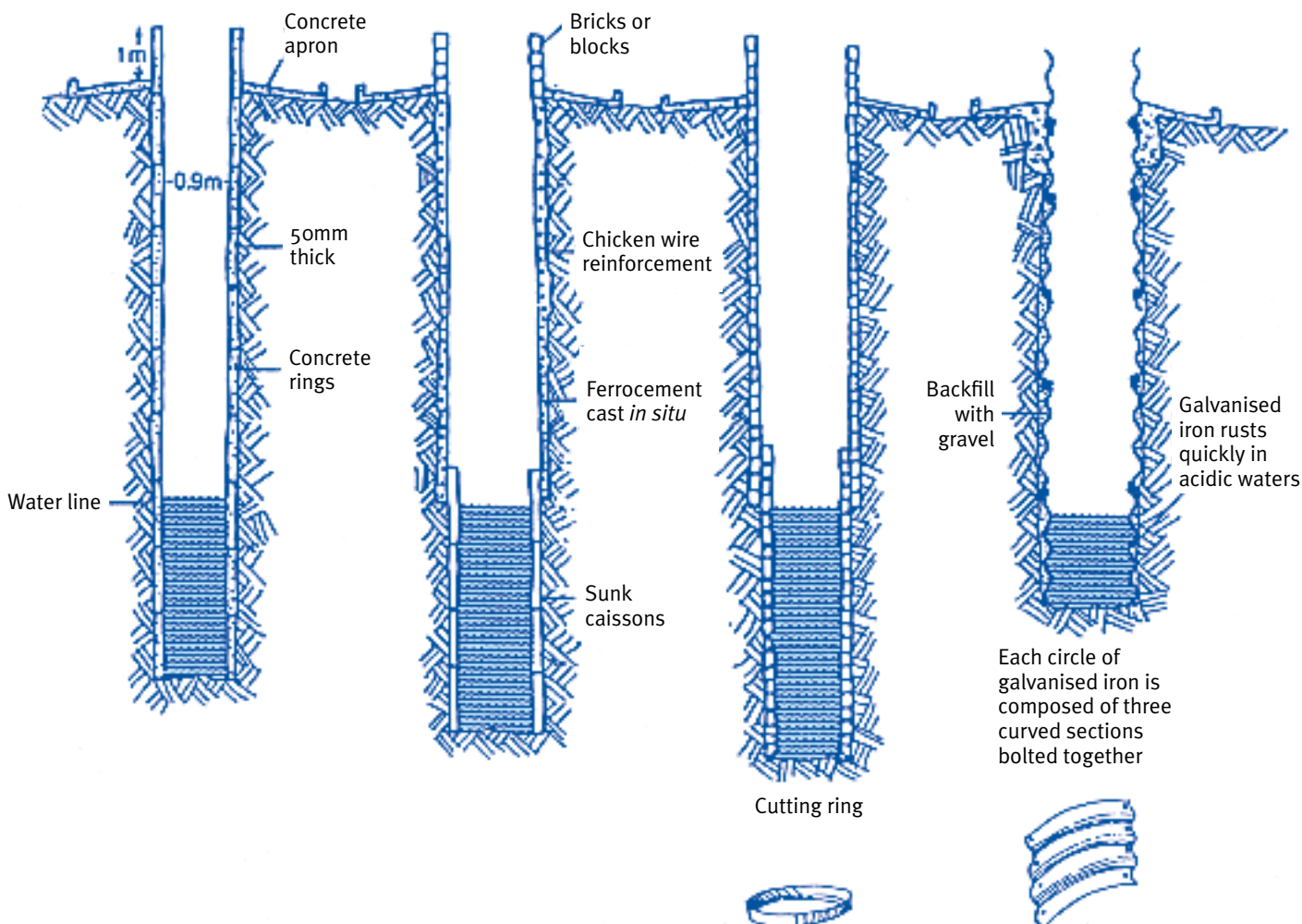


Alternative ways of lining a well

Although WaterAid favours the use of pre-cast concrete rings, which become the permanent lining of the well after being sunk progressively as excavation proceeds within them, many other materials have been used successfully. Some of these are shown in the following diagrams:

Alternative methods

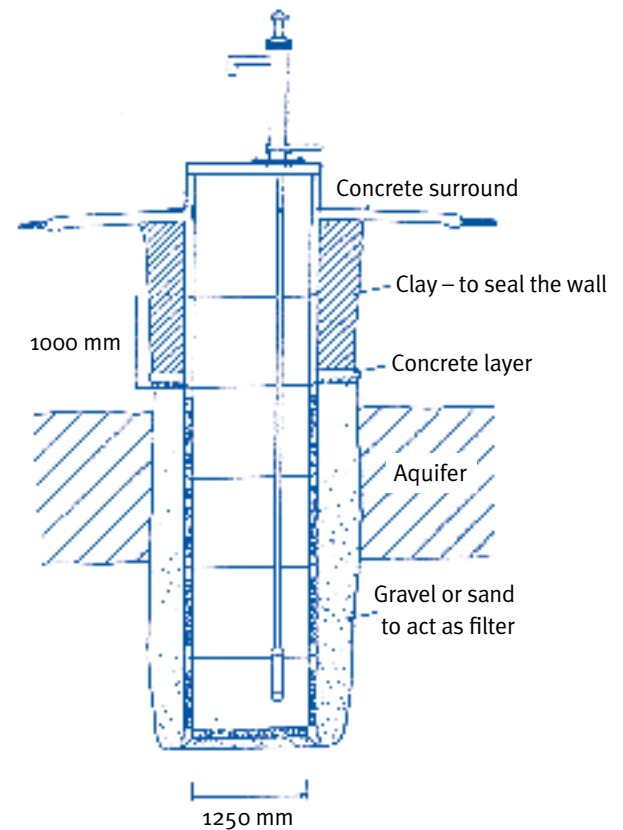
- 1 Sinking caissons (concrete rings).
- 2 Reinforced concrete or ferrocement cast *in situ* above water line, concrete rings sunk below the water line.
- 3 Masonry lining of burnt bricks above water line, caisson made of blocks with cutting ring below water line.
- 4 Galvanised iron rings bolted together as temporary measure for emergencies.



Completion

After construction of the well shaft has been completed, the bottom is plugged with gravel. This helps to prevent silty material from clay soils, or fines from sandy materials, being drawn into the well. Any annular space between the pre-cast caisson well rings and the side of the excavation should also be filled with gravel; such filling behind the rings which are below the water helps to increase water storage and to prevent the passage of fine silts and sands into the well.

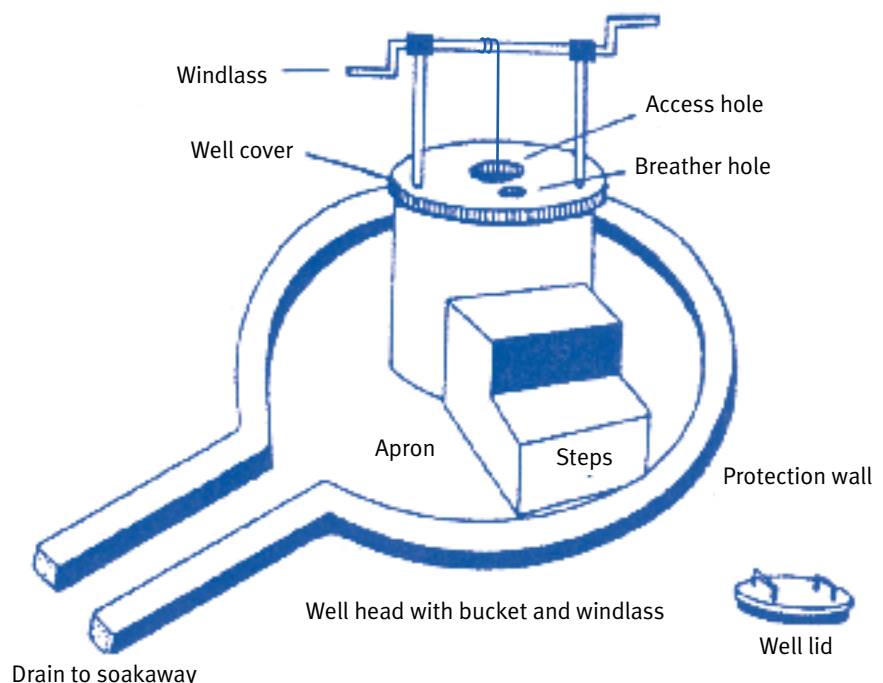
The space behind the top three metres, or so, of the well rings should be backfilled to ground level with puddled clay, or concrete, and the well rings should project about one metre above a concrete apron. This apron provides a sanitary seal to prevent polluted surface water seeping into the well and should slope away from it and drain into a channel which discharges into a soakaway.



Abstraction

It is desirable for the well to have a concrete cover slab to reduce the possibility of contamination. Water is abstracted by means of either a bucket and windlass above an access hole, or a handpump, depending upon the yield of water available and the ability of the benefiting community to pay for ongoing maintenance for the handpump, spare parts, etc. A hand-dug well fitted with a handpump can serve the needs of about 300 people.

The following diagram shows a typical layout for the well head of a well with a hand operated windlass:



REFERENCE:

1. **Watt S B and Wood W E** (1985) *Hand-dug – wells and their construction*
IT Publications
2. *WaterAid's Health and Safety Policy* (July 2000)

TUBEWELLS AND BOREHOLES

Introduction

Depth for depth on any given site, hand-dug wells may yield more water than tubewells, but tubewells 100 or 150 mm diameter are usually quicker and cheaper to sink, need no dewatering during sinking, require less lining material, are safer in construction and use, and involve less maintenance. From a hygienic point of view, the fact that a pump is needed to lift water from a tubewell is an asset, not a liability.

These notes describe some features of tubewells which have handpumps, and two methods of sinking them in generally soft ground using only man-powered low technology equipment, namely, hand auguring using a Vonder rig, and sludging.

Salient features

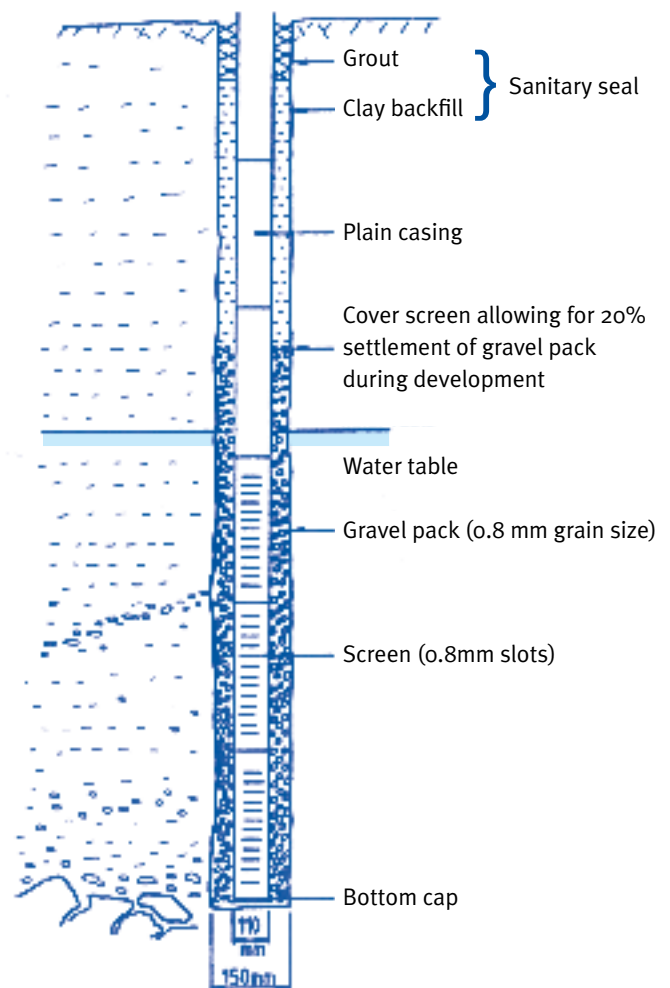
Some salient features of a simple tubewell are shown in the following diagram:

The casing – often in PVC, which is both cheap and inert – houses the inlet, cylinder, piston valves and rising main of a “down-the-hole” type handpump, which can be lifted out for maintenance or repair. Seepage down the tubewell bore is prevented by the sanitary seal. Seepage from the ground above the aquifer is excluded by the lengths of plain casing. Water to be pumped is admitted through slots in the lower lengths of casing. Casing to support the external surfaces of the borehole against collapse may be needed, either temporarily or permanently, but is not shown.

Water abstracted from aquifers in relatively soft ground usually contains sand or silt particles, which are liable to cause rapid wear to pump valves and cylinders (and dissatisfaction among consumers). Methods of preventing these particles from reaching the pump are of two general types:

- **Screening:** The drawing shows slots in the PVC casing which can be cut on site, using a hacksaw. More elaborate, and far more compact, screens are available commercially; some can be bolted on to pump inlets. Materials used include woven wire and man-made fabric; the latter can be wrapped around the pump inlet assembly.
- **Sand/gravel packing:** The drawing shows graded sand and gravel, which is placed from the top of the borehole. More compact, pre-bonded packs of sand and/or gravel are available commercially; some of these can also form part of the pump inlet assembly.

Screening is nearly always needed in some form. Sand and/or gravel packing is meant to eliminate particles from the water before they reach the screen and would otherwise have passed through the screen.



Developing the well

Over-pumping (that is, pumping at above the design-rate) before the well enters service can improve the efficiency of the packing by drawing further fine particles into it. Where the surrounding ground has many fine particles, the flow of water can be accelerated by back-flushing at a higher rate. This over-pumping and back-flushing is known as developing the tubewell.

Sinking tubewells

At least two experienced operators are required; communities will usually supply unskilled labour. Samples of the excavated material should be taken at regular intervals of depth (and also if the strata changes) and a borehole record should be kept.

Particular attention is needed to maintain verticality. A “down-the-hole” pump which has been installed out of the vertical may be hard to operate and subject to excessive wear.

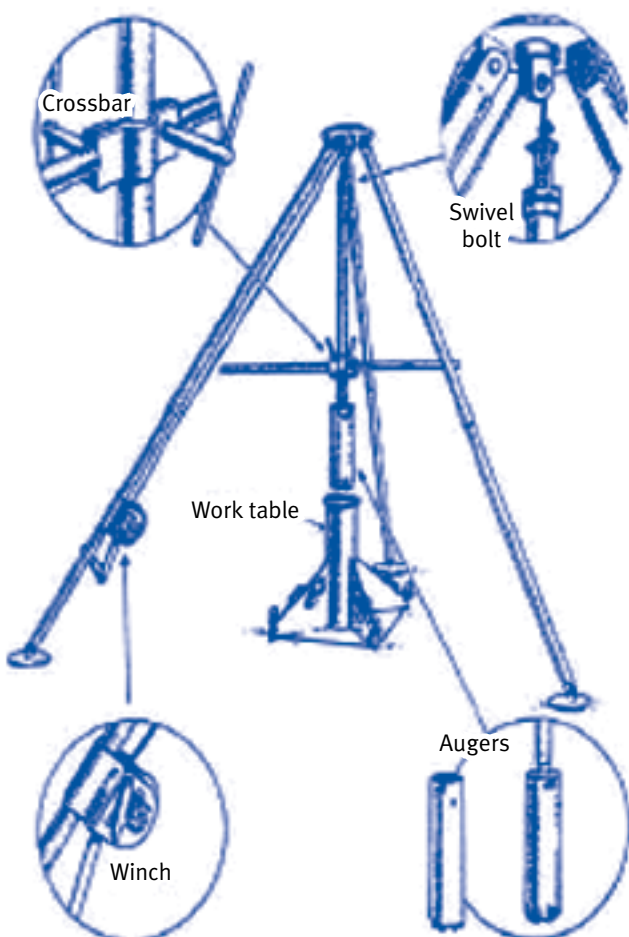
Auguring

Auguring cuts earth away by the rotation of a cylindrical tool with one or more cutting edges. The excavated earth feeds upwards inside the tool body, which needs lifting to the surface for emptying at intervals. This requires the whole auguring (drilling) train to be uncoupled and lifted; the weight involved can be considerable, and puts a limit to the depth of hand-operated auguring.

The next diagram shows hand-augering using a Vonder rig:

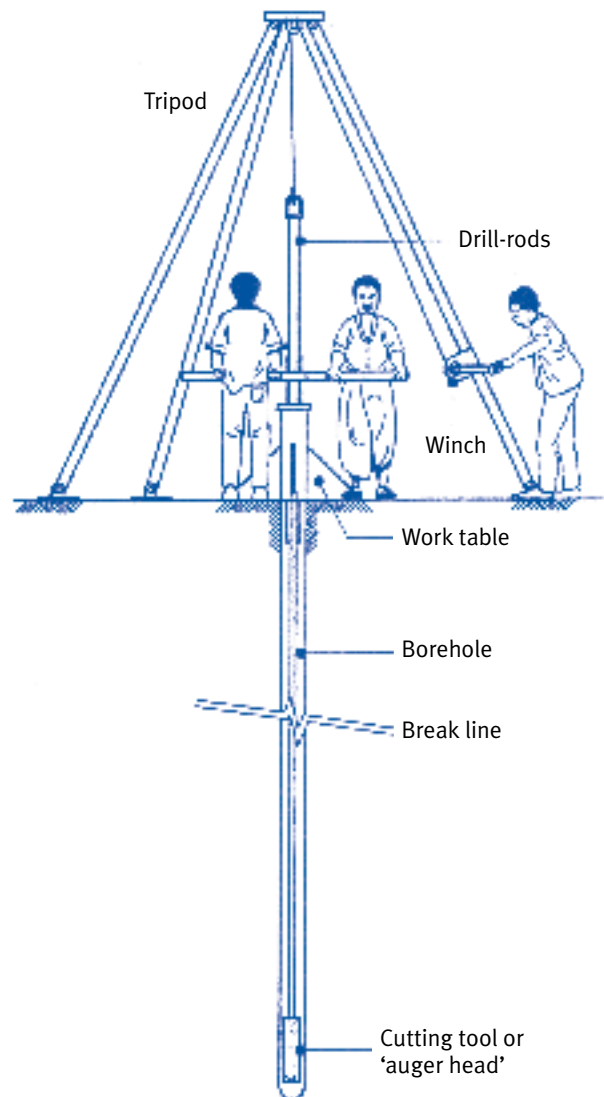
Auguring using the Vonder Rig

The Vonder Rig, manufactured in Zimbabwe and possibly elsewhere, can sink a tubewell hole up to 170mm in diameter and about 115m deep in about two days in ground which is predominantly soft. The drawing below shows its salient parts, all of which are made of mild steel and can be carried by hand between sites. The crossbar is friction-bolted to a stem, at a height suitable for pushing round by hand. Helpers can sit on it if auguring needs extra weight (or even if it doesn't). Additional stem sections are added as auguring proceeds. Several shapes and sizes of augerbit are provided, including a “hole-saw”; this is intended to tackle soft rock, but has rarely been successful. Thin layers of rock have been penetrated, however, by an improvised arrangement including a slow-speed diesel drive to the drilling train.



Hand-auger drilling

Method: The cutting tool (known as the auger head) is rotated to cut into the ground, and then withdrawn to remove excavated material. The procedure is repeated until the required depth is reached. Note: This method is only suitable for unconsolidated deposits.



Advantages of hand-auger drilling:

- Inexpensive.
- Simple to operate and maintain.

Disadvantages of hand-auger drilling:

- Slow, compared with other methods.
- Equipment can be heavy.
- Problems can occur with unstable rock formations.
- Water is needed for dry holes.

Useful contacts:

Van Reekum Materials b.v., 115 Kanaal Noord, PO Box 98, AB Apeldoorn, The Netherlands.
Tel: +31 55 395466 Fax: +31 55 313335

V & W Engineering Ltd. (Vonder Rig), PO Box 131, Harare, Zimbabwe. Tel: +263 4 64365/63417 Fax: +263 4 64365

Sludging

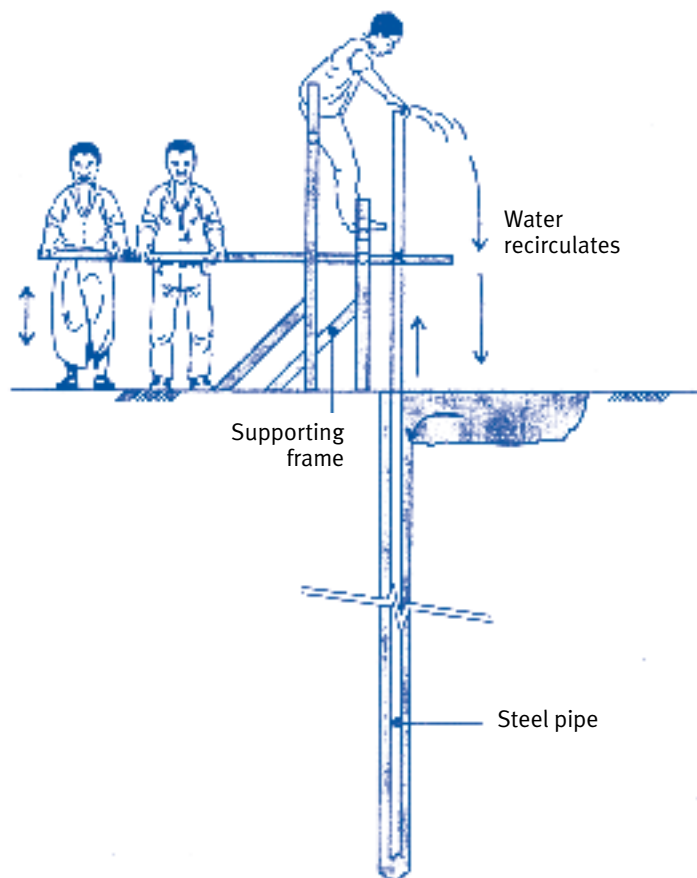
Sludging is a cheap but effective method of sinking small-diameter tubewells to a great depth in the water-logged silts and fine sands which underlie some flat river plains and deltas, notably those in the Indian subcontinent. Tubewells 25mm and upwards in diameter (the larger ones are able to accommodate a “down-the-hole” pump) are sunk to depths of 60m or more.

A boring pipe, usually a galvanised mild steel tube fitted with a case-hardened open socket at its base, moves vertically under the action of a bamboo lever pivoted on an H-frame. The boring pipe rests initially in a shallow pit filled with a water/ cow-dung mixture, which acts as a drilling mud and helps to stabilise the walls of the bored hole during drilling (thrusting would be a better word). Using a lever, two men raise and drop the pipe successively. For the duration of each upstroke, another man seals the open top of the pipe with his hand, creating a partial vacuum inside it, so that the water within the pipe rises with it. He removes his hand for the downstroke, during which the pipe drops faster than the water inside it. As this hand-on / hand-off cycle repeats, water starts to gush from the top of the pipe and the whole assembly begins to work as an elementary force pump. Soil, fluidised by repeated strokes of the case-hardened socket, is entrained into the upward flow of the water and the boring pipe sinks further into the ground with each stroke. Boring rates of 20m per hour have been achieved. Additional lengths of boring pipe are attached successively until the required depth is reached. The whole pipe is then withdrawn and replaced by a PVC rising main (for a suction pump) or PVC casing (for “down-the-hole” pumps).

The process of sludging is illustrated in the next diagram:

Sludging (reverse jetting)

Method: This method has been developed and used extensively in Bangladesh. A hollow pipe of bamboo or steel is moved up and down in the borehole while a one-way valve – your hand can be used to improvise successfully – provides a pumping action. Water flows down the borehole annulus (ring) and back up the drill-pipe, bringing debris with it. A small reservoir is needed at the top of the borehole for recirculation. Simple teeth at the bottom of the drill-pipe, preferably made of metal, help cutting efficiency.



Advantages of sludging:

- The equipment can be made from local, low cost materials, and is simple to use

Disadvantages of sludging:

- Water is required for pumping.
- Suitable for unconsolidated rocks only.
- Boulders can prevent further drilling.

Anything that may be termed ‘rock’ is rarely met within these types of strata, but isolated stones, or groups of them, do occur occasionally. They totally inhibit sludging operations as just described, but a technique has been evolved which will usually deal with them.

On being stopped by a stone, the sludger boring pipe (with its open socket end) is withdrawn and replaced by a butt-jointed ‘hammering pipe’ which is fitted, at its base, with a cone of the same diameter as the open socket. The latter can be used to protect the top end of the hammering pipe, which is driven down by a two-man operated weighted sleeve driver. When the stone has been successfully broken and passed, the hammering pipe is winched or jacked out, the sludge boring pipe with its open socket replaced, and normal sludging operations re-started.

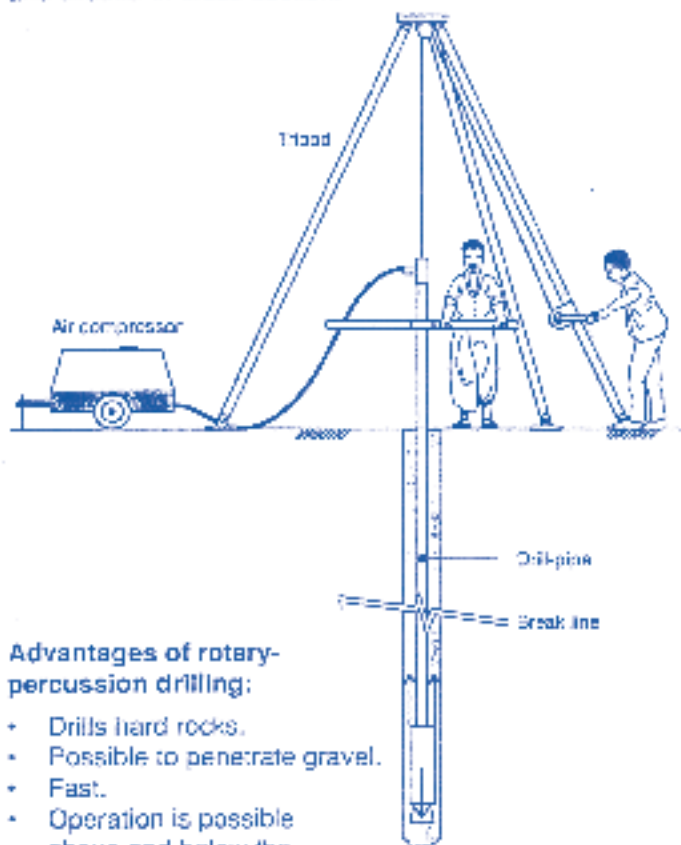
Other methods of drilling

WaterAid prefers the simplest methods of drilling, particularly those which can be operated by villagers themselves. However, there are several other, more complicated, techniques which can be used and the next few diagrams illustrate the following methods:

- Percussion drilling
- Rotary percussion drilling
- Rotary drilling with flush
- Jetting

Rotary-percussion drilling

Method: In very hard rocks, such as granite, the only way to drill a hole is to pulverize the rock, using a rapid-action pneumatic hammer, often known as a 'down-the-hole hammer' (DTH). Compressed air is needed to drive this tool. The air also flushes the cuttings and dust from the borehole. Rotation of 10-30 rpm ensures that the borehole is straight, and circular in cross-section.



Advantages of rotary-percussion drilling:

- Drills hard rocks.
- Possible to penetrate gravel.
- Fast.
- Operation is possible above and below the water-table.

Disadvantages of rotary-percussion drilling:

- Higher tool cost than other tools illustrated here.
- Air compressor required.
- Requires experience to operate and maintain.

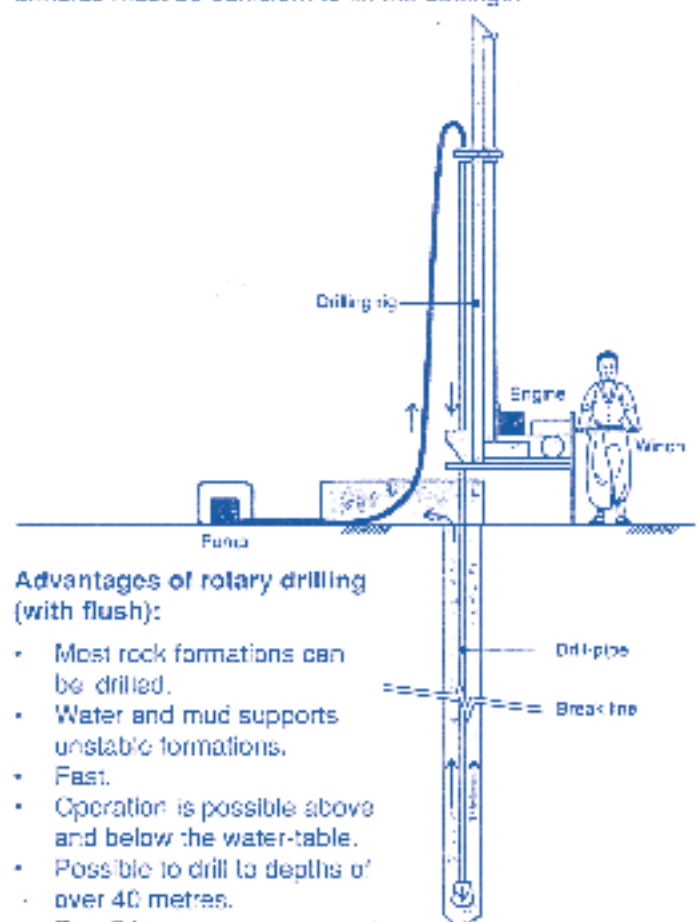
Useful contacts:

Consallion Group Sales Ltd., 23 Oakwood Hill Industrial Estate, Loughton, Essex, IG10 3TZ, UK. Tel/Fax: +44 81 508 5006

Eureka UK Ltd., 11 The Quadrant, Hassocks, West Sussex BN6 8BP, UK. Tel: +44 273 846333 Fax: +44 273 846332

Rotary drilling with flush

Method: A drill-pipe and bit are rotated to cut the rock. Air, water, or drilling mud is pumped down the drill-pipe to flush out the debris. The velocity of the flush in the borehole annulus must be sufficient to lift the cuttings.



Advantages of rotary drilling (with flush):

- Most rock formations can be drilled.
- Water and mud supports unstable formations.
- Fast.
- Operation is possible above and below the water-table.
- Possible to drill to depths of over 40 metres.
- Possible to use compressed-air flush.

Disadvantages of rotary drilling (with flush):

- Requires capital expenditure in equipment.
- Water is required for pumping.
- There can be problems with boulders.
- Rig requires careful operation and maintenance.

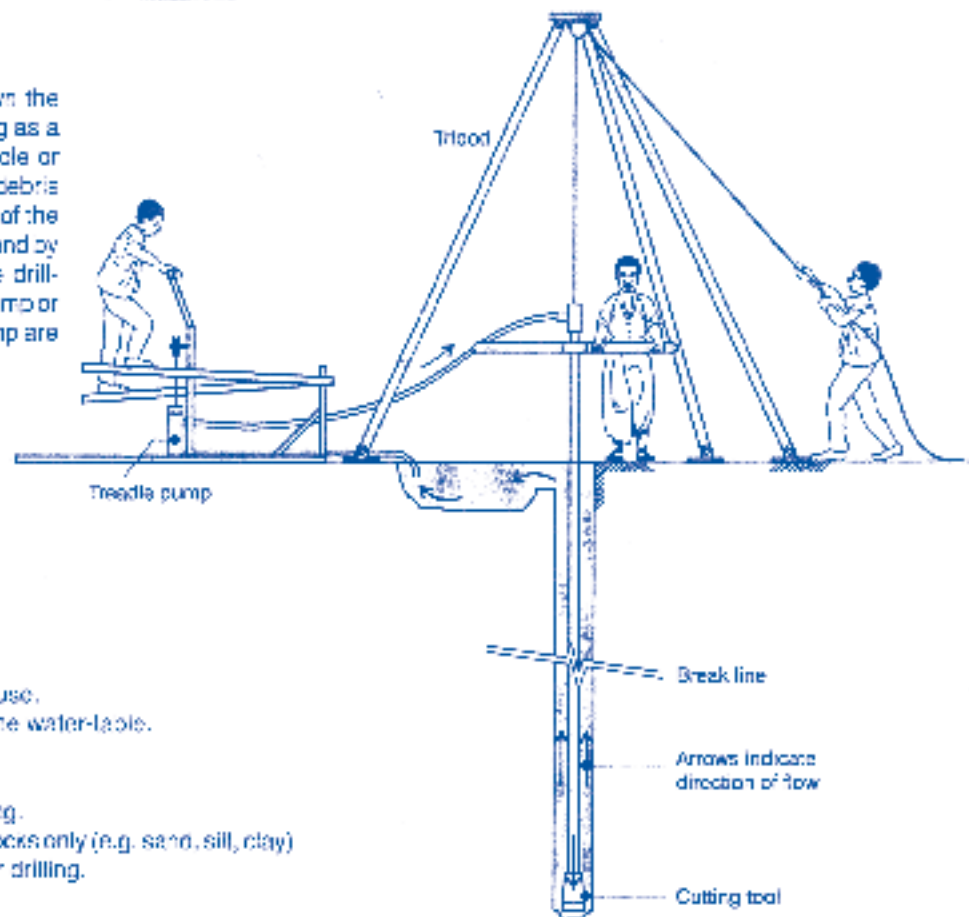
Useful contacts:

Eureka UK Ltd., 11 The Quadrant, Hassocks, West Sussex BN6 8BP, UK. Tel: +44 273 846333 Fax: +44 273 846332

PAT Co. Ltd., 1016 Taskin Road, Thonburi, Bangkok, Thailand. Tel: +66 2 476 1845 Fax: +66 2 476 5316

Jetting

Method: Water is pumped down the centre of the drill-rods, emerging as a jet. It then returns up the borehole or drill-pipe bringing cuttings and debris with it. The washing and cutting of the formation is helped by rotation and by the up-and-down motion of the drill-string. A foot-powered treadle pump or a small internal-combustion pump are equally suitable.



Advantages of jetting:

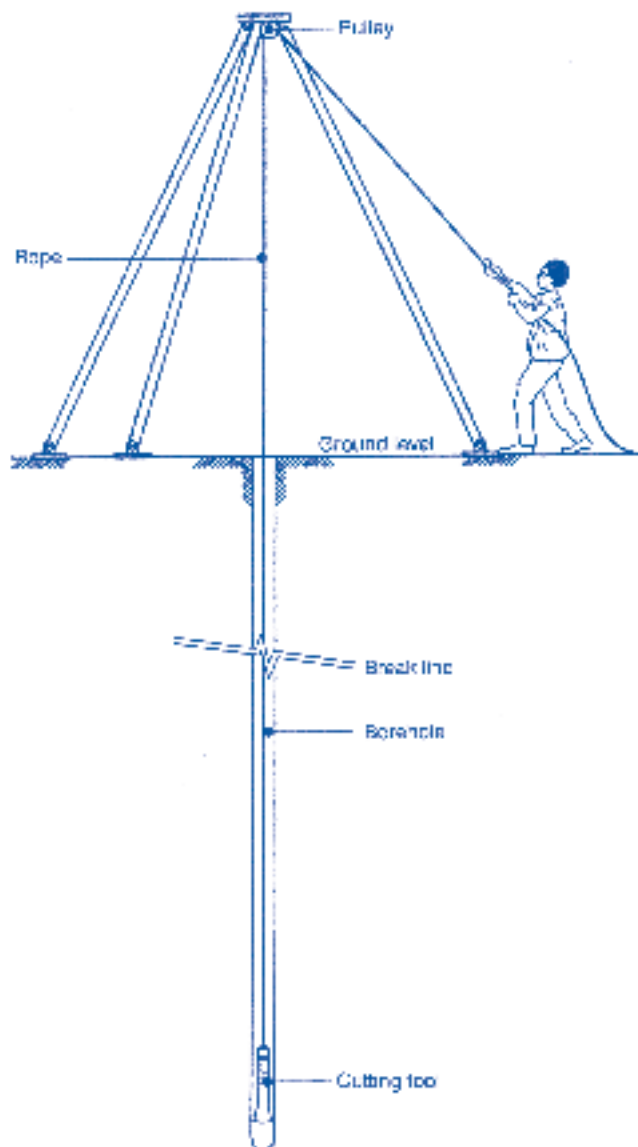
- The equipment is simple to use.
- Possible above and below the water-table.

Disadvantages of jetting:

- Water is required for pumping.
- Suitable for unconsolidated rocks only (e.g. sand, silt, clay)
- Boulders can prevent further drilling.

Percussion drilling

Method: The lifting and dropping of a heavy (50kg+) cutting tool will chip and excavate material from a hole. This drilling method has been used in China for over 3000 years. The tool can be fixed to rigid drill-rods, or to a rope or cable. With a mechanical winch, depths of hundreds of metres can be reached.



REFERENCES

- 1 **Stapleton C K** (July 1983) *Tubewells and their construction* Waterlines, Vol 2, No 1 IT Publications
- 2 *The Vonder Rig: Instructions for use* V & W Engineering Ltd, PO Box 131, Harare, Zimbabwe
- 3 **Whiteside G F J and Trace S** (January 1993) *The use of Sludger and Well-pointing Techniques*, Waterlines, Vol 11, No 3 IT Publications

Advantages of percussion drilling:

- Simple to operate and maintain.
- Suitable for a wide variety of rocks.
- Operation is possible above and below the water-table.
- It is possible to drill to considerable depths.

Disadvantages of percussion drilling:

- Slow, compared with other methods.
- Equipment can be heavy.
- Problems can occur with unstable rock formations.
- Water is needed for dry holes to help remove cuttings.

HANDPUMPS

Introduction

The majority of people in the developing world gain access to groundwater either by means of a bucket and rope, or by using a handpump. Using a bucket and rope can be made easier if the well is provided with a windlass to help to lift the bucket. However, although easy to operate and repair, the bucket and windlass arrangement has serious disadvantages: it does not allow the well to have a cover slab which can be sealed to prevent ingress of polluted water or other contaminants, and the bucket and rope themselves are continually being polluted by mud and dirty hands. Therefore if the water to be raised from a well or borehole is for people to drink, it is preferable to instal a handpump.

Main principle of handpumps

There are many different types of handpump. However, most of them are positive displacement pumps and have reciprocating pistons or plungers. In a piston pump, the piston is fitted with a non-return valve (the piston valve) and slides vertically up and down within a cylinder which is also fitted with a non-return valve (the foot valve). Raising and lowering the handle of the pump causes vertical movement of pump rods which are connected to the piston.

When the piston moves upwards, the piston valve closes and a vacuum is created below it which causes water to be drawn into the cylinder through the foot valve, which opens. Simultaneously, water above the piston, held up by the closed piston valve, is displaced upwards; in a simple suction pump it emerges through the delivery outlet; in a pump with a submerged cylinder it is forced up the rising main.

When the piston moves downwards, the foot valve closes, preventing backflow, and the piston valve opens, allowing the piston to move down through the water in the cylinder.

Range of lift

The ranges over which water can be lifted are grouped in the following categories:

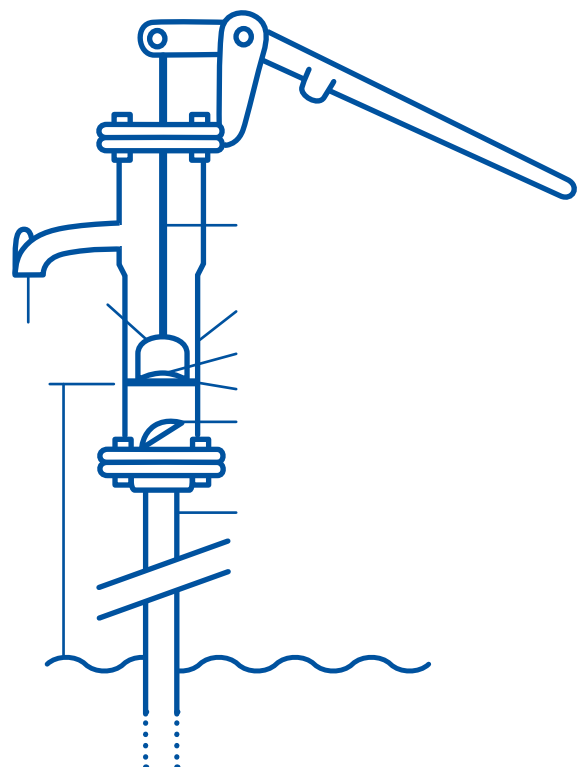
Suction pumps	0 – 7 metres
Low lift pumps	0 – 15 metres
Direct action pumps	0 – 15 metres
Intermediate lift pumps	0 – 25 metres
High lift pumps	0 – 45 metres, or more

Suction pumps

At shallow lifts the cylinder and piston operate by suction and can be housed in the pumpstand above ground. In practice, the maximum suction lift is about seven metres (i.e atmospheric pressure less about 30% system losses due to the ineffectiveness of seals, friction etc) and defines the working range of the suction pump.

Suction pumps have to be primed where seals have dried out or have been replaced; therefore they can be contaminated by dirty priming water. They have a limited range of application, but are the most numerous handpumps in the world, mainly because they are relatively cheap and are suitable for use as a household pump.

The following diagram shows a shallow well suction lift handpump:



Low lift pumps

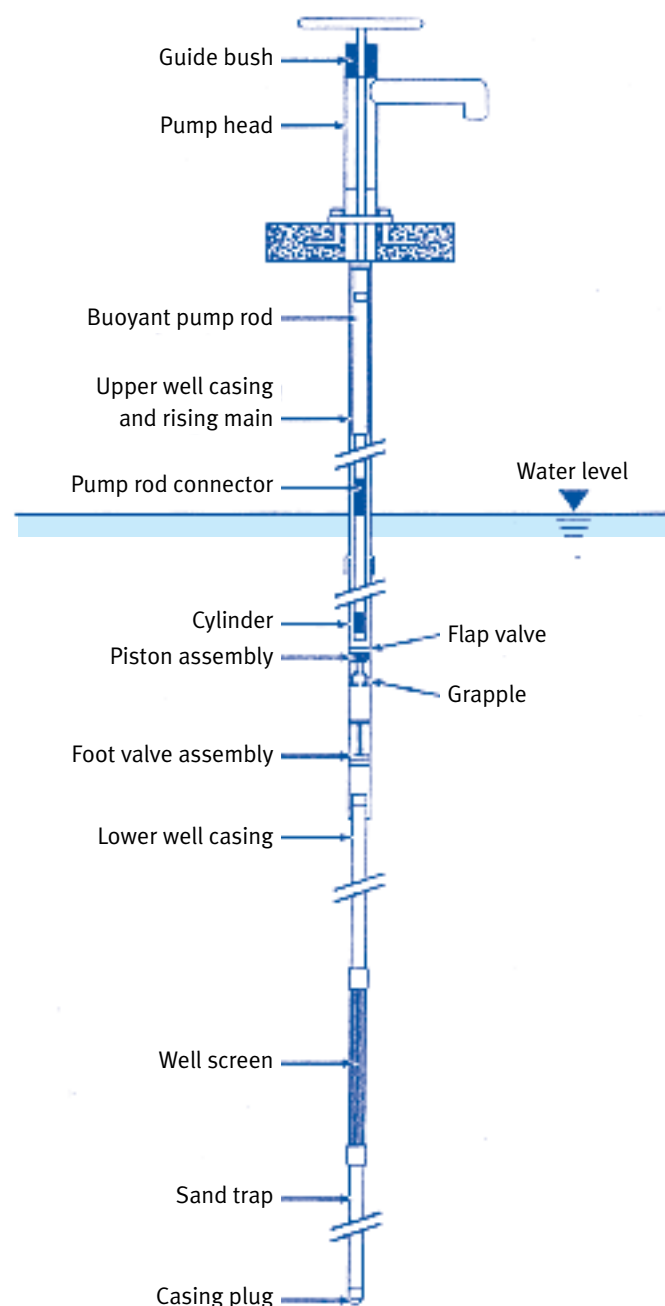
These operate in the range 0–15 metres. With lifts above seven metres, the cylinder and piston have to be located down the well, or borehole, and preferably below water level in order to provide a positive suction head. Theoretically, the lift could be achieved by operating with the cylinder seven metres above the water table but it is usually better to provide a positive suction head, as this assists pumping.

Direct action pumps

In the low lift range some piston handpumps are designed to operate as simple direct action pumps, ie ones which operate without the help of leverage, linkages and bearings. Direct action pumps depend upon the strength of the operator to lift the column of water.

Some designs, such as the Tara (illustrated below) make this easier by using as the pump rod a plastic pipe filled with air, the buoyancy of which helps the upstroke operation. Other designs use very small diameter cylinders and rising mains to pump smaller quantities from greater depths.

In general, direct action pumps, being simple in action, are cheaper to buy and operate than high lift handpumps.



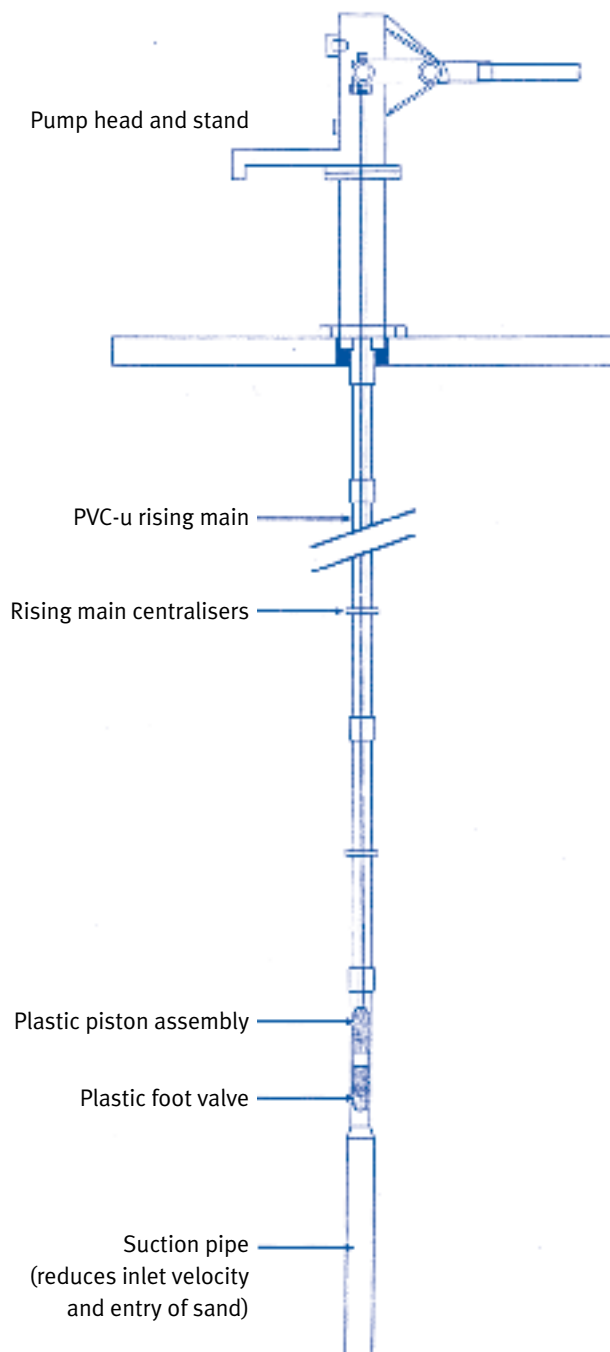
Intermediate and high lift (deep well) handpumps

An intermediate lift pump operates in the range 0 – 25 metres and a high lift one in the range 0 – 45 metres. Some of the high lift handpumps can operate at lifts of 60 metres or more, albeit with reduced output.

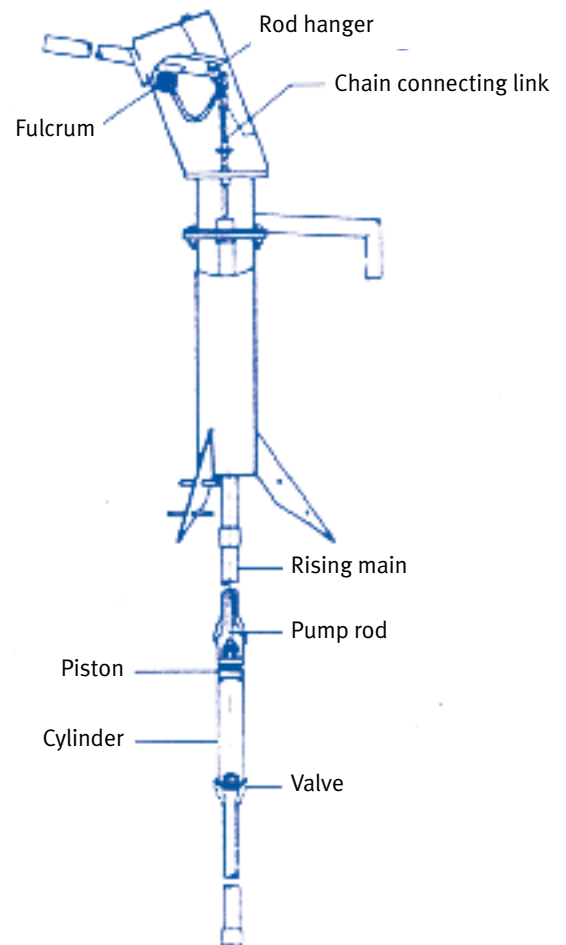
Intermediate and high lift piston handpumps are designed so as to reduce, by means of cranks or levers, the physical effort required when pumping. They have to be more robust and are provided with bearings and components capable of handling the larger stresses which are imparted by the pumping efforts required.

The Afridev handpump is shown in the following diagram and a more detailed one, showing the component parts, is given at the end of this section.

High lift 'Afridev' handpump



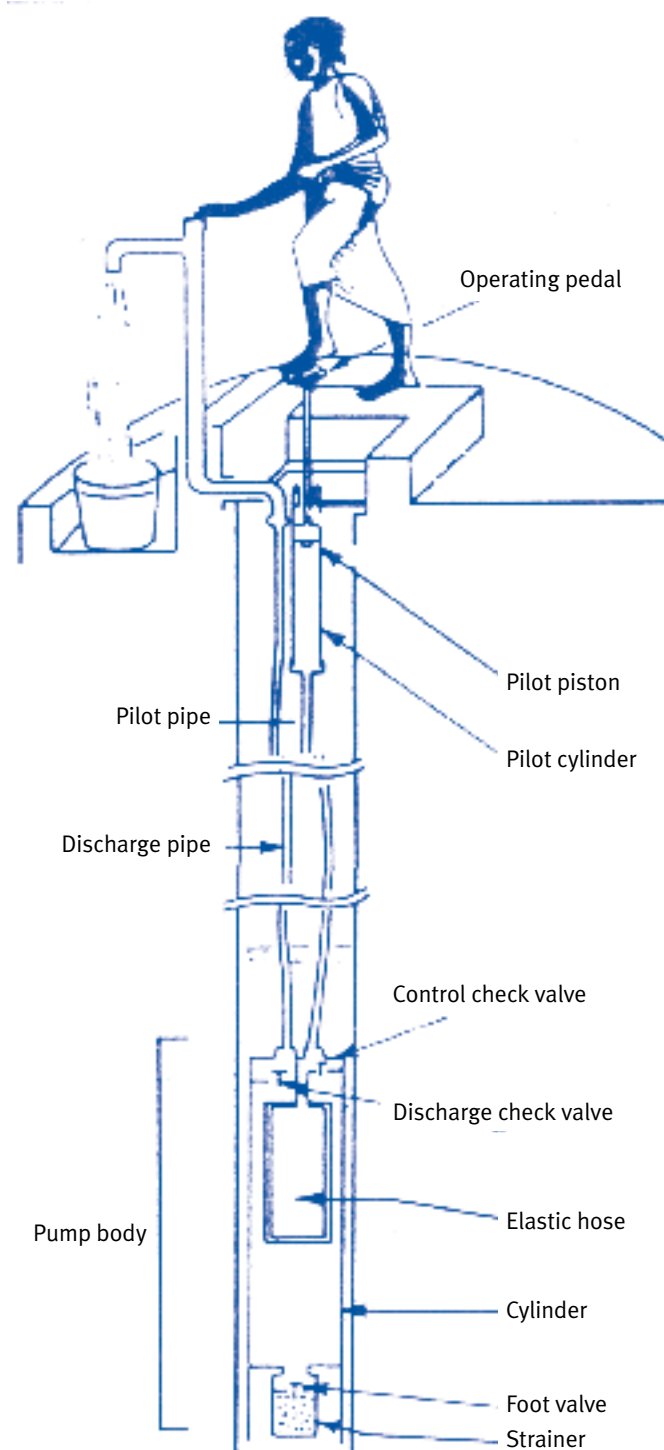
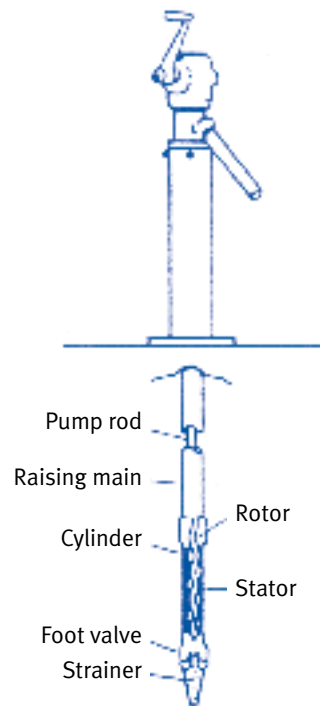
Deepwell reciprocating pumps



Non-piston pumps

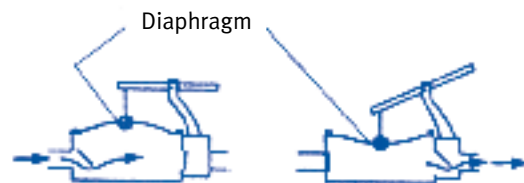
A high lift pump that is not a piston pump is the Mono progressing cavity hand pump; this has a rotating pump rod in the rubber stator within the pump cylinder, thereby producing a progressing cavity, which screws the water upwards. The meshing surfaces provide a moving seal.

Although a very reliable handpump, any maintenance task that requires removal of the rods and rotor assembly requires special lifting equipment.



Diaphragm pumps

Another type of deep well handpump is the diaphragm pump.



This operates by the expansion and contraction of a flexible diaphragm within a closed system actuated by a secondary piston pump, itself actuated by a foot pedal or hand lever. The primary rigid cylinder has a suction valve and a delivery check valve. On the contraction of the diaphragm the suction valve opens to draw water into the primary cylinder and the discharge valve closes. When the diaphragm is expanded by operating the secondary system, the suction valve closes and the discharge valve opens to pump water up a flexible rising main. Although the pump is easy to maintain, replacement diaphragms are required at relatively short intervals; these are expensive and the cost is often beyond the capacity of village communities to fund repeatedly.

Examples of a diaphragm pump are the Vergnet handpump, originated in France, and the Abi – ASM, a variant made in the Ivory Coast.

Choice of handpumps

The recommendations for handpumps which are proposed for use in community based water supply projects have been set out clearly in the World Bank/UNDP Handpumps Project (see Reference No.1 below). As well as the manufacture and performance specifications, the VLOM principles (see below) outline many attributes relating to ease of maintenance, local manufacture, robustness, standardisation, low capital cost and operating costs, availability of spares, community management and maintenance, etc.

When considering the most appropriate pump for a particular project, it is also important to take into account local preferences and government policy. The adoption of subsidised or 'free' handpumps by a major donor should be resisted if they are inappropriate and would not be sustainable in use.

Handpump performances

Typical performances of some common types of handpumps.

Name	Type	Lift range (metres)			Discharge rates (litres/min)			VLOM	Origin
Afridev	Deep well	7	25	45		22	15	Yes	Kenya, etc.
Afridev	Direct action	7	15		26	22		Yes	Kenya, etc.
Bucket pump	Improved bucket and rope	6	15		5	10		Yes	Zimbabwe
Consallen	Deep well	7	25	45	14	14	14		UK
India MK II	Deep well	7	25	14	12	12	12	No	India, etc.
India MK III	Deep well	7	25	45	50% of MK I				India, etc.
Monolift	Deep well progressing cavity	25	45	60	16	16	9	No	UK, South Africa
Nira AF 76	Deep well	7	25		25	26		No	Finland
Nira AF 84	Deep well	7	25	45	23	22	21	No	Finland
Nira AF 85	Direct action	7	15		26	24		Yes	Finland
New No. 6	Suction pump	7			36				Bangladesh
Tara	Direct action	7	15		24	23		Yes	Bangladesh
Vergnet	Deep well diaphragm	7	45		24	25		No	France
	Windlass and Bucket	0	45		5	15			Universal

Notes

Deep well handpumps are lever-operated reciprocating action pumps unless otherwise stated.

The VLOM concept

The term VLOM (Village Level Operation and Maintenance) was coined during the World Bank/UNDP Rural Water Supply Handpumps Project which, from 1981 – 91, considered the availability around the world at that time of handpump technologies and maintenance systems. A series of performance tests was undertaken: laboratory testing of 40 types of handpump and field performance monitoring of 2700 handpumps. It was concluded that centralised maintenance systems were the cause of many problems and that village level maintenance was desirable, but only feasible if the design of the pump made it possible.

Initially the VLOM concept was applied to the hardware, with the aim being to develop pumps which were designed to be:

- Easily maintained by a village caretaker, requiring minimal skills and few tools
- Manufactured in-country, primarily to ensure the availability of spare parts
- Robust and reliable under field conditions
- Cost effective

Subsequently, the VLOM concept was extended into software and organisational matters. Thus the "M" in "VLOM" has become "management of maintenance", for the success of a project was generally seen to be dependent on a strong

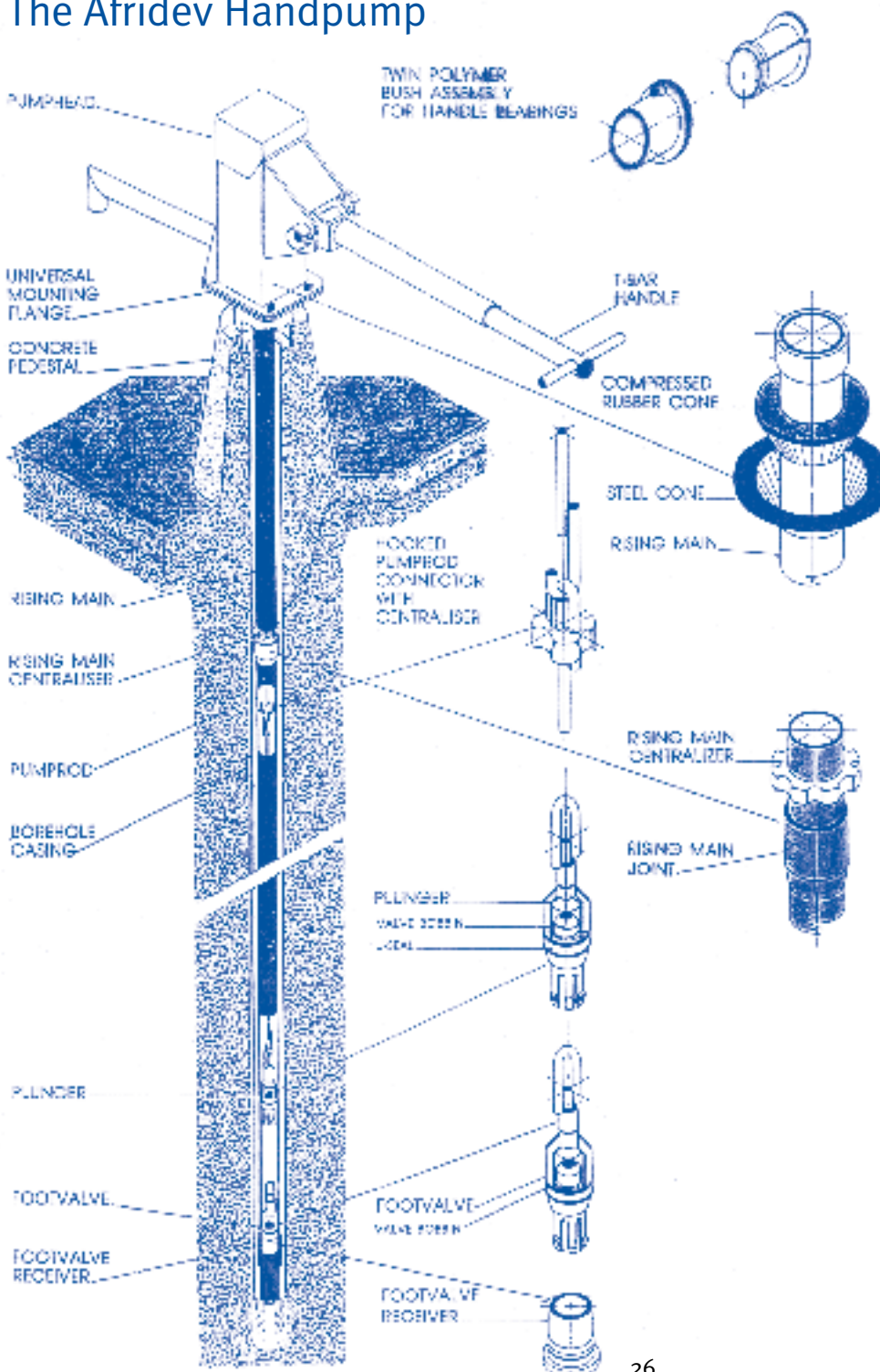
emphasis on village management. Therefore the following elements were added:

- Choice by the community of when to service pumps
- Choice by the community of who will service pumps
- Direct payment by the community to the caretakers

The application of VLOM principles, when considering pump selection, often involves compromising one principle to take advantage of another. A handpump with a low rate of breakdown might be thought preferable to another with a higher rate. However, a handpump that breaks down monthly, but can be repaired in a few hours by a local caretaker, is preferable to one that breaks down once a year but requires a month for repairs to be completed and needs replacement parts to be imported and skilled technicians to be available.

The Afridev handpump was developed during the course of the project to embody all of the VLOM design principles. Production began in Kenya in 1985 and modifications were made after field trials in Kwale in Southern Kenya. Improvements continue to be made. SKAT (Swiss Centre for Development Cooperation in Technology and Management) acts as a repository for the design drawings and specifications for the benefit of users and manufacturers of the handpumps. An exploded view of the pump is shown in the following diagram:

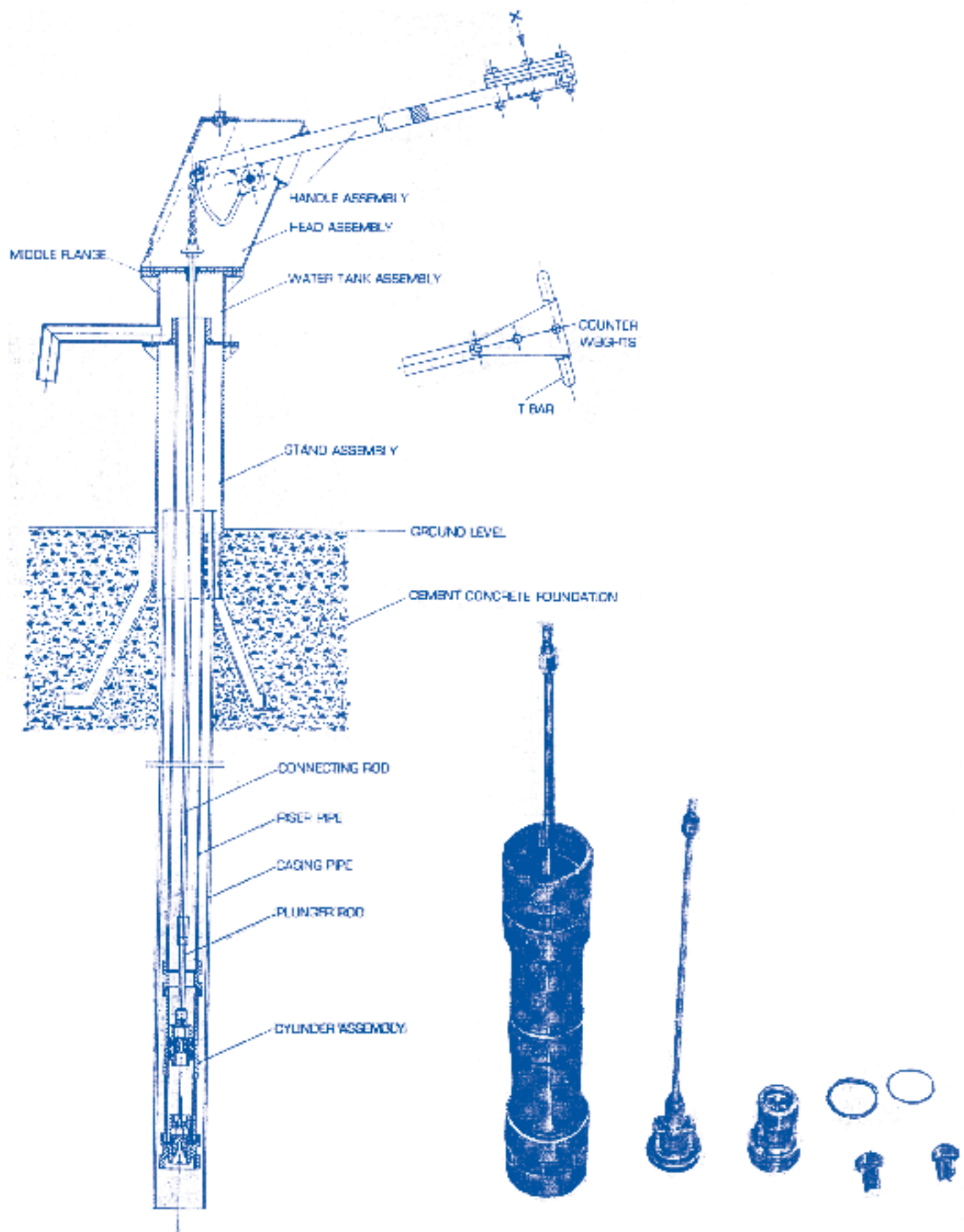
The Afridev Handpump



REFERENCES:

1. *Community water supply: The handpump option, rural water supply project*, UNDP/World Bank ISBN 08213-0850 1986
2. *Rural water supply handpumps project: Laboratory testing, field trials and technology development*, UNDP/World Bank Report No. 1 March 1982
3. *Reynolds J Handpumps: Towards sustainable technology – research and development during the water supply and sanitation decade*, UNDP/World Bank Report No. 5

Meera Vlom India Mark IV extra deepwell handpump



CYLINDER WITH SINGLE PIECE PLUNGER AND CHECK VALVE

THE PROTECTION OF SPRING SOURCES

Introduction

Surface springs occur where groundwater emerges at the surface because an impervious layer of ground prevents further seepage downwards. The rate of flow of water from the spring will vary with the seasons. It is necessary to measure the spring's flow at the end of the dry season to determine its potential reliable yield.

An inspection of the ground upstream of the spring is essential to ascertain that there is no danger of pollution or, if there is, that measures can be taken to prevent it.

A spring source can be used either to supply a gravity scheme or just to provide a single outlet, running continuously, which is set at a sufficient height to allow a bucket or container to be placed below it. To prevent waste, any flow which is surplus to that required for domestic use can be used to irrigate kitchen gardens.

If the flow from the spring is not sufficient to meet peak demands during the day, a storage tank can be incorporated into the structure of the spring protection. This enables the flow from the spring over the full 24 hours to be stored, then used throughout the day to meet intermittent demands by means of a tap in the structure.

Methods of spring protection

Many different methods of getting the clear spring water from its source into the bucket or pipeline are described in the textbooks. The essential matters are to protect the spring water from pollution, and to arrange for it to be delivered at a suitable level so that it falls directly into a container.

The following points should be considered when investigating a potential spring source:

- Making sure that the spring is not really a stream which has gone underground and is re-emerging
- Making sure that the source and the collecting area are not likely to be polluted by surface runoff
- Checking that there are no latrines within 30 metres upstream of the spring
- Fencing the area around the spring tank to prevent pollution by children or livestock
- Making sure that if the spring is to be connected to a piped water system it is on higher ground than the area to be supplied
- Taking care that the spring tank is not built on swampy ground or on land which is subject to erosion or flooding and that the flow from the protected spring itself will not cause erosion or damage

Typical spring flow rates

A flow in excess of 0.1 litres per second is sufficient to fill a 20 litre container in just over 3 minutes, which is an acceptable waiting time. From such a spring a daily useful yield of about 3000 litres can be expected, which is enough water for about 150 people.

If the flow were to be only 0.05 litres per second it could still be made to supply the same population by incorporating a storage tank of 1 cubic metre capacity.

If the flow were to be 0.5 litres per second or more the source would be suitable to supply multiple outlets or a piped gravity scheme.

Stages in the protection of a spring

The following three diagrams illustrate the stages in the construction of a collecting chamber:

Stage one is a plan view, showing:

- A cut-off drain to divert surface water
- Clearance of vegetation above the eye of the spring
- A temporary diversion of the spring water to allow construction of the collection chamber

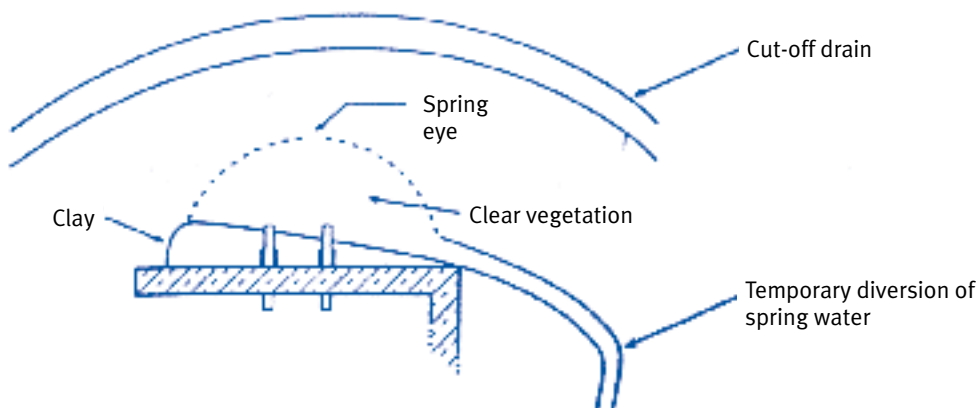
Stage two is a plan view, showing:

- Large stones placed above the eye of the spring
- The construction of the collection chamber

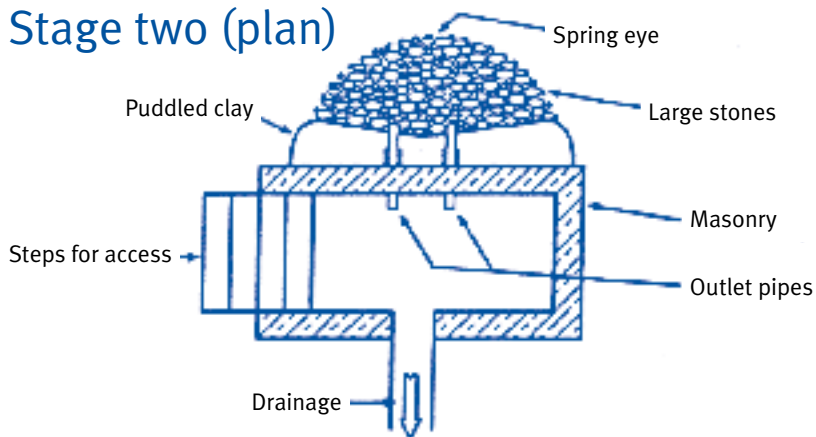
Stage three is a cross-section of the finished scheme, showing:

- Further protection of the eye by layers of impervious material above it

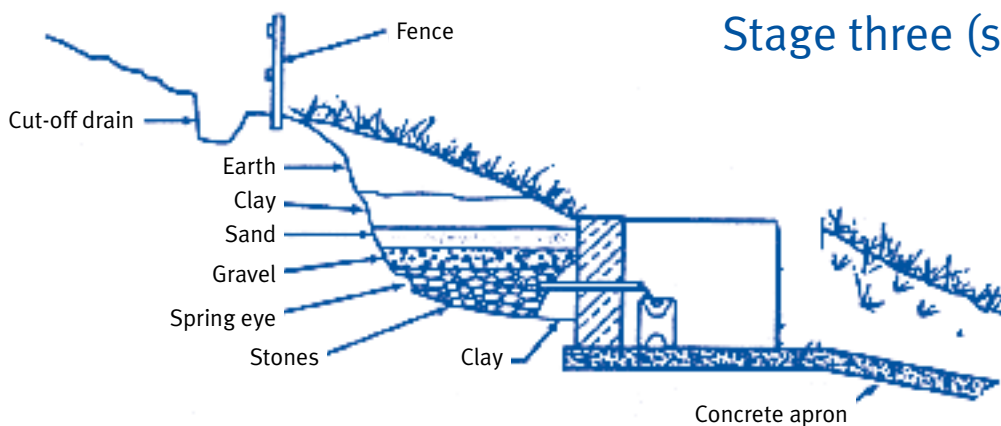
Stage one (plan)



Stage two (plan)



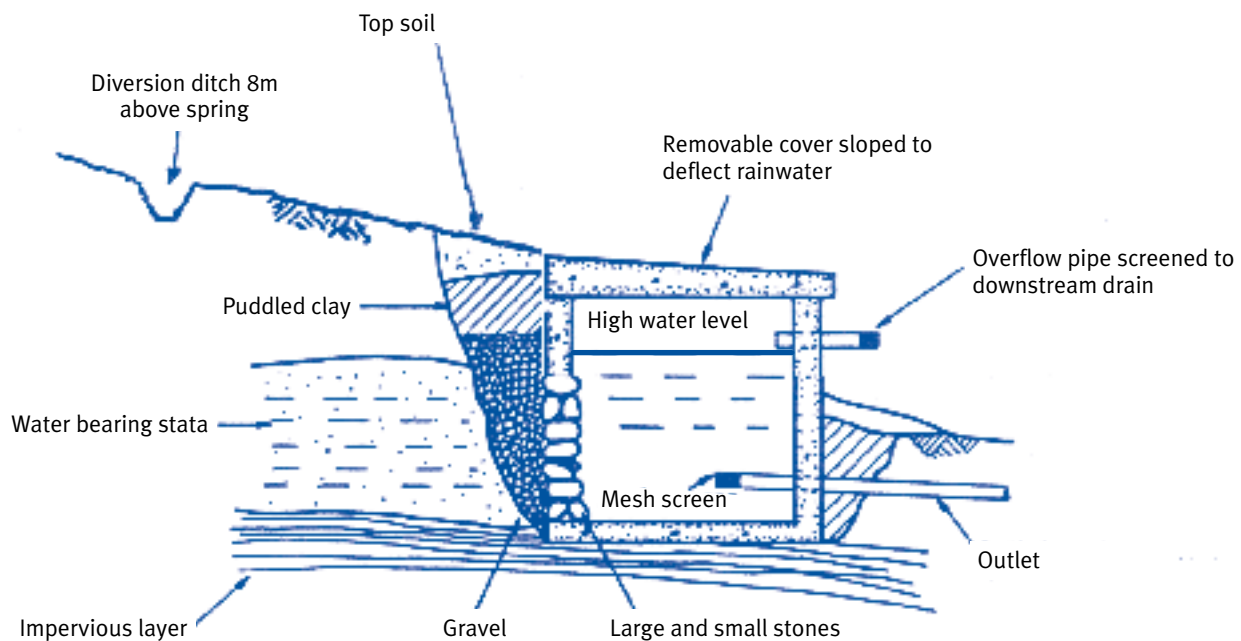
Stage three (section)



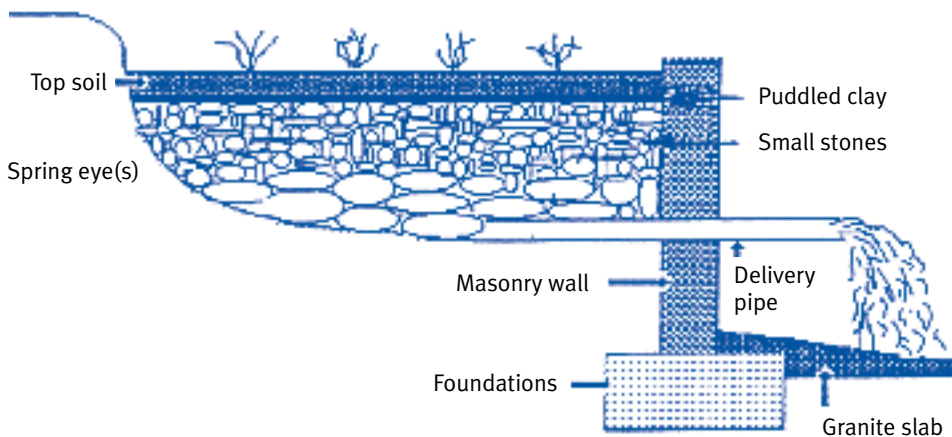
Examples of spring protection work

The following cross-sectional diagrams illustrate various spring protection schemes:

Section through a spring tank



Cross section of a spring protected by WaterAid in Uganda



REFERENCES:

- 1 Edited by J Pickford (1991) *Worth of Water*, IT Publications
- 2 Davis J and Lambert R (1995) *Engineering in Emergencies*, IT Publications
- 3 Shaw R (1999) *Running Water*, IT Publications

These three publications include more details not only of the ideas set out in this section but also those in most sections of these notes.

RAINWATER HARVESTING

Introduction

Falling rain can provide some of the cleanest naturally occurring water that is available anywhere. This is not surprising, as it is a result of a natural distillation process that is at risk only from airborne particles and from man-made pollution caused by the smoke and ash of fires and industrial processes, particularly those which burn fossil fuels.

Most modern technologies for obtaining drinking water are related to the exploitation of surface water from rivers, streams and lakes, and groundwater from wells and boreholes. However, these sources account for only 40% of total precipitation.

It is evident, therefore, that there is considerable scope for the collection of rainwater when it falls, before huge losses occur due to evaporation and transpiration and before it becomes contaminated by natural means or man-made activities.

Where there is no surface water, or where groundwater is deep or inaccessible due to hard ground conditions, or where it is too salty, acidic or otherwise unpleasant or unfit to drink, another source must be sought. In areas which have regular rainfall the most appropriate alternative is the collection of rainwater, called “rainwater harvesting”.

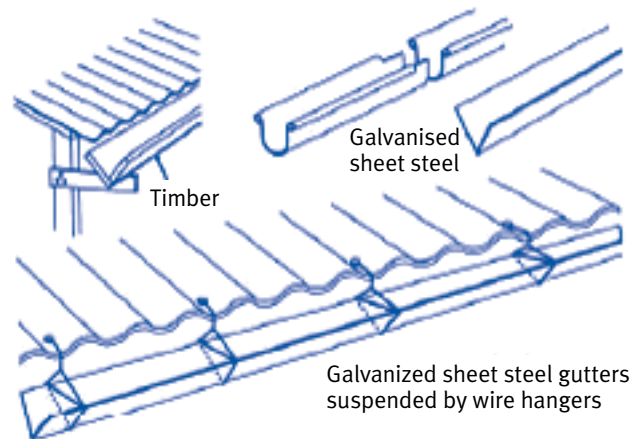
The term “rainwater harvesting” is usually taken to mean “the immediate collection of rainwater running off surfaces upon which it has fallen directly”. This definition excludes run-off from land watersheds into streams, rivers, lakes, etc.

WaterAid is concerned primarily with the provision of clean drinking water; therefore the rainwater harvesting projects which it supports are mainly those where rainwater is collected from roofs, and only to a lesser extent where it is collected from small ground, or rock, catchments.

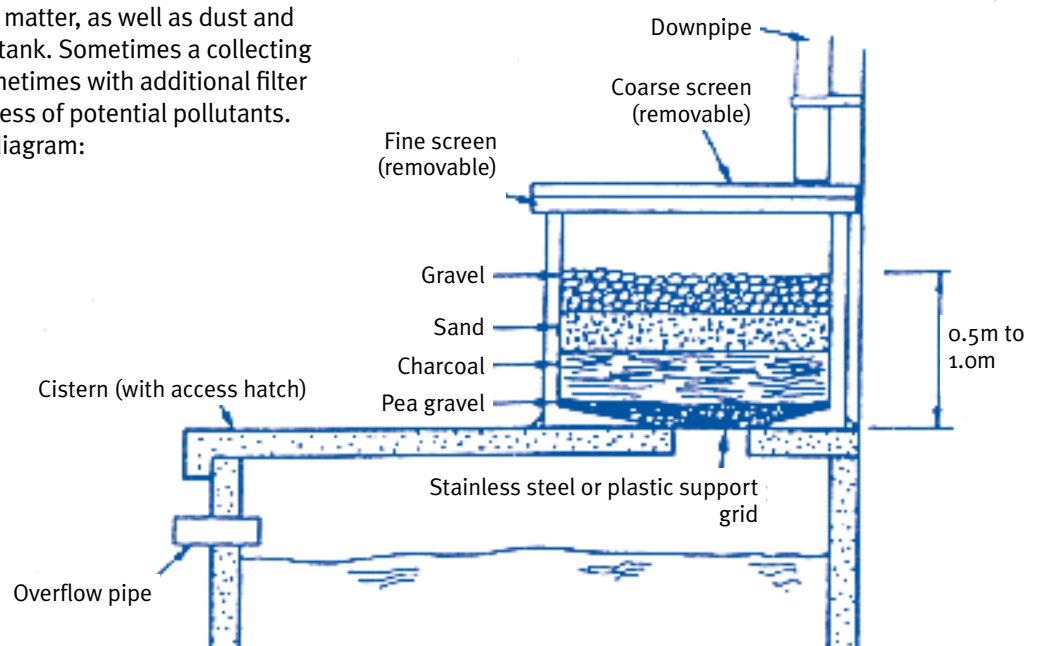
Roof catchments

Rainwater can be collected from most forms of roof. Tiled roofs, or roofs sheeted with corrugated mild steel etc, are preferable, since they are the easiest to use and give the cleanest water. Thatched or palm leafed surfaces are also feasible, although they are difficult to clean and can often taint the run-off. Asbestos sheeting or lead-painted surfaces should be avoided.

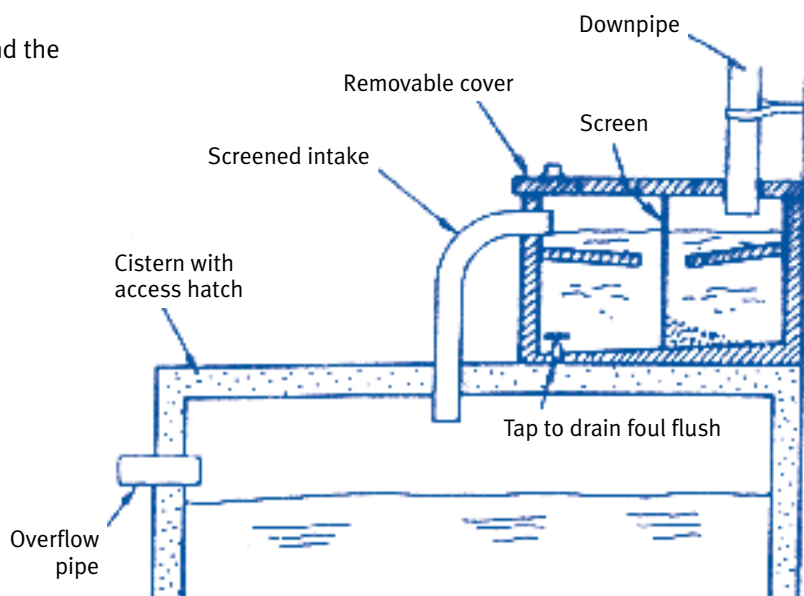
The rainwater is collected in guttering placed around the eaves of the building. Low cost guttering can be made up from 22 gauge galvanised mild steel sheeting, bent to form a ‘V’ and suspended by galvanised wire stitched through the thatch or sheeting, as shown in the following diagram:



The guttering drains to a down-pipe which discharges into a storage tank. The down-pipe should be made to swivel so that the collection of the first run-off can be run to waste (the first foul flush), thus preventing accumulated bird droppings, leaves, twigs and other vegetable matter, as well as dust and debris, from entering the storage tank. Sometimes a collecting box with a mesh strainer (and sometimes with additional filter media) is used to prevent the ingress of potential pollutants. An example is shown in the next diagram:



Alternatively, a foul flush box, which can be drained separately, may be fitted between the down-pipe and the storage tank, as shown in the following diagram:



The run-off from a roof is directly proportional to the quantity of rainfall and the plan area of the roof. For every 1mm of rain a square metre of roof area will yield 1 litre of water, less evaporation, spillage losses and wind effects. The guttering and downpipes should be sized so as to be capable of carrying peak volume of run-off; in the tropics this can occur during high intensity storms of short duration.

Storage tanks

The capacity of the storage tank is based upon several design criteria: rainfall patterns and volume, the duration of the dry period and, of course, the estimate of demand. Sometimes sophisticated calculations are involved, but these tend not to take into account human behaviour and the willingness to use water if it is available and not to conserve it for future use, in the hope that the dry spell will soon be over.

The provision of the storage tank is the most costly element of a rainwater harvesting project, usually about 90% of the total cost. Storage can range from small containers made for other purposes, for example oil drums, food cans, etc, but used as domestic storage, up to large tanks of 150 cu. metres or more at ground level, or sometimes beneath it; these are made of concrete or ferrocement and are used as storage for schools, clinics or other institutions with large areas of roof.

Domestic storage tanks

Tanks for household use can be made cheaply in a variety of ways. "Basket tanks" are baskets made of bamboo, originally intended for carrying or storing maize, which have been plastered internally and externally, in two stages, with sand/cement mortar. Storage of up to 2 cubic metres can be provided by such baskets.

Corrugated galvanised mild steel sheeting, bent and welded or bolted into a circular plan, and often coated with sand/cement mortar, can provide similar storage capacity, but at a greater cost.

Tanks of larger capacity can be made of ferrocement, which substitutes chicken wire for the bamboo reinforcement of the basket tank. These are cheaper to construct than tanks made of masonry, blockwork, reinforced concrete etc, and do not require the rendering with waterproof cement mortar that masonry and blockwork often need.

Ferrocement tanks

Above ground level, tanks are constructed with a plain or reinforced concrete base, cylindrical walls of ferrocement and a roof of ferrocement, or sometimes mild steel sheeting.

The construction of ferrocement walls is carried out by first assembling a cylindrical mesh of chicken wire and/or fence wire reinforcement, with or without the aid of formwork. On to this, a cement-rich mortar of 3:1 sand:cement is applied by trowel and built up in layers of about 15 mm to a finished thickness of between 30 to 100 mm, depending on wall height and tank diameter. Thicker walls may have two layers of mesh. The mesh helps to control local cracking and the higher walls may call for the provision of small diameter vertical steel reinforcing bars for bending resistance. Sometimes barbed fence wire is wound spirally up the wall to assist with resistance to ring tension and stress distribution.

Effective curing of the mortar between the trowelling of each layer is very important and affects the durability of the material and its resistance to cracking. Mortar should be still green when the next layer is placed. This means that the time gap between

layers should be between 12 and 24 hours. The finished material should then be cured continuously for up to 10 days under damp hessian, or other sheeting. A ferrocement tank is easy to repair and, if the mortar has been properly applied and cured, should provide long service as a water-retaining structure at a fraction of the cost of a reinforced concrete structure.

Rock catchments

Just as the roofs of buildings can be exploited for the collection of rainwater, so can rock outcrops be used as collecting surfaces. Indeed, if access to the catchment area by animals, children, etc, can be prevented, a protected catchment can collect water of high quality, as long as its surfaces are well flushed and cleaned before storage takes place.

A significant proportion of Gibraltar's water is obtained from sloping rock catchments on the Rock. At the foot of the slopes, collecting channels drain into pipes which lead to tanks excavated inside the rock. Some artificial collection surfaces have also been formed: cracks and voids in rock surfaces have been filled in and a large, soil covered, sloping area has been covered in corrugated mild steel sheeting supported on short piles driven into the subsoil. This is a huge example of what may be possible on a smaller domestic or village scale.

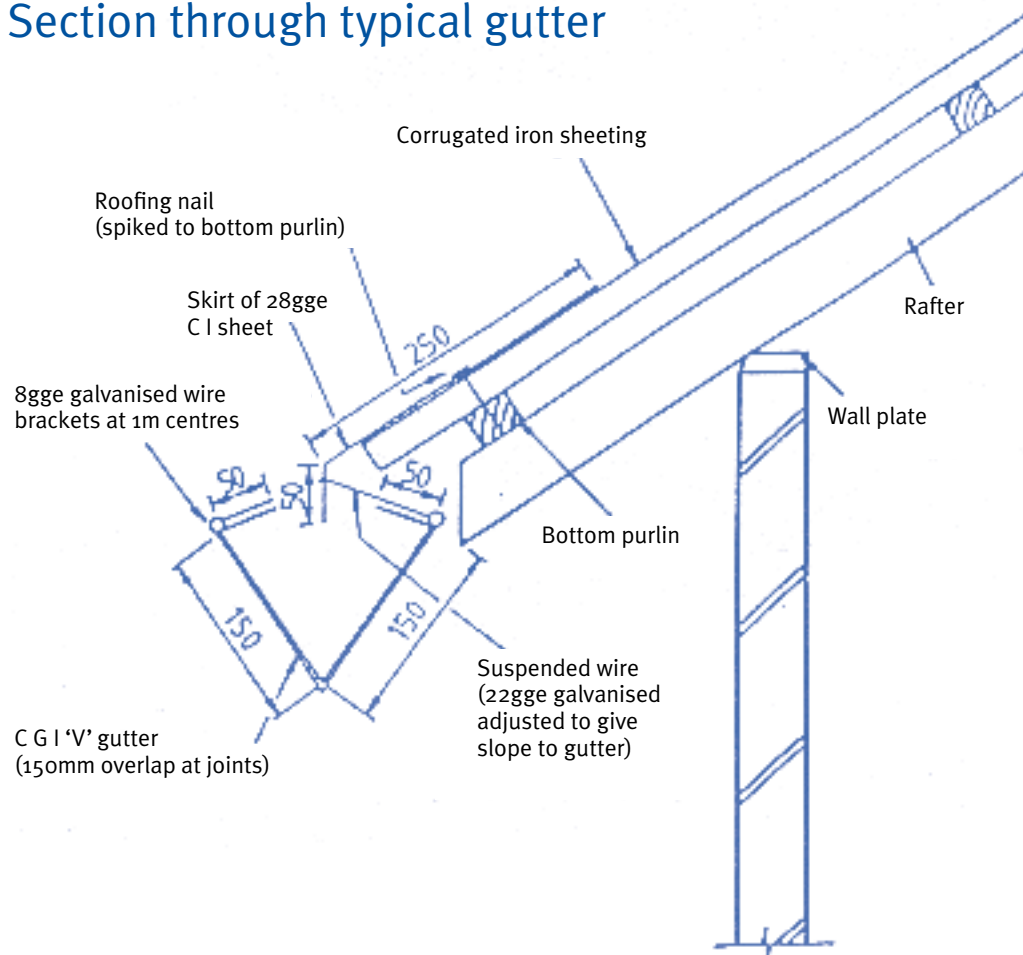
Sometimes it proves difficult to prevent the collected water from being polluted. If so, it is sensible to use this water for purposes that do not require a potable water supply, such as house cleaning, laundry, horticulture, etc, and reserve for drinking water, cooking and personal hygiene the better quality water which has been collected from a clean roof.

Use can also be made of other forms of ground catchment where, although the collection coefficient can be as low as 30%, useful volumes of water can be collected and used for agriculture and animals.

REFERENCES:

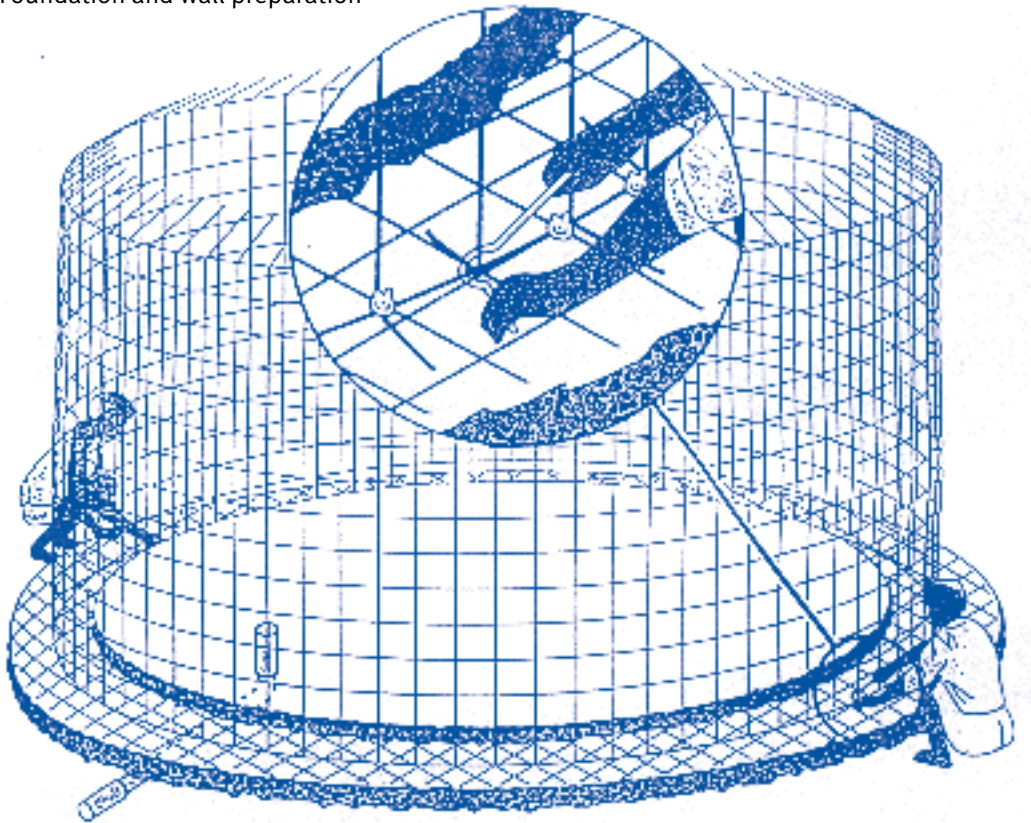
- 1 **Pacey A and Cullis A** (1986) *Rainwater Harvesting The Collection of rainfall and run-off in rural areas*, IT Publications, London
- 2 **Niessen-Petersen E** (1982) *Rain Catchments and Water Supply in Rural Africa: A Manual*, Hodder and Stoughton
- 3 **Watt S B** (1978) *Ferrocement Water Tanks and their construction*, IT Publications, London

Section through typical gutter

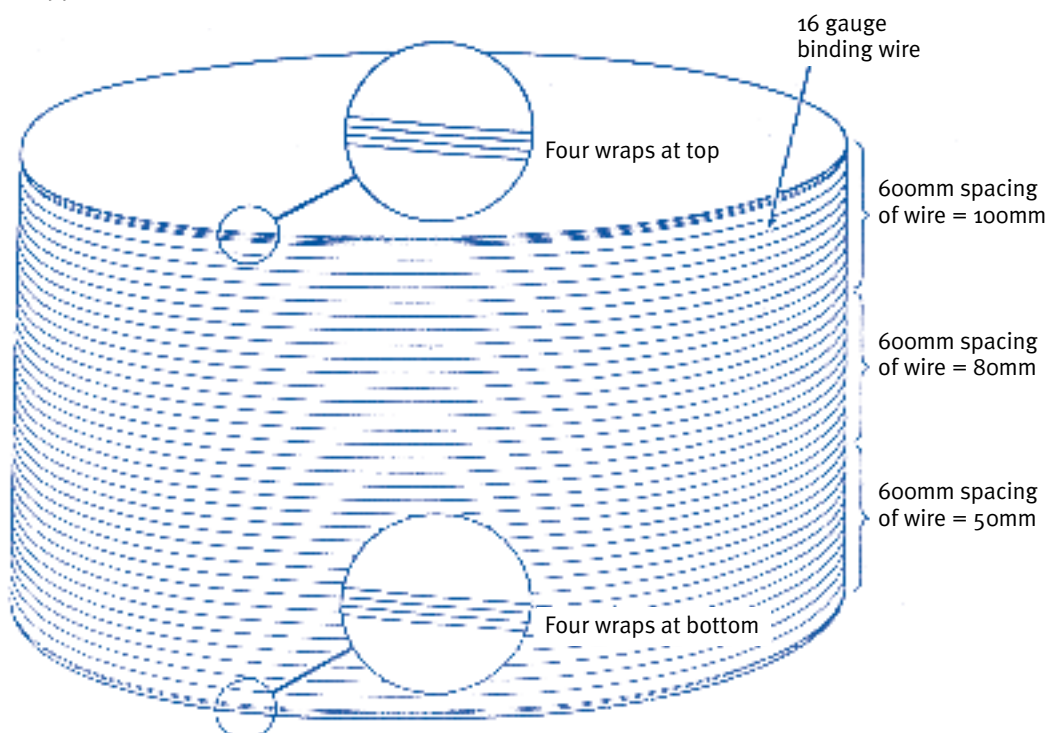


Ferrocement water tanks

Foundation and wall preparation



Wrapping the binding wire



SUB-SURFACE DAMS

Introduction

In arid and semi-arid areas of the world, sand and gravel deposits associated with streams and rivers can provide water for drinking purposes as well as for irrigation. Such watercourses are generally seasonal, but can be perennial. Riverbeds which are dry, but have green vegetation along their banks and bed, indicate that there must be a source of water in the vicinity, below bed level.

Sub-surface dams

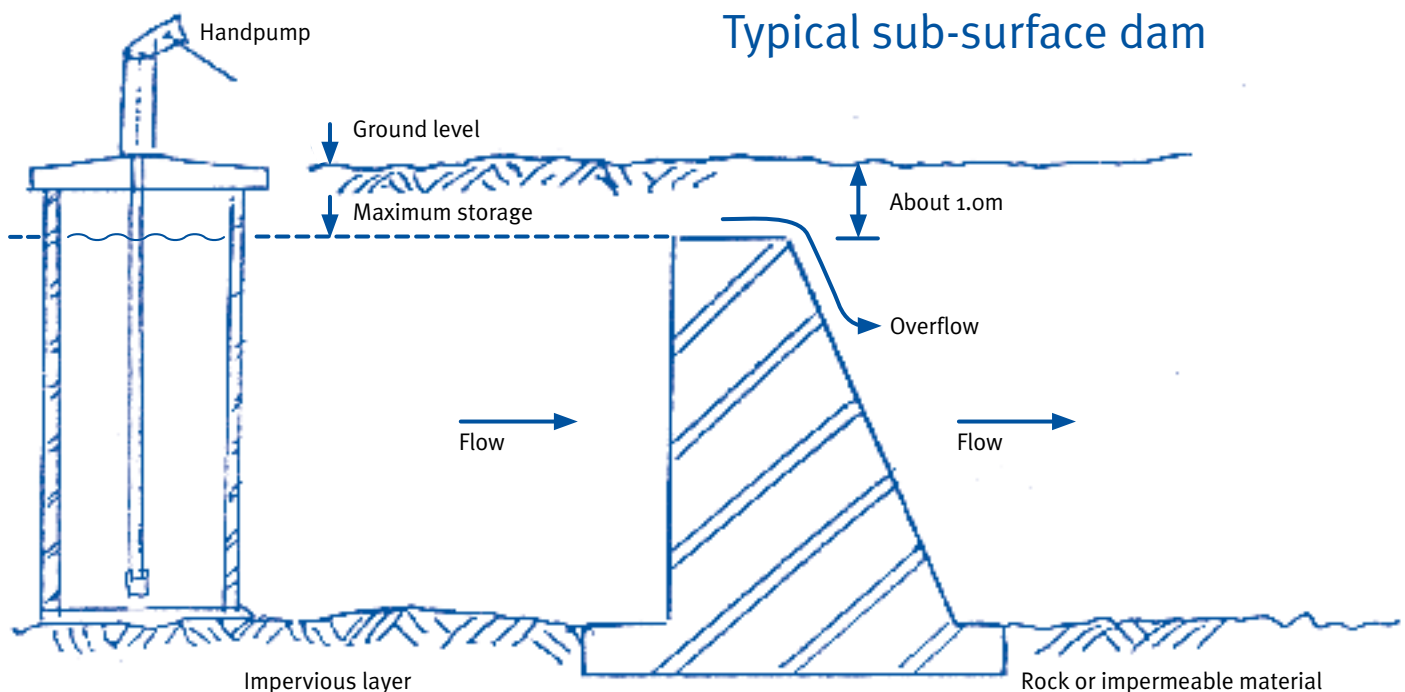
Natural sub-surface dams are often the reason for such areas of accumulated water and the resultant greenery. An outcrop of bedrock lying across a river acts as a dam and prevents the downstream flow of the sub-surface water within the sand bed of the river. Seasonal flood flow also saturates the riverbanks.

The improvement of natural sub-surface dams in valleys and rivers beds, and the construction of new ones is an effective and, usually, an inexpensive means of augmenting water resources. The dam can be constructed of concrete, masonry, blockwork, stone-filled gabions with waterproof membranes such as plastic sheet or clay layer, or stabilised soil.

It is important that the dam is founded upon impermeable bedrock, that the ends of the dam are keyed in to the river banks and, where necessary, wing walls are constructed to prevent erosion and the bypassing of flow when the river valley is in flood. Several dams, in cascade, are often constructed to increase the total volume stored.

There are many advantages in the use of sub-surface dams compared to surface dams; these include:

- (a) Losses from evaporation are very much less than the 2.0 metres lost annually from a free water surface in a dry tropical area.
- (b) The breeding of insects and parasites such as mosquitoes and bilharzia parasites is prevented.
- (c) Contamination of stored water, by people and animals, is greatly reduced, particularly as a well and handpump can be provided to abstract water in a hygienic and controlled manner.

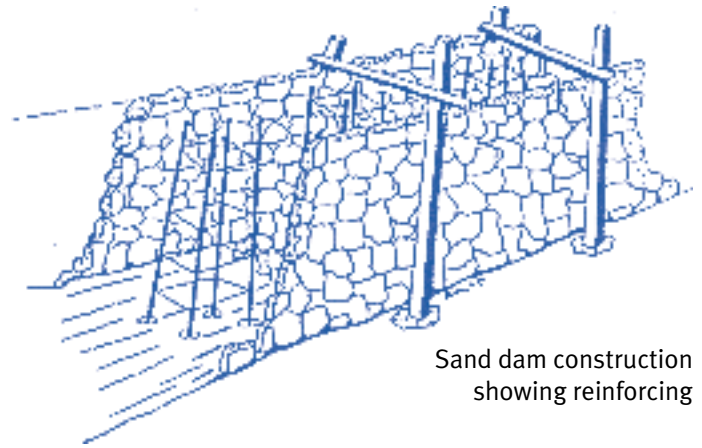


Sand dams

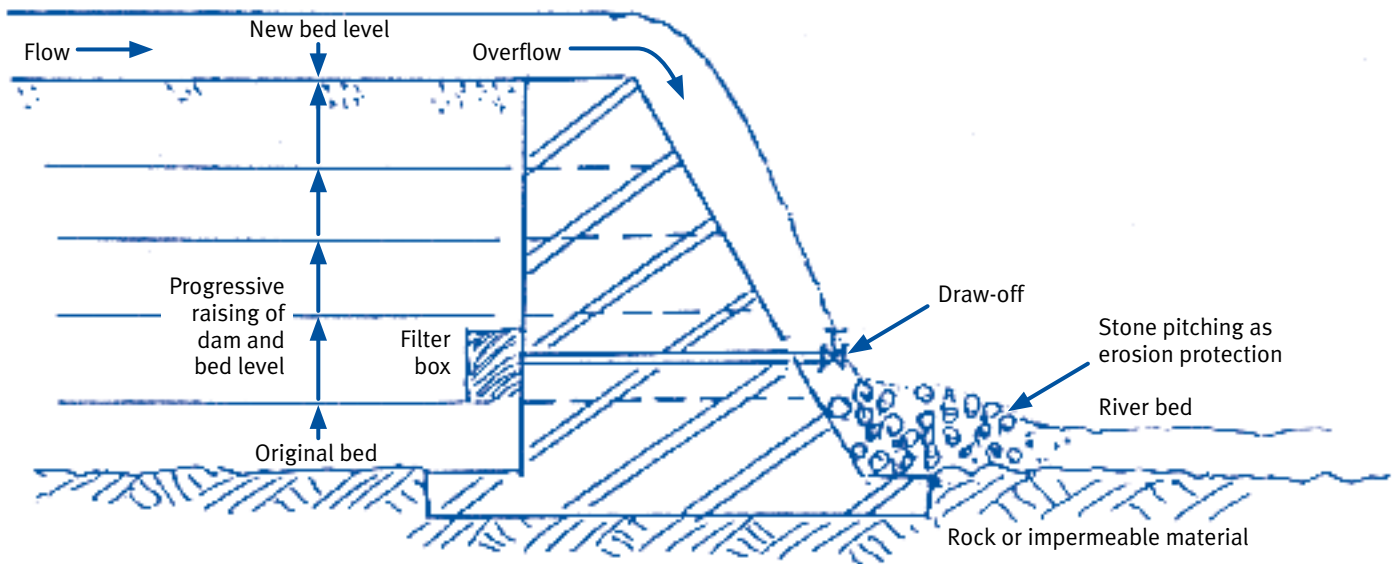
A sand dam is a special type of sub-surface dam built across a seasonal river. It provides a means of increasing water storage capacity by accumulating sand and gravel upstream of the dam, which is raised progressively before each rainy season until it reaches an appropriate height.

This incremental raising should be to such an extent that it allows finer material such as silts to be washed out of the deposited sand and gravel by the turbulence created at times of overflow. The coarser the sand and gravel collected by the dam, the greater the size of voids and, therefore, the potential storage capacity. Gravels and coarser sands can store up to 35% of their total volume as water.

The final height of the dam is governed by the bank height at its extremities and, in any case, should not be greater than about five metres. It should be constructed preferably of concrete or masonry, because its upper surface acts as an overflow weir and has to resist the erosive action of water which is laden with silt and sand in suspension.



Sand dam construction showing reinforcing



Abstraction

Water can be abstracted from the sand, gravel or soil upstream of the sub-surface dam via a well or tubewell formed in this storage material. The use of a concrete well, sealed with a cover slab and provided with a handpump, is advisable. (See Hand-dug wells). Alternatively, a draw-off pipe, with a control valve downstream and a filter box upstream, can be provided in the dam wall.

However, if the river is in spate it can cause problems with either of these abstraction methods. The use of a Rower-type handpump, sited away from the impoundment and potential area of inundation, may help to make maximum use of the time available when it is safe to abstract water.

REFERENCES:

- 1 Nilsson A (1988) *Groundwater dams for small-scale water supply*, IT Publications
- 2 Nissen-Petersen E (1982) *Rain catchment and water supply in rural Africa: A manual*, Hodder and Stroughton, SUB-

SANITATION

Introduction

Casual defecation “out in the bush” spreads disease. Any latrine, provided it is used, is an improvement on no latrine. In rural situations, family pit latrines can provide satisfactory and acceptable sanitation. They are all that most people in the developing world can afford. Given sensitive guidelines and a little technical help, families can build latrines for themselves, at very low cost.

Simple pit latrines

A family pit latrine should be about 1.2m diameter, or square, (the smallest dimension that can be dug conveniently), with the pit wholly above the water table. It should be at least 3m deep and, if necessary to attain this depth, the floor level of the building above it should be raised above ground level. With this capacity, the contents of the pit should digest and, in practice, the pit may never become full. By constructing twin pits, it should be possible to dig out a filled pit, after it has stood for a year, without any objectionable smell, whilst the other pit is in use.

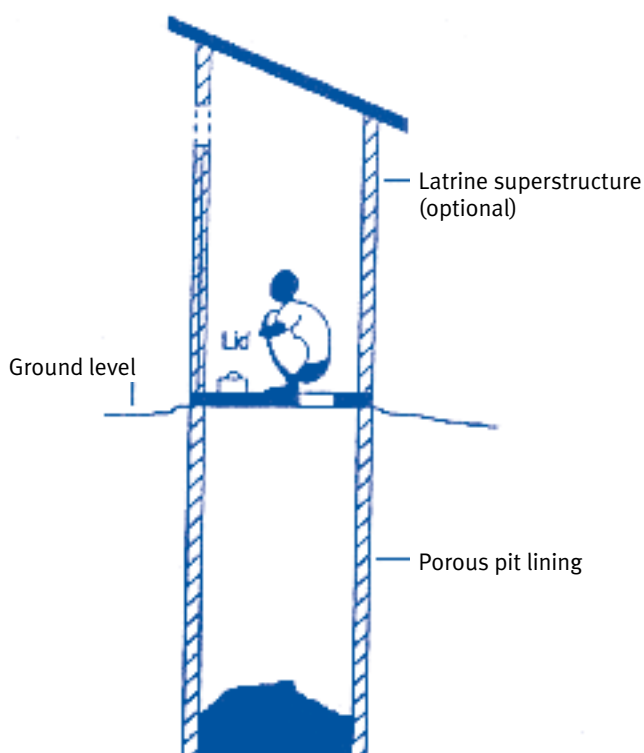
Concrete cover slabs should not be cast over the pit. Casting the slab in two pieces can reduce the weight to be carried. As an absolute minimum, communities should be supplied with well-designed steel or timber shuttering for the casting of the slabs, and advice on concrete mix proportions. Well-trained local craftsmen must supervise the mixing and placing of the concrete in the slab.

Pit latrines should be sited at least 50m from the nearest well or borehole. When water is used for anal cleansing this rule can be difficult to enforce and hydrogeological advice should be sought.

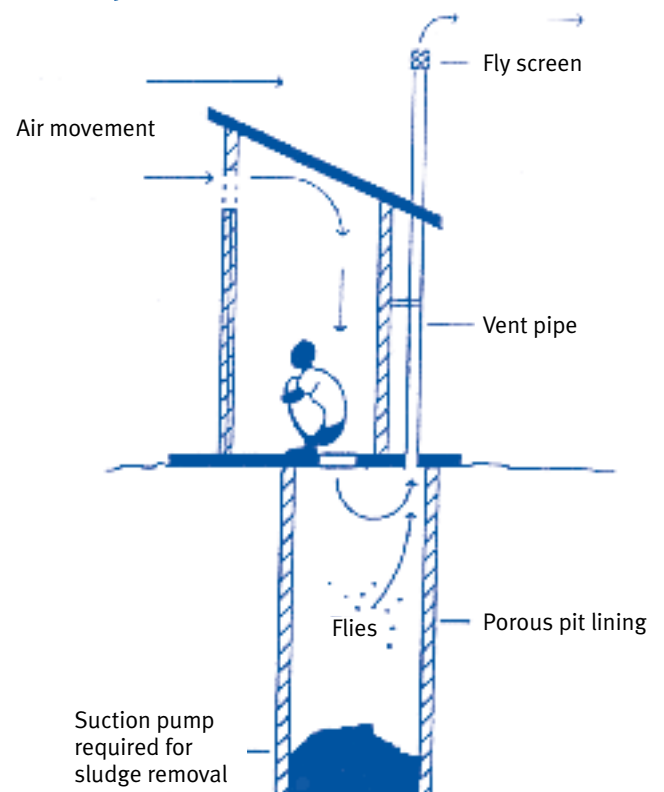
A latrine is a permanent installation. In unstable ground the pit walls should be supported with timber, bricks or blocks. Struts spanning across the pit should be avoided as they will become fouled and will cause smells. The pit cover slab needs to be strong (for obvious reasons) and its top surface should be smooth and easy to keep clean. Concrete is the best material; structural strength can be achieved by a slightly domed shape, or by using steel reinforcement.

Various modifications of the standard pit latrine are available, depending on local conditions and customs. Sketches of some of these are shown below.

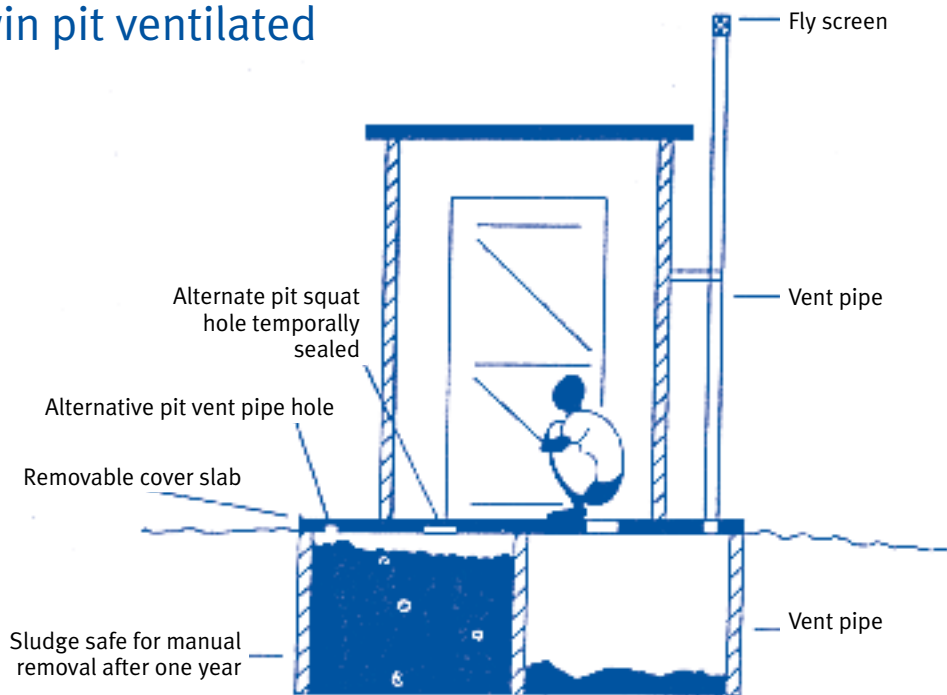
Single pit sealed lid



Single pit ventilated



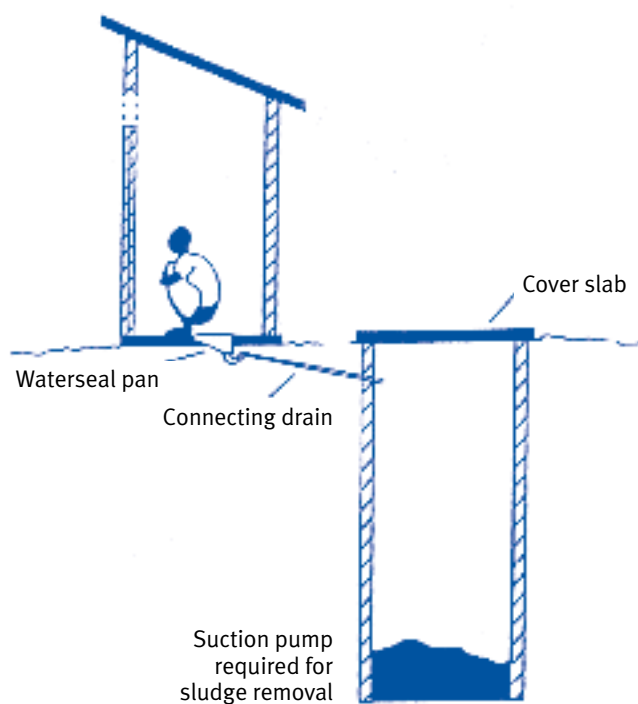
Twin pit ventilated



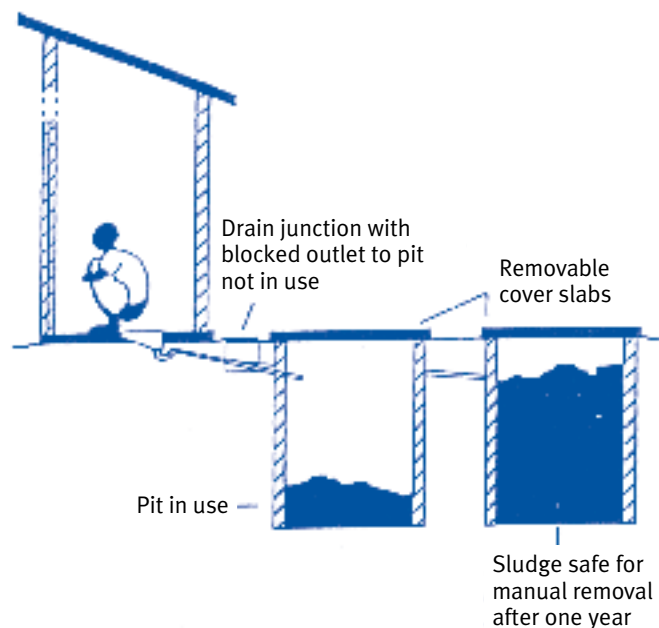
Pour flush latrines

In villages where people use water for anal cleansing, pour flush latrines can be constructed. The squatting slab can then be sited a metre or two away from the pit, to which it drains via a communication pipe. The squatting plate and pit cover are easier to construct and are just as satisfactory. To prevent smells rising from the pit a U-bend water seal can be incorporated but such seals are worse than useless if they are not properly flushed; a close-fitting squat-hole cover can do the job just as well. Raised “footpads” should be cast into the slab on each side of the squat hole and the surface of the slab should slope towards it.

Pour flush single pit offset



Pour flush twin pit



Demonstration latrines

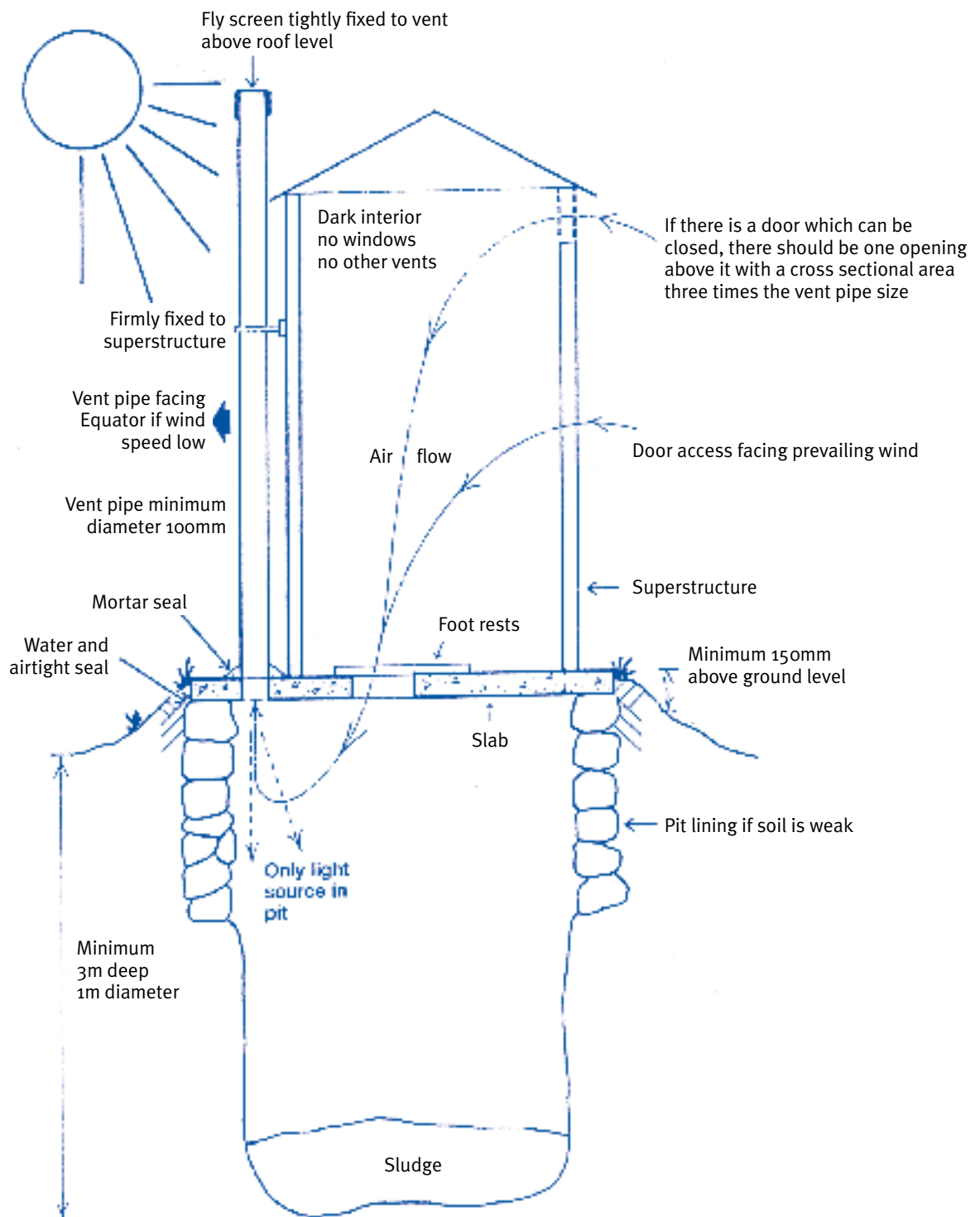
Full-scale demonstration latrines, preferably showing the range of designs for squat-holes, should be built in each village before the start of a sanitation project. It is vitally important that the families should be enabled to provide themselves with what they are happy with, not with what is thought good for them. Each family should be given detailed advice on siting (preferably downwind, away from trees and not too close to places where food is stored or prepared).

Superstructure

A superstructure (latrine house) is needed to give privacy and can be built of any local material.

The Ventilated Improved Pit (VIP) latrine

The ventilated improved pit latrine was introduced in Africa in the 1970s and has proved successful in rural areas in overcoming problems with flies and odours. Its essential features are illustrated in the following diagram:



The interior of the superstructure should be darker than the daylight outside and the superstructure building should be well ventilated so as to allow the flow of air into the pit. The pit should have a vent pipe which should be at least 100mm diameter and should extend from the pit to about 1 metre above the roof, and the top of it should be fitted with a fine-mesh stainless steel, GRP or aluminium fly-screen. Flies which are drawn by smell into the pit will be attracted up the vent pipe by the brightness of daylight at the top of it, but cannot escape because of the screen. Wind passing over the vent pipe will cause an updraught, removing any smell and helping to draw flies up to the top of the pipe.

Small scale community sewerage schemes

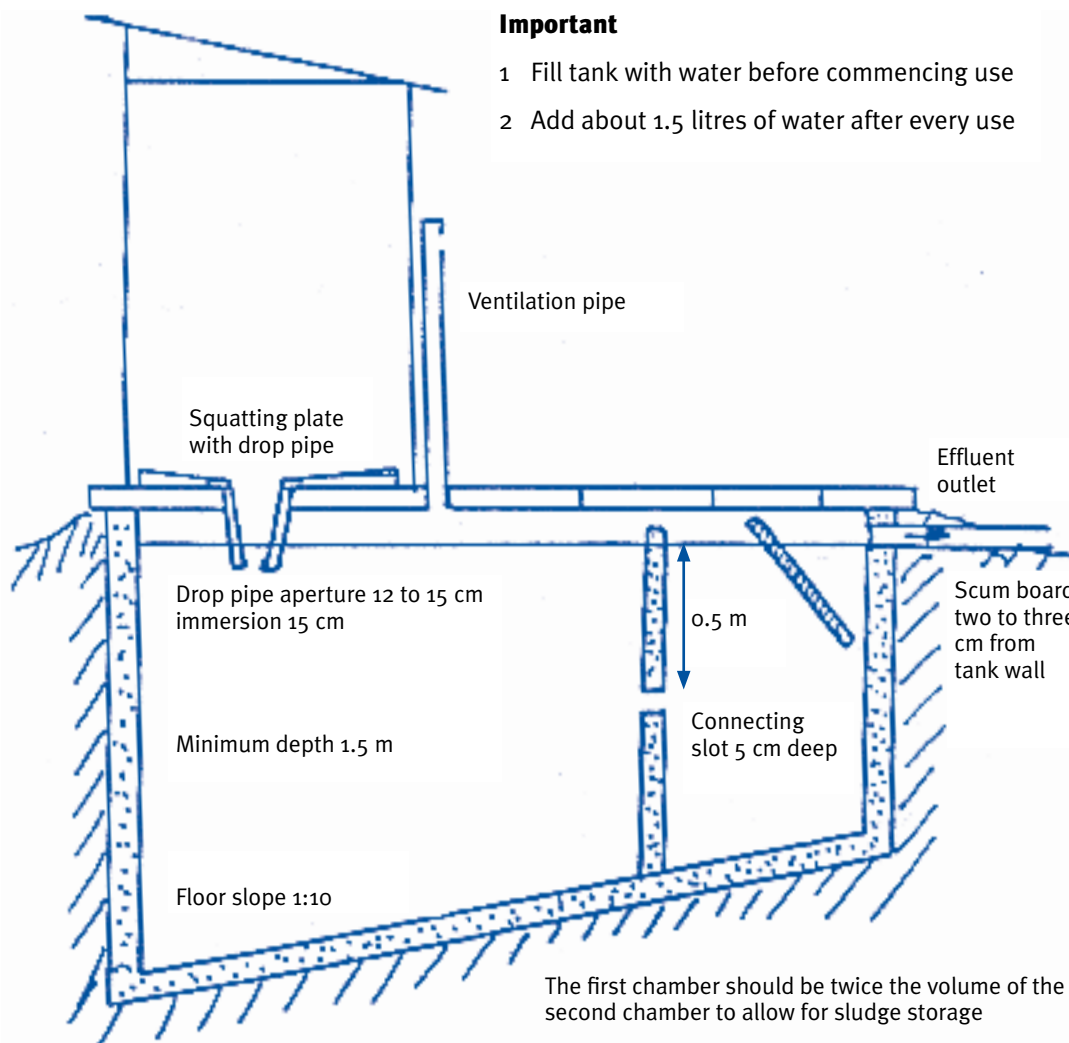
In high-density population areas where properties have flushing toilets, it is sometimes possible to install a piped sewerage scheme. Advantages are improved health and a great reduction in smells. However, disadvantages are the relatively high capital cost, construction difficulties in congested areas and the disposal of the effluent at the end of the system. The topography of the area may well make or break this type of system.

Some schemes of this sort have been very effective where there has been strong community leadership and a real desire in the community to improve conditions.

REFERENCES:

- 1 **Pickford J** (1995) *Low-Cost Sanitation*, IT Publications
- 2 **Winblad U and Kilama W** (1985) *Sanitation without water*, Macmillan Education
- 3 **Brandberg B** (1997) *Latrine Building*, IT Publications
- 4 **Reed R A** (1995) *Sustainable Sewerage*, IT Publications
- 5 **Mara D** (2004) *Domestic waste water treatment in developing countries*, Earthscan

The aqua privy



$$V = PQ + SV$$

Where:

V = volume

P = number of users

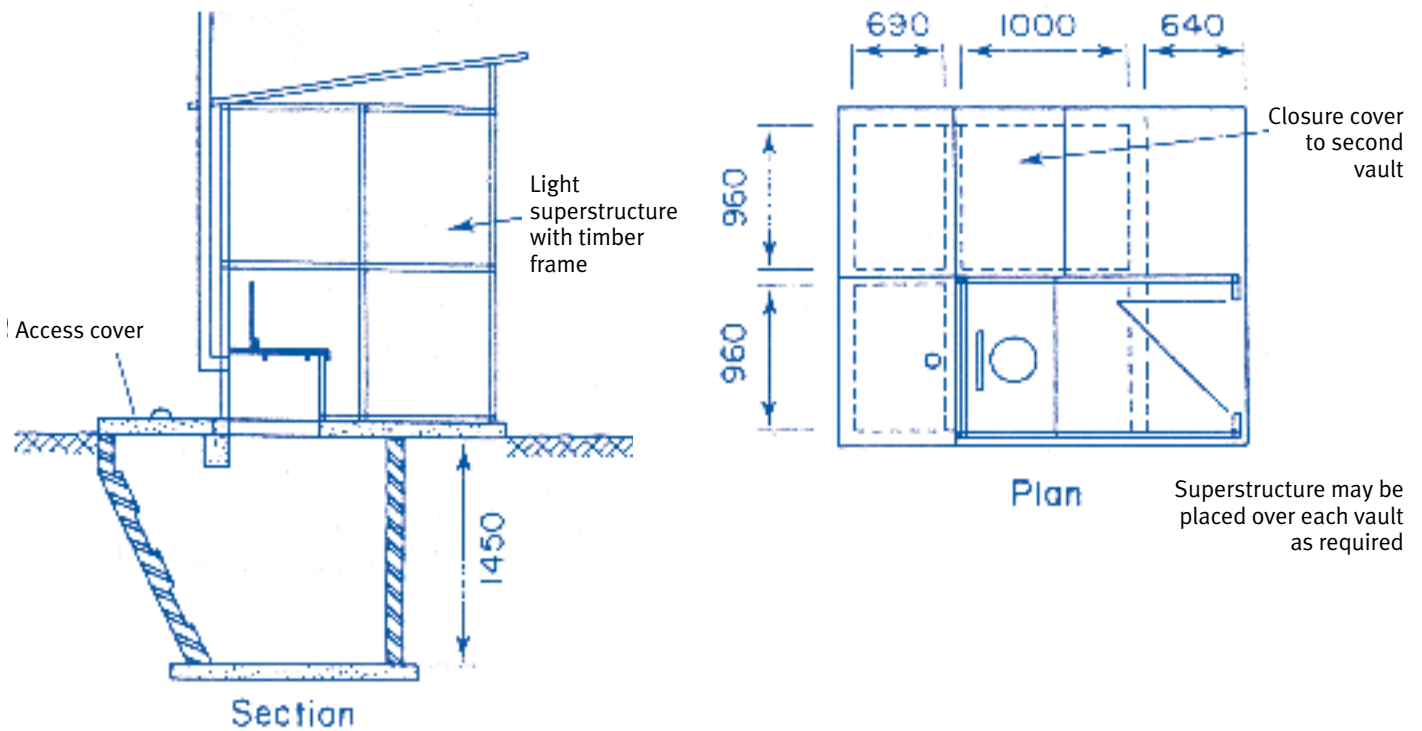
Q = volume of liquid discharged per person per day 9 to 12 litres

S = volume of sludge storage space allowed per person, a reasonable factor is 120 to 250 litres

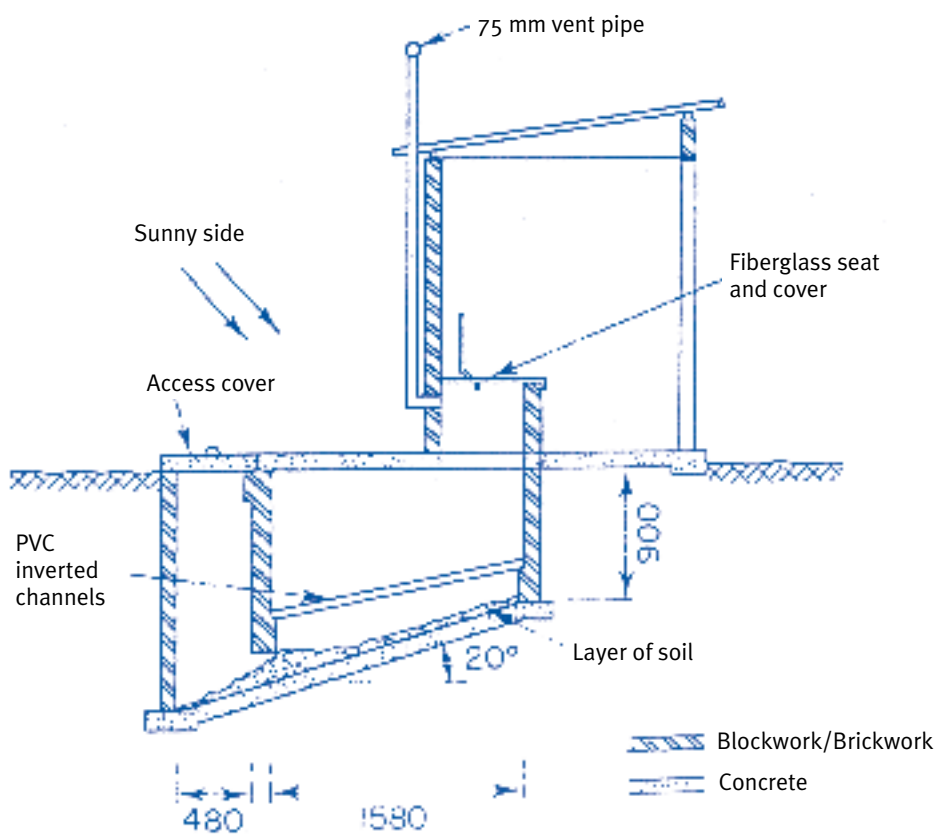
A minimum recommended volume for aqua privies is about 1500 litres which will serve up to 10 people.

Aqua Privies may be used as communal toilets where somewhat smaller volume allowances per person may be used.

Double vault composting latrine



Modified Multrum latrine



DISINFECTION

Introduction

It is essential that drinking water is free of pathogenic organisms. Storage, sedimentation, coagulation, flocculation and filtration of water, both individually and jointly, reduce the number of bacteria in the water to a certain extent. However, disinfection is needed for the complete removal of germs. It is possible to disinfect water with a low turbidity by direct exposure to sunlight for at least 60 minutes around midday. Occasional vigorous agitation will increase the effect of the sunlight.

Chlorination

Chlorination is the most widely used method of disinfection. It is both effective and economical, but must be administered constantly and safely.

Chlorine is available in various forms, but all are corrosive and need careful handling. Chlorine gas is available in cylinders and drums and requires specialist equipment to enable the gas to be injected into a water flow. In powder form, chlorine is available as sodium hypochlorite (bleaching powder) or HTH powder. A solution can be prepared from these powders and injected into the water flow at a rate proportional to the flow.

The amount of chlorine required at any given time varies according to the flow, the impurities in the water, the temperature and the pH value of the water. A contact time with the water of about 20 minutes is necessary to achieve complete reaction. Since almost all water contains some ammonia, the initial reaction of the chlorine is with the ammonia to form chloramines, which are further oxidised by more chlorine to give a free chlorine residual. This is commonly called “breakpoint chlorination”.

The actual dose of chlorine needed could vary from 0.3 milligrams per litre for an underground water to 4 mg/l for a turbid river water, when a chlorine residual of 0.5 mg/l would be expected after 20 minutes contact.

The chlorine residual, or the amount of chlorine left in the water after complete sterilization, can be measured as either the free chlorine or combined chlorine. Colour comparator equipment with the necessary tablets is required for this test.

REFERENCES

- 1 **Edited by Shaw R** (1999) *Water Lines*, Vol 14, No 2, Technical Brief No 46 and published in Running Water, IT Publications
- 2 **Davis J and Lambert R** (1995) *Engineering in Emergencies*, IT Publications

TREATMENT OF WATER

Introduction

Wherever possible, a water source that is chosen for development should be one which does not require treatment in order to give a satisfactory quality of water. A source which is relatively expensive to develop can often be more economical in the long-run than a source which is cheaper to develop but which requires daily maintenance - or even if it requires maintenance only weekly.

A community water supply scheme must be within the capacity, both financial and technical, of the benefiting community to operate and maintain it. It is more likely to be sustainable if the emphasis of the project is on the protection of the sources of water so as to maintain safe water quality rather than on the treatment of polluted water.

Sometimes it is necessary to develop a source for purposes other than drinking, such as bathing or clothes washing, where a reasonable supply quality is needed to combat "water washed" diseases.

Ground water from wells or springs is usually of an acceptable quality, due to natural filtration through the ground. However, water from surface sources such as streams, lakes and ponds will usually require some form of treatment. The quality of this water may vary greatly with the seasons of the year.

The treatment of surface water can be an expensive exercise and one which it is difficult for communities to sustain without long-term external support. Routine maintenance is essential and, in addition, an ability to vary the method of treatment so as to respond to changes in water quality is required. The ultimate water treatment, namely, using chemicals, is not considered viable in sustainable community development.

Three simple methods of treatment are considered viable: settlement, roughing filtration and slow sand filtration. Either of the first two will improve the appearance of the water but the third, particularly when used with one of the first two, should give a clear and bacteriologically pure water.

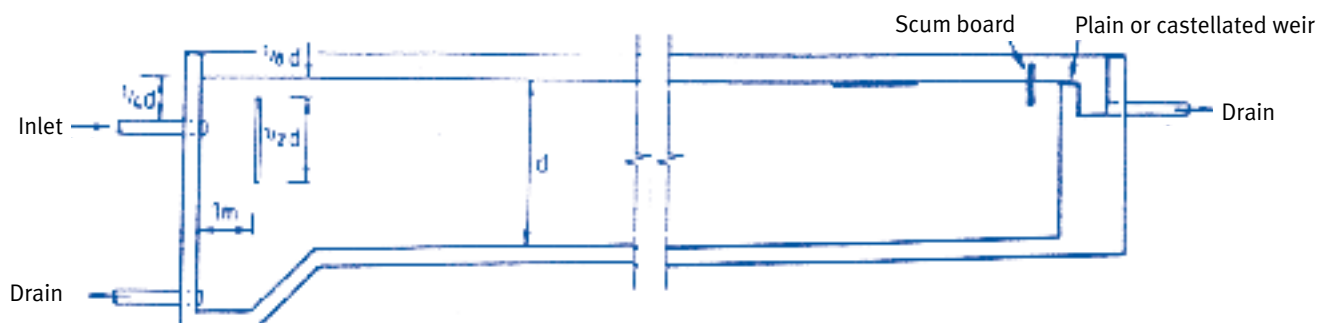
Settlement

The quality of water from streams etc can often be significantly improved by the removal of suspended matter by simple settlement.

Most suspended particles are heavier than water (although a few may float) and will settle in quiescent conditions; very fine clay particles may not settle out at all. Most structures that hold water will function as a settlement basin. Natural or manmade ponds or lakes will suffice, but purpose-made structures which incorporate efficient inlet and outlet arrangements and facilities for silt removal are generally more effective.

A layout of such a settlement tank is shown below. The length is usually about three times the width, and a practical depth is about 2 metres. A capacity of two to four hours retention at maximum flow should be sufficient to remove most sand and silt. On small installations it may be better to fill the basin with stone or gravel to prevent the incoming flow from disturbing the settled solids. The sediment can then be washed out with a hose pipe.

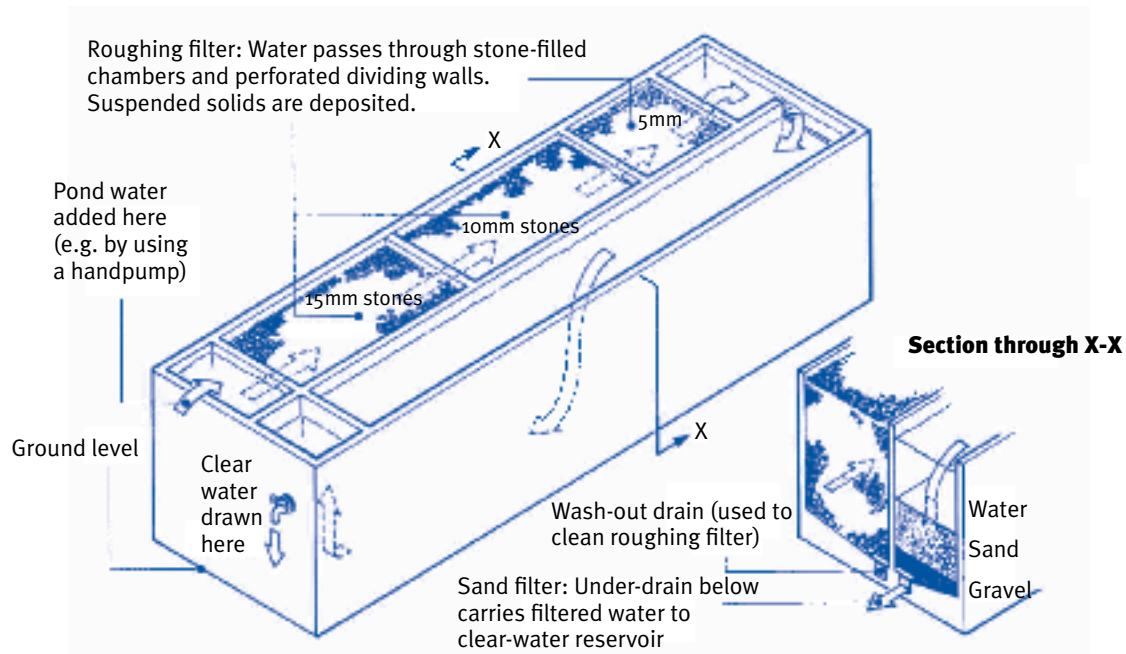
Typical section through a settlement tank



Roughing filters

A settlement tank for small flows, as described above, is, in fact, a roughing filter. However roughing filters are usually vertical flow filters where the sediment is deposited on the filter media as the water flows down through it. This filter media can vary in size but 4mm to 20mm is the range to be considered, depending on the sediment to be removed. The filter media can be cleaned by washing it down, or by backwashing under pressure, with a supply of clean water.

The ultimate roughing filter is a rapid gravity filter with sand 1mm to 4mm as the filtering media. Such a filter needs careful design and must have the facility for backwashing under pressure with water at a high rate of flow. The filter rate for this type of filter is usually about 5 metres per hour, but this can safely be exceeded in many situations.



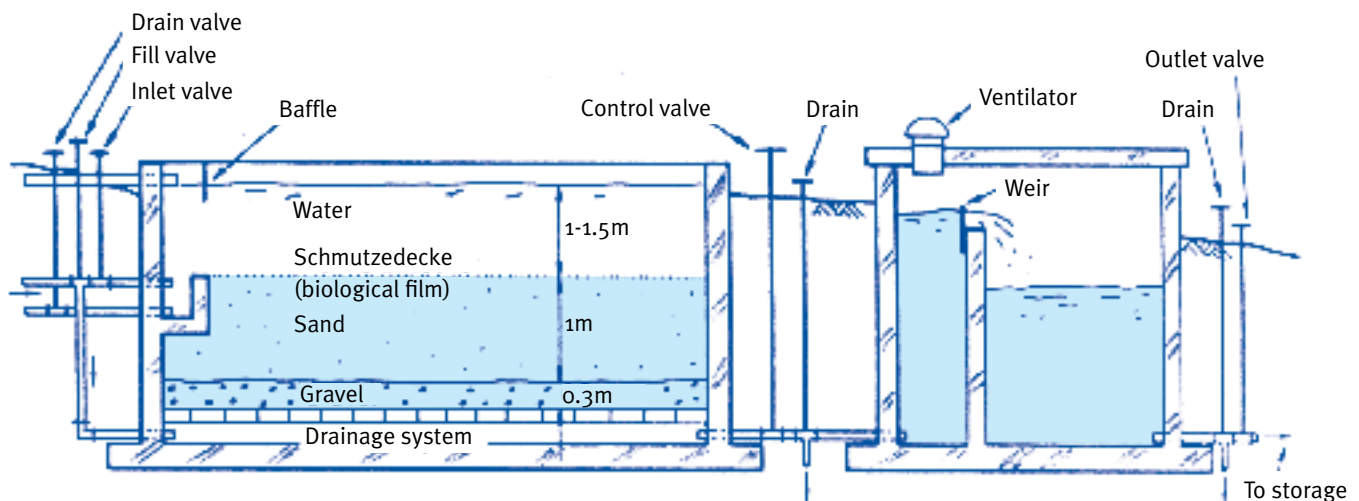
Slow sand filters

Slow sand filters function by forming a film of bacteria and algae on the surface of the sand as the water passes through it. The rate of flow must be controlled to 2.5 cubic metres per square metre per day, or a vertical flow rate of 0.1 metres per hour, and the filter must be cleaned periodically as the flow rate drops, by removing a skim of sand (20mm). The incoming water must be of a reasonable quality, or must receive pre-treatment, to prevent the slow sand filter from blocking too quickly. It is usually necessary to have two units in parallel, so that some supply can be maintained when one unit is out of commission for cleaning.

A typical layout is shown in the diagram below but the following factors should be borne in mind:

- The open tank should be about three metres deep.
- The filter media is one metre deep with clean sand of one size, between 0.15mm and 0.35mm.
- The filter media is supported on gravel, varying between 2mm and 10mm.
- An underfloor drainage system is required, which is constructed of bricks, blocks or pre-cast slabs.
- The baffled inlet should be about one metre above the sand.
- The outlet flow needs to be controlled by a weir and outlet valve.

Section through filter



Treatment of water on a household basis

Sometimes it is necessary to remove suspended matter, either occurring naturally within the water or precipitated by aeration or chemical action, in a small domestic treatment system. A basic slow sand filter can be set up in a 200 litre drum with a flow velocity of 0.1 to 0.2 m/hr downwards or, similarly, an upward flow filter can be set up to handle a flow of about 1m/hr. The former can be used to remove silt, algae or particulate matter and the latter to remove iron or manganese precipitated by aeration, or fluorides or arsenic precipitated by chemicals.

Note

The treatment of polluted water is a major undertaking and these notes give only an indication of what may be involved. The reference books listed below will give more details of the design and operation of a treatment plant. Without proper maintenance a treatment plant is worse than useless.

REFERENCES:

- 1 Edited by Pickford J (1998) *The Worth of water*, Intermediate Technology
- 2 Edited by IRC Wiley J (1983) *Small community water supplies*
- 3 Morgan P (1990) *Rural water supplies and sanitation*, Macmillan
- 4 R Shaw (1999) *Flowing water*, IT Publications

WaterAid – water for life

WaterAid is an international non-governmental organisation dedicated exclusively to the provision of safe domestic water, sanitation and hygiene education to the world's poorest people. These most basic services are essential to life; without them vulnerable communities are trapped in the stranglehold of disease and poverty.

WaterAid works by helping local organisations set up low cost, sustainable projects using appropriate technology that can be managed by the community itself.

WaterAid also seeks to influence the policies of other key organisations, such as governments, to secure and protect the right of poor people to safe, affordable water and sanitation services.

WaterAid is independent and relies heavily on voluntary support.



For more information, please contact:

WaterAid, 47-49 Durham Street, London SE11 5JD

Telephone: 020 7793 4500

Fax: 020 7793 4545

Email: wateraid@wateraid.org

UK charity registration number 288701

www.wateraid.org