4 Raising water

4.1 Introduction

Whatever device is used for raising water, it will have moving parts. These will require regular maintenance and occasional repair. No new water-raising device should therefore be installed unless appropriate arrangements have been made to ensure that this repair work is affordable (ideally to the users) and will be promptly carried out.

A bewildering variety of methods are available for lifting water. Unfortunately, many of them are not suitable for small water supplies because:

- they cannot lift water very high
- they expose the water to the risk of pollution
- they are too expensive to install and operate.

The simplest methods are often the cheapest, and are easier to make and repair using local materials. However, they are sometimes less durable, and usually require more maintenance by the local community. The following sections describe the main methods in order of increasing complexity and cost. Which of these is the most appropriate will depend on the local conditions, the funds available, the feasibility of regular maintenance in the future and the opinions of users.

The first decision to make, though, is whether to use human power for raising water, or to use a motor of some kind. Hand power is suitable for a supply where water is drawn straight from the source, such as a well, and the person drawing water operates the device. If water is to be pumped to a storage tank first, some other type of power will have to be used, such as wind, diesel or electricity.

4.2 Human powered systems of raising water

4.2.1 Hand devices using buckets

The simplest method of raising water is a bucket of some kind on the end of a rope. It is best to use roller bars across the well (Figure 34), a pulley (Figure 35), a shaduf (Figure 36), or a windlass (Figure 37). These devices all ensure that people do not have to lean over the well to raise the bucket, and also make lifting easier. The risk of pollution of the well water will be less if the bucket and rope are never put on the ground. However, with a simple bucket and rope

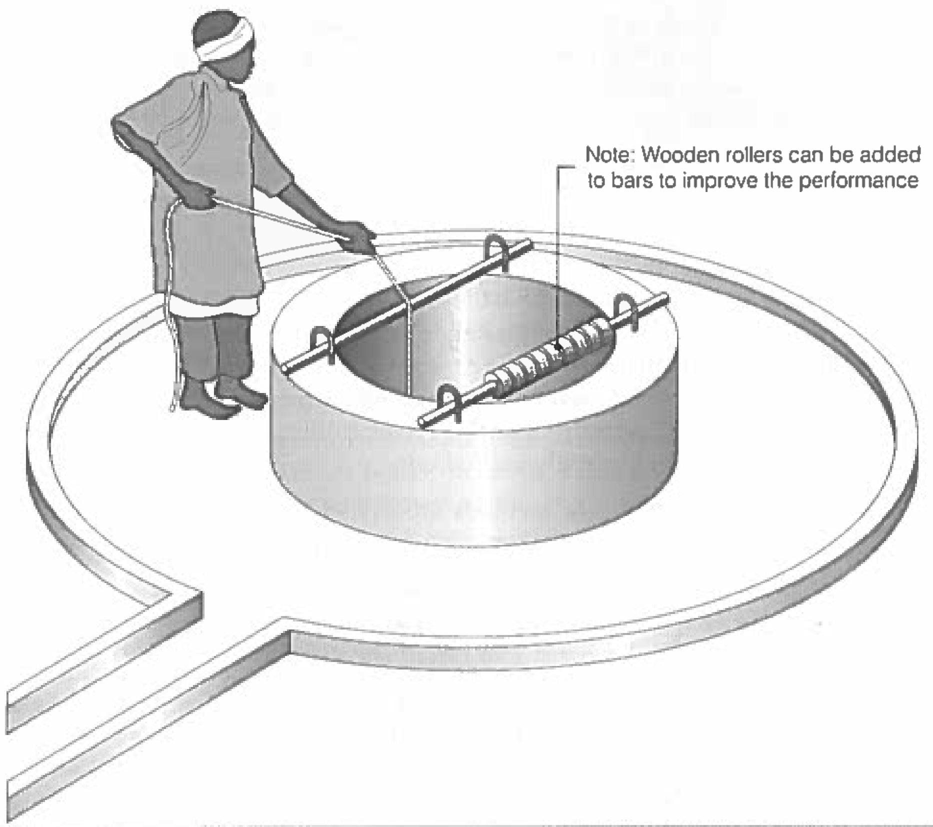


Figure 34 A well provided with roller bars to protect ropes from abrasion.
Source: WEDC

system, only users who understand the reduced health risks are likely to adopt this practice. A good hygiene education programme will help increase awareness of these issues. The windlass and the shaduf are good systems because they usually keep the bucket and rope off the ground during use.

The Blair bucket pump (Figures 38 and 39) uses a narrow bucket with a simple valve in its base. This allows it to be used in a borehole. Its simple design means that it can be locally manufactured and repaired, but experience has shown that it is not normally suitable for use by more than 60 people, or where the water is more than about 15 m deep.

4.2.2 Human powered pumps

The devices mentioned in Section 4.2.1 can often be made using materials available in rural areas. Some simple handpumps can also be made by hand in the community from wood, rubber (from vehicle tyres or inner tubes) and plastic pipes. These bucket and rope systems or locally made pumps have the

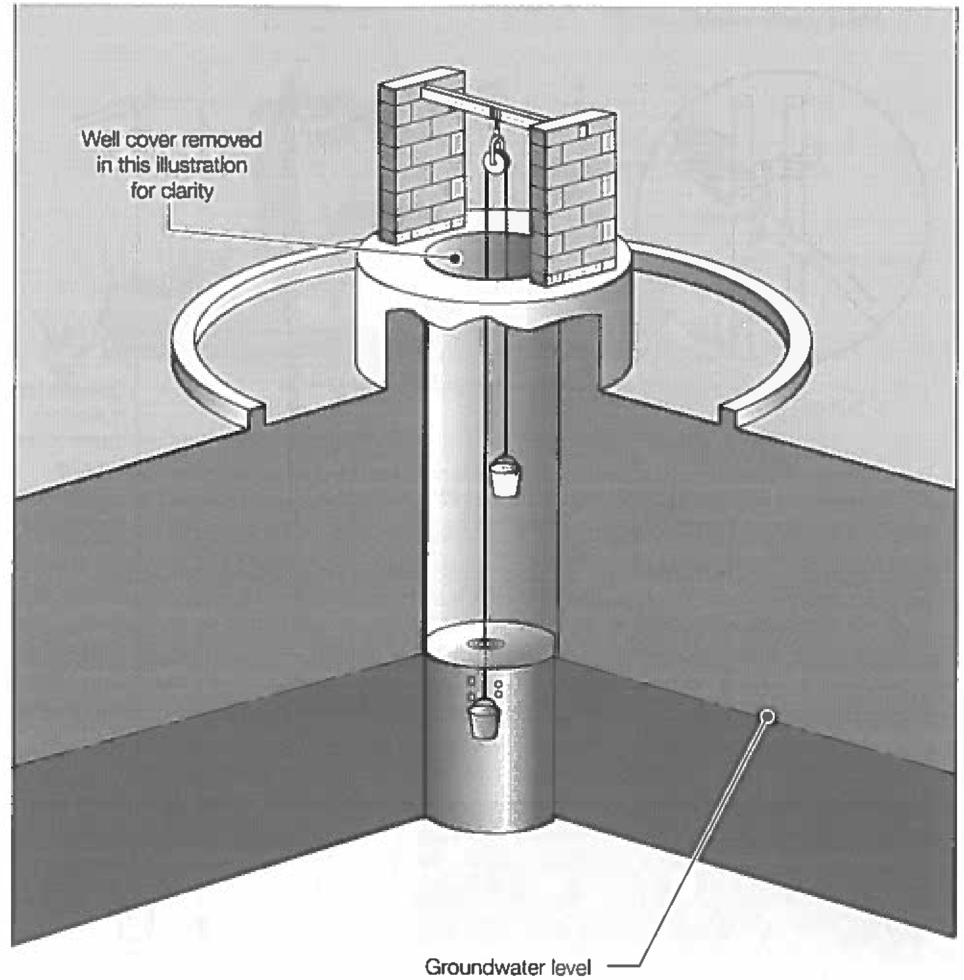


Figure 35 A protected well with a double bucket system.
Source: WEDC

advantage that their maintenance and repair is well within the capability of the people who made them. However, their disadvantages are:

- they are not usually rugged enough for use by many people
- they can not usually lift water very far
- their design may expose the water they collect to contamination.

In practice a handpump that is manufactured in a factory outside the community, sometimes in another country, will often be used. Such a pump will usually be more rugged and more reliable than a homemade pump, but it will also require regular maintenance and repair. Some of this maintenance requires special tools and a certain amount of skill. For instance, with the

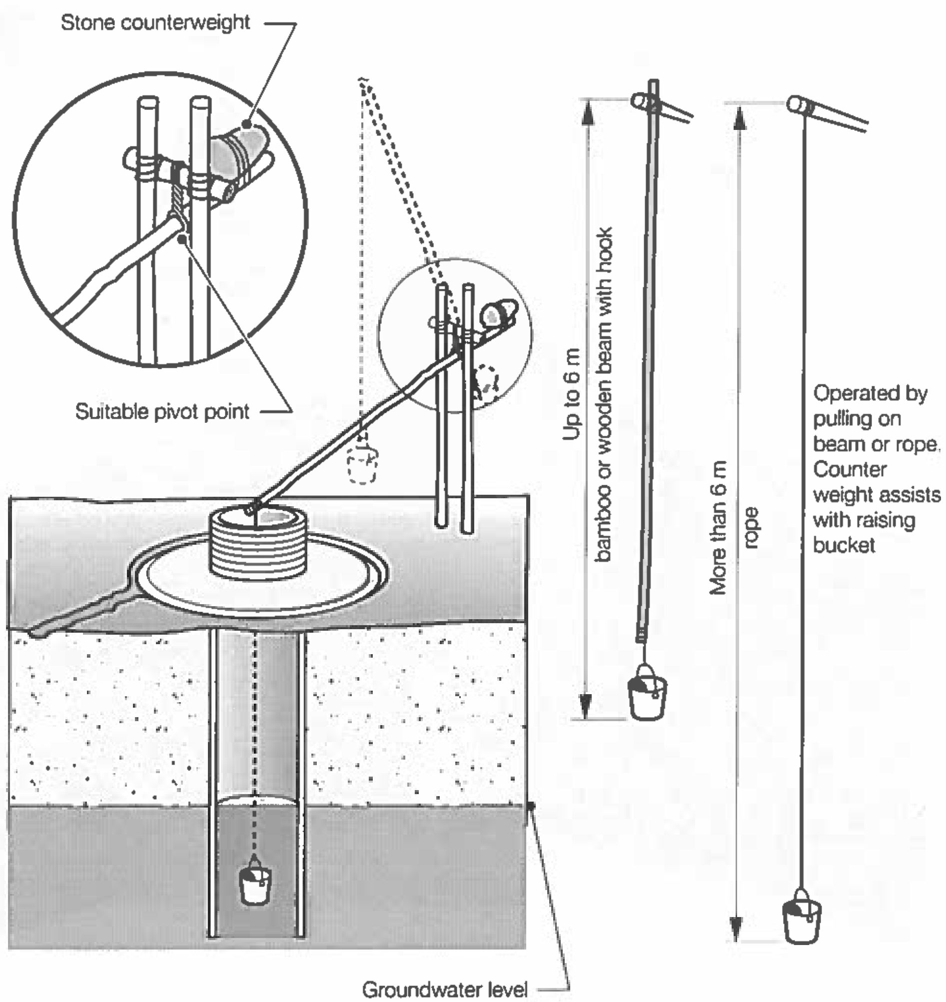
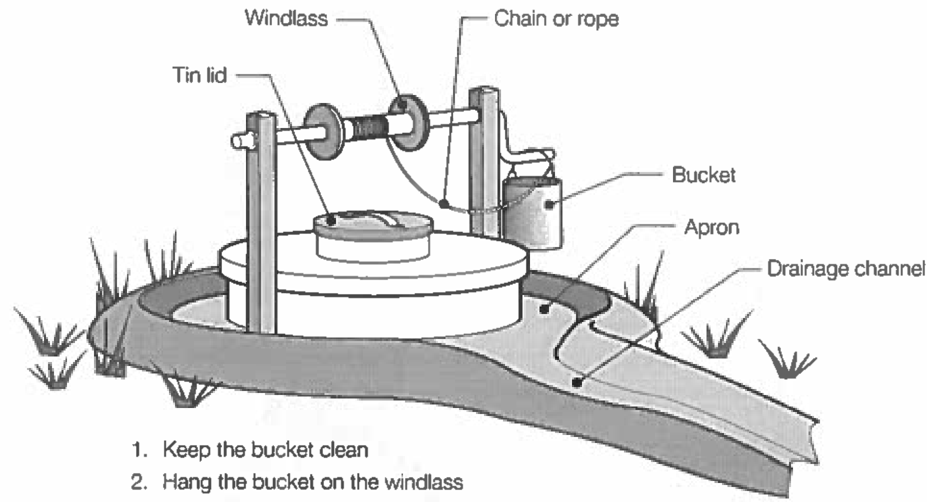


Figure 36 A simple shaduf.
Source: IRC (1988)

traditional design of pump (Figure 44), removing the cylinder from a deep borehole requires great care, and usually some external assistance. Fortunately, some designs (Figure 45) introduced over the last 20 years now incorporate improvements that make maintenance possible without external assistance. Such types of pump are often termed VLOM pumps, meaning that they are generally suitable for village level operation and maintenance. Whatever handpump is chosen, affordable spares must be readily available locally throughout the life of the pump. This usually needs to be arranged by national agencies.



1. Keep the bucket clean
2. Hang the bucket on the windlass
3. Keep the well cover in place
4. Keep the apron and drain clean
5. Always use the same bucket in the well
6. Keep chain wrapped around windlass

Figure 37 A typical windlass and user's instructions.
Source: Morgan (1990)

Reciprocating piston handpumps

Most handpumps are reciprocating piston pumps. These operate on the principle of a valved piston being raised and lowered in a valved cylinder (Figure 40). The piston in such pumps is usually moved by a rod connected to a lever at the pumphead, but a flywheel and crankshaft can also be used to create the reciprocating (up and down) motion. There are three distinct categories of reciprocating piston pump, which are described below. In each category there are many different designs but the names of some well known versions are mentioned for each category.

Suction pumps

These can be of a traditional design (Figure 41) or the more recent rower design (Figure 42). The cylinder to these pumps is usually positioned above ground level and to be regarded as a suction pump the cylinder is always above the water level of the source.

When the piston in the cylinder of a suction pump is moved upwards this creates a partial vacuum below the piston which results in water being sucked up the rising main pipe. In fact the water is pushed into the pipe by the atmospheric pressure acting on the surface of the water source. Because of this reliance on atmospheric pressure these pumps can only lift water from a maximum of about 7 m below the cylinder if the site is at sea level.

Figure 38 The Blair bucket pump.
Source: Morgan (1990)

Where the site is at a higher level the maximum lift is less because the atmospheric pressure reduces by 1.1 m per 1000 m change in altitude.

The main disadvantage of these pumps is that if the piston valve seal and piston seal (see Figure 41) are poor, a partial vacuum cannot be formed. The seal provided by the suction valve is also important for the pump to operate properly. In practice water may need to be added to the cylinder to improve the airtightness of these seals before the pump will work. In many situations this 'priming water' is likely to be polluted, leading to contamination of the water which is subsequently pumped through the cylinder. If the pump has a good suction valve it should hold water in the cylinder overnight so that the pump is ready for use in the morning. If the seal is poor then the water will drain out of the cylinder, so priming water will need to be added each

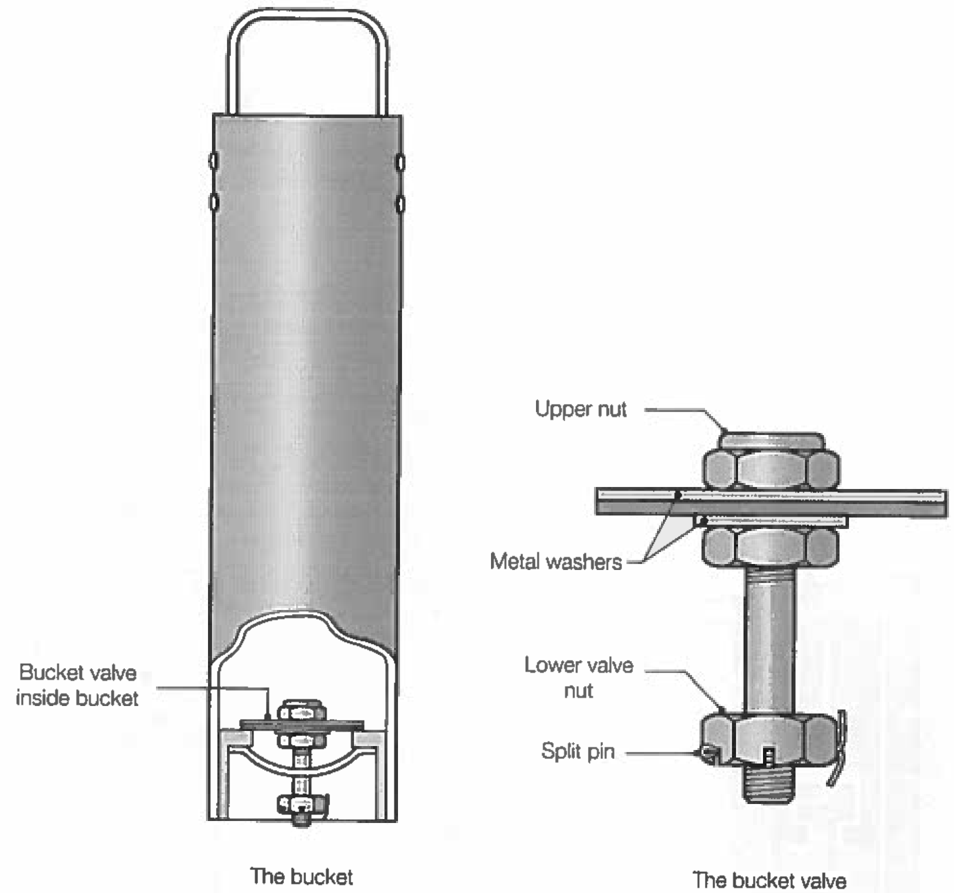


Figure 39 The Blair bucket and its valve.
Source: Morgan (1990)

morning. If the suction pipe is not airtight the pump will not work at all, or will work ineffectively.

Examples of the traditional suction pump are the Singur and the New No.6. Examples of the rower version are the Rower, and SWS Rower.

Direct action pumps

With these pumps the cylinder is below groundwater level (Figure 43) and the piston lifts the water directly and does not rely on atmospheric pressure. They have no lever handle and the maximum depth from which they can lift water is mainly dependent on the strength of the operator and pump components. It is usually less than 12 m. Good designs allow the piston and the footvalve to be withdrawn through the rising main. Most direct action pumps use air-filled pipes as operating rods but with a few designs water flows inside this pipe rather than around it.

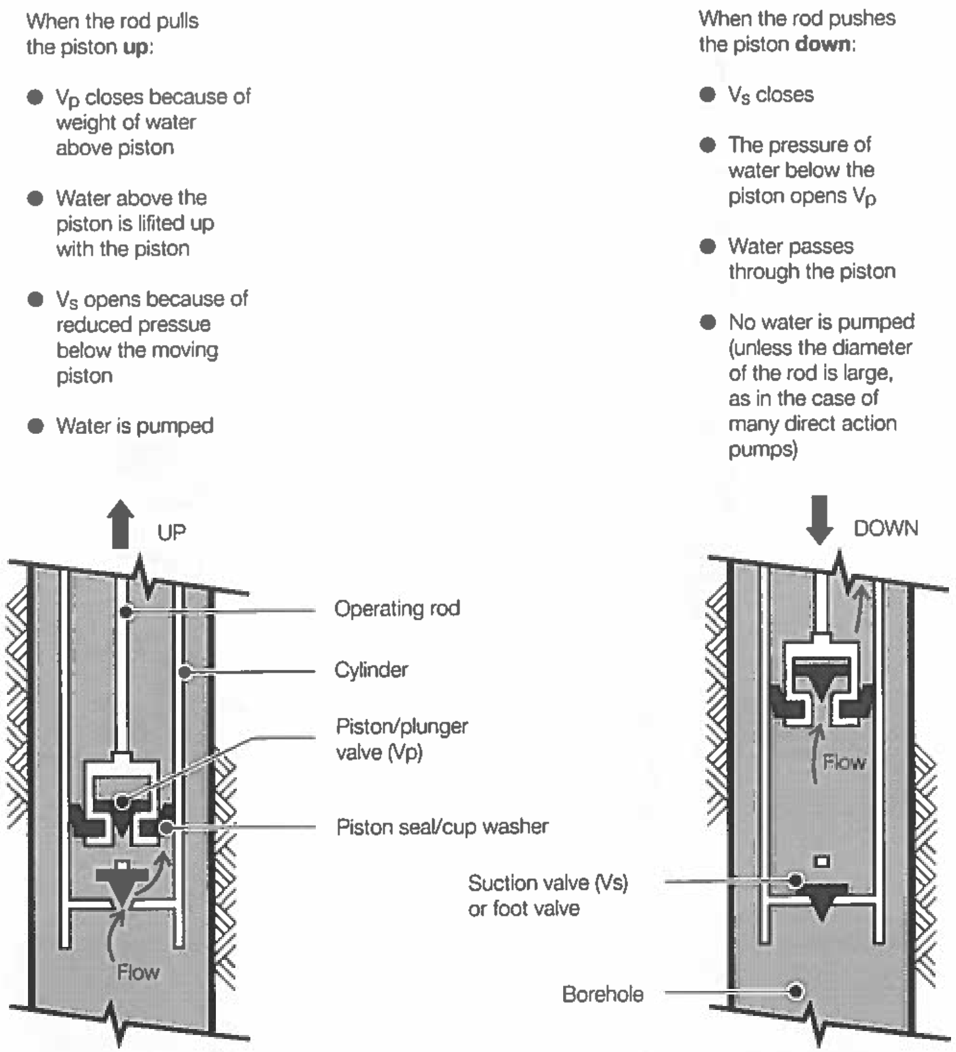
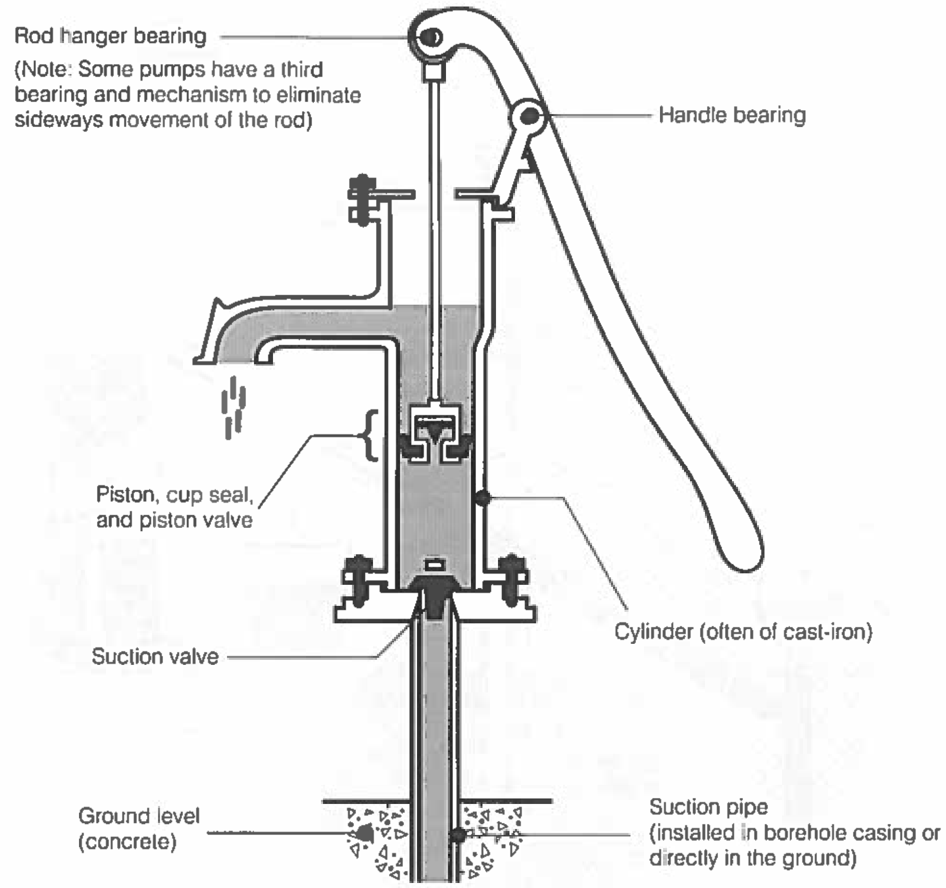


Figure 40 How most types of handpump cylinders work.
Source: Pickford (1991)

Examples of direct action pumps include the Tara, the Malda and the Nira AF85.

Deepwell pumps

Deepwell reciprocating piston pumps can be of a traditional design (Figure 44) and or the more recent open-top-cylinder design (Figure 45). If a deepwell pump is of a strong design it can lift the water from great depth as long as the operator(s) can apply sufficient force to the handle. However, very few deepwell handpumps are available to operate beyond about 45 m. An



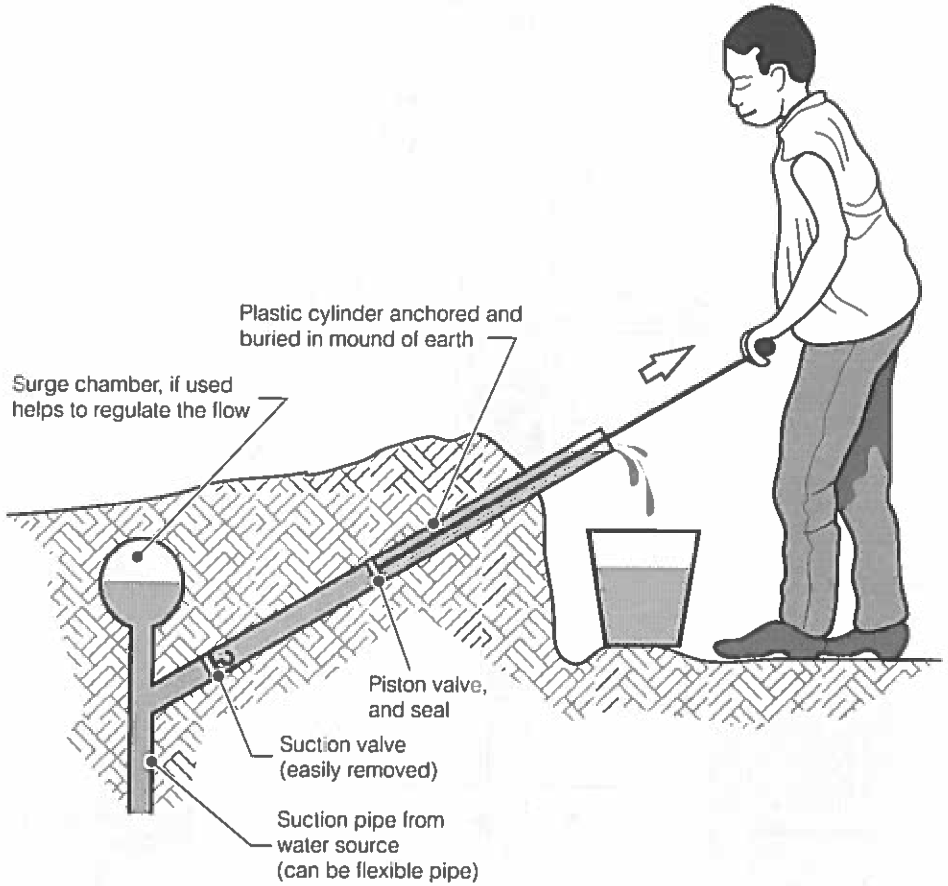
VLOM designs similar to traditional pumps are available, but often with these improvements:

- better suction valves to eliminate priming
- smoother cylinder walls to reduce wear on piston seals
- wear-resistant seal instead of leather (e.g. nitrile rubber) and
- better bearings to prevent the pivot pins wearing out the cast-iron (e.g. using hardened bushes around the pivot pins)

Figure 41 Traditional suction handpump.
Source: Pickford (1991)

open-top-cylinder design makes maintenance much easier, particularly if it is a design which allows the footvalve to also be pulled out through the rising main.

A well known example of the traditional version of a deepwell handpump is the India Mark II pump. Examples of the open-top-cylinder version are the India Mark III and the Afridev pumps.



The Rower pump has the following VLOM features.

- it allows very easy access to the piston and suction valve and footvalve
- it is relatively cheap and easy to manufacture
- on some versions the valves can be replaced using discs cut from vehicle tyre inner tubes

Figure 42 Rower suction handpump.
Source: Pickford (1991)

Force pumps

Some designs of suction and deepwell reciprocating piston pumps can be used to raise water above the level of the pumphead (e.g. to fill an elevated tank). Sometimes these are called force pumps. Normal reciprocating piston handpumps can not achieve this because water leaks out of the pumphead.

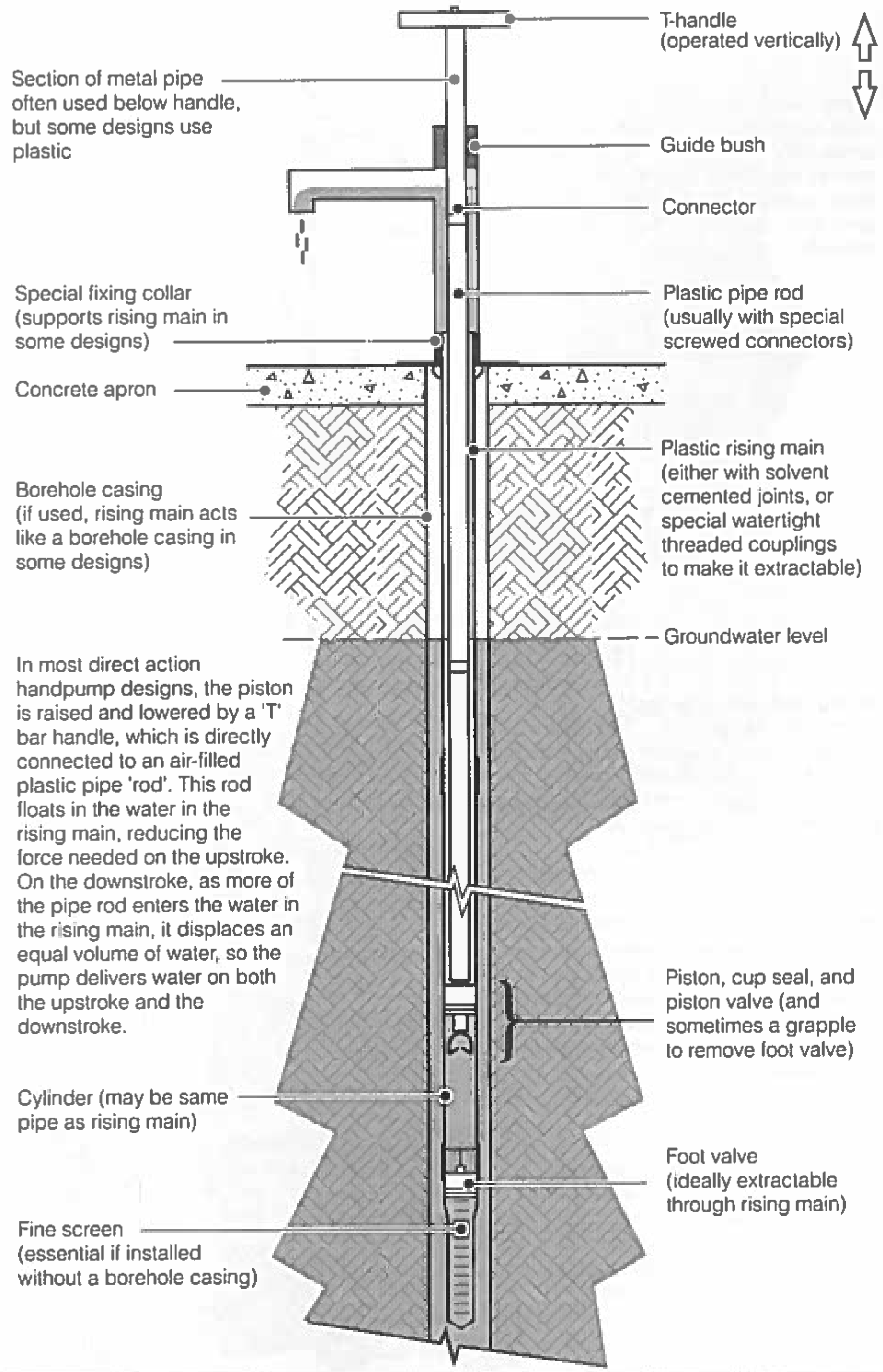


Figure 43 Direct-action handpump.
Source: Pickford (1991)

Pump-head:
Most pump-head lever handles work on a similar principle to the handle shown for the traditional suction pump (Fig 41). Some pumps use just one pivot and a chain (or belt) and quadrant system, such as in the India Mk II, shown here.

Rising main and cylinder:
Traditionally, the rising main is of galvanized steel pipes with a smaller diameter than the piston. All pipes and operating rods have to be lifted so that the rod joints (a) and pipe joints (b) can be unscrewed, section by section, to reach the cylinder (c). This operation needs strong people with appropriate lifting and clamping tools, or a mechanized lifting system. Some manufacturers therefore now supply lightweight, thin-walled stainless steel pipes joined with 'rope threads', or plastic pipes with special threaded collars to reduce the weight which needs to be lifted. Rubber 'O' rings can be used to make such joints watertight.

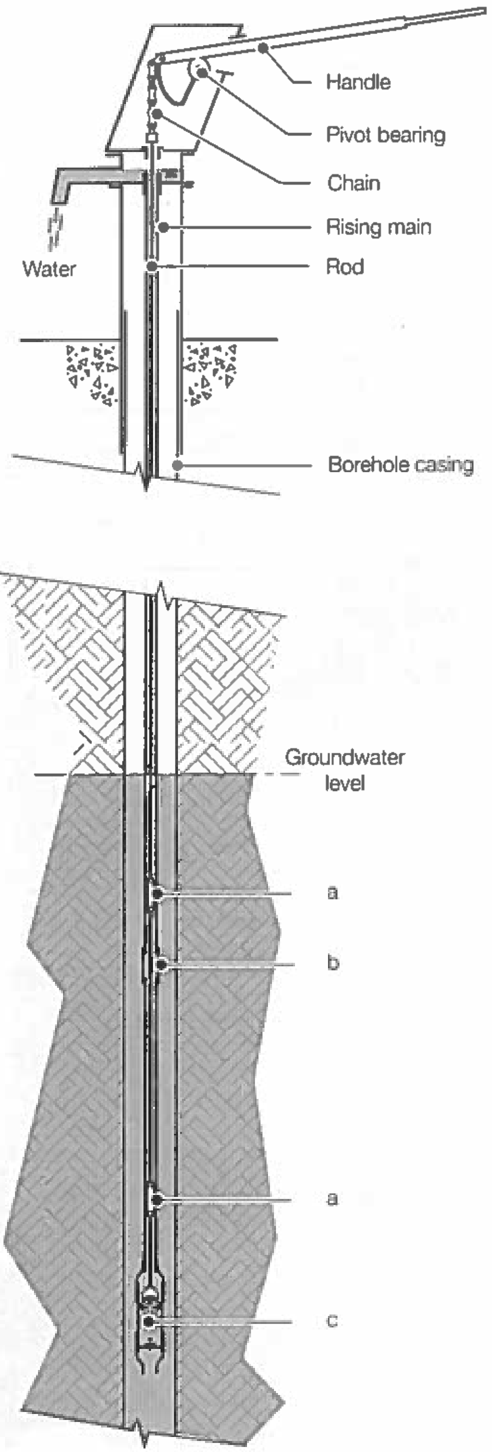


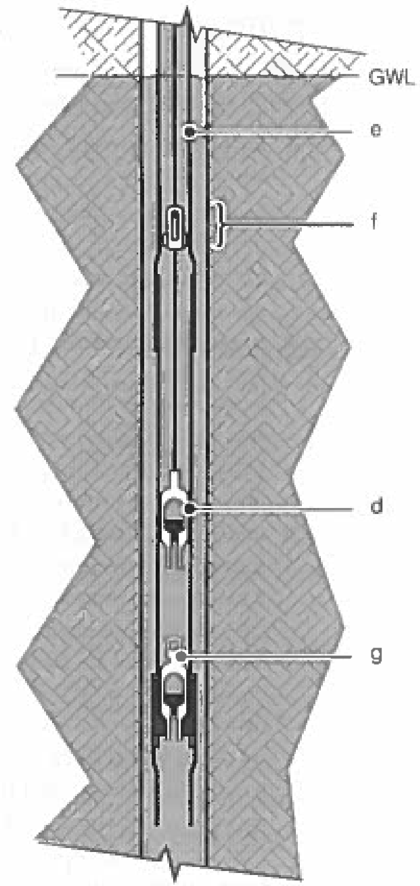
Figure 44 Deepwell handpump, traditional design.
Source: Pickford (1991)

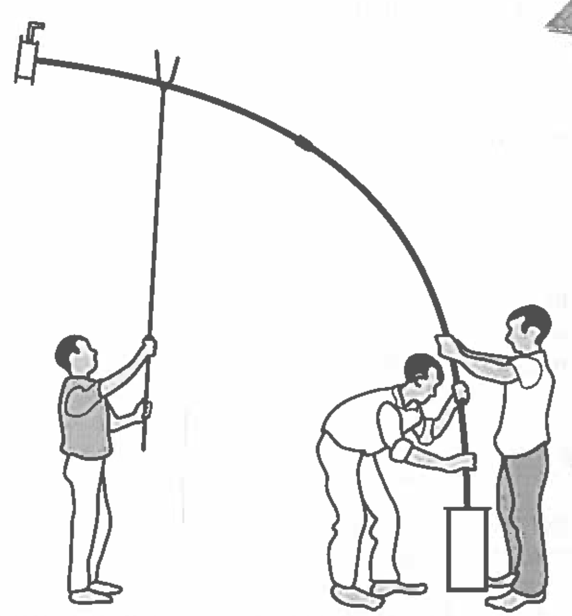
Cylinder:
Recent deepwell pump designs have 'open top cylinders' (OTC). These allow the piston (d) to be pulled up through the rising main (e) which is of the same or, preferably, a slightly larger, diameter than that of the cylinder. With these pumps, the piston can be pulled to the surface by pulling out the string of rods.

Rods:
Most rod strings are joined by threaded couplings, but some pumps use special rod joints (f) which can be easily disassembled without tools.

GWL: Groundwater level

Foot valve:
The best designs of OTC allow the foot valve (g) to be removed through the rising main, either with the piston, or by using a fishing tool which is lowered down inside the rising main on a piece of rope after the piston has been removed.





Rising main removal:
In OTC pumps with extractable foot valves, the rising main should never need removing unless the pipe or the lining to the cylinder becomes damaged. Mains with screwed couplings are easily removed.

Should the removal of a solvent-cemented plastic rising main be necessary, sometimes the whole length can be removed by supporting it with tall poles so that it can bend to a large radius curve as it leaves the borehole.

Figure 45 Deepwell handpump, open top cylinder design.
Source: Pickford (1991)

Other types of handpump and footpump

Although most handpumps are of the reciprocating piston type there are some that operate on quite different principles. These include:

- **cylindrical diaphragm pump:** a well known example of this is the Vergnet Hydropump. This is a foot-operated pump that works using hydraulic pressure to inflate a rubber hose positioned inside a cylinder (Figure 46). A hand-operated version, which looks like a direct action pump, and one that uses a converted India Mark II pumphead are now also available.
- **progressive cavity pump:** in this pump the water is lifted by a rotor driven by a rotating rod positioned in the rising main. In the cylinder at the bottom of the rising main, the helical rotor intermeshes with a specially shaped rubber stator to form pockets of water which are lifted from the bottom to the top of the stator and into the rising main. The Monolift pump is one example of this type of pump.
- **oscillating water column pump:** this is a hydraulically operated pump. One unique version, which will now be described, is called the Pulsa pump. It uses a single flexible pipe from a cylinder at the surface to another cylinder below water level. The lower cylinder, which has a valve at its base, contains rubber balls which are hydraulically compressed when the piston in the cylinder at the surface is pushed down. When the piston at the surface is then lifted, the balls expand, pushing water back up the pipe (the polyethylene pipe also contracts to add to this upward movement of water). At the top of its upstroke the piston is lifted out of the cylinder, and the inertia of the water flowing up the pipe causes some water to leave the pipe. At the same time more water is sucked into the bottom cylinder through the valve. The piston is operated by hand and foot via a special lever.
- **rope and washer pump:** in this pump a loop of rope, carrying regularly spaced washers, is continually pulled through a plastic pipe. This type of pump used to only be suitable for wide wells, but in Nicaragua a version suitable for use in boreholes (Figure 47) is now being produced. It can lift water at 8 l/min from 40 m depth. The rope and washer pump has the advantage of a simple design and fairly easy maintenance.
- **Blair bucket pump**: this has already been mentioned in Section 4.2.1.

4.3 Wind powered pumps

The advantage of wind power is that it is free. However, a windmill is required to use it, and they can be expensive. In addition there is the cost of typically about seven days of storage to cope with windless days. Home-made windmills can be made, but they are often not strong enough to last very long under village conditions.

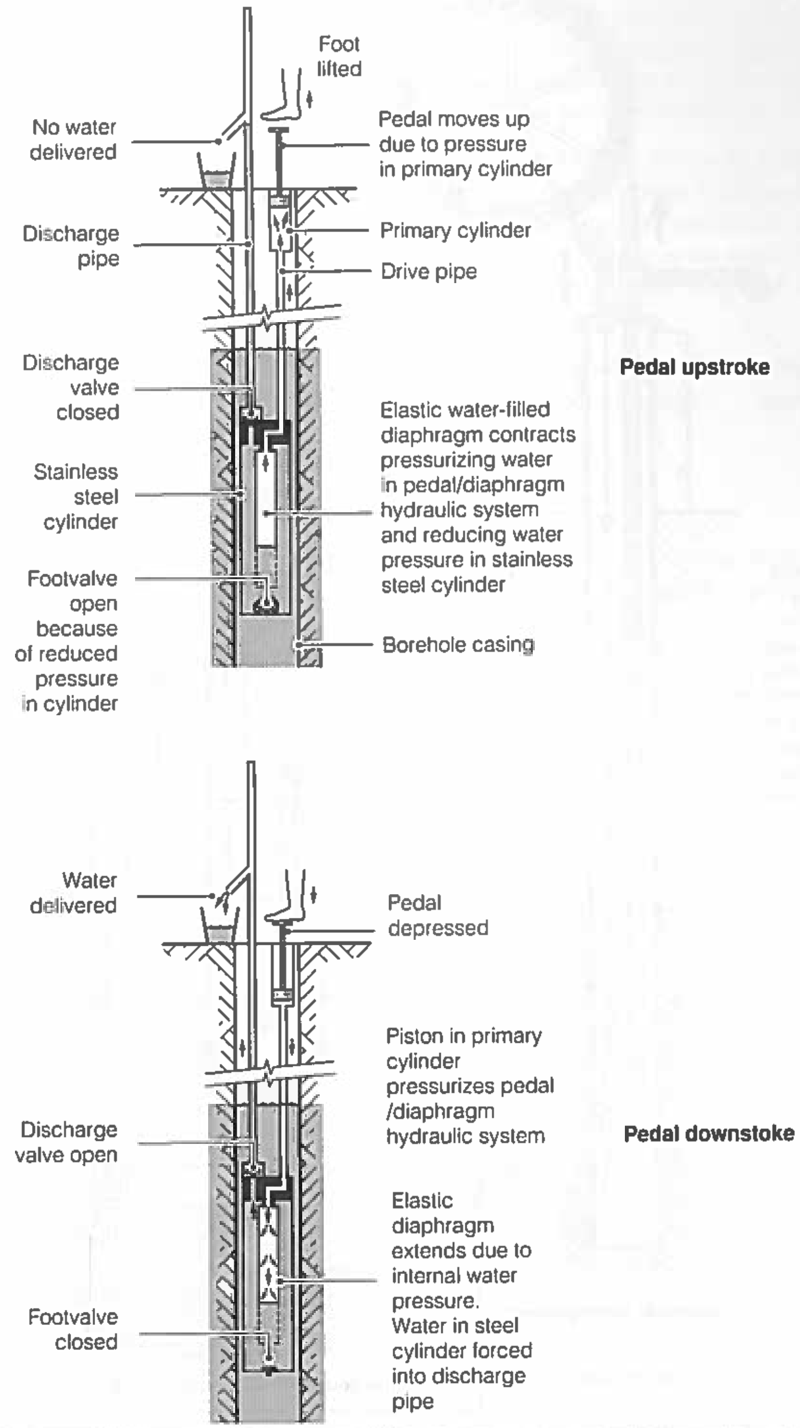


Figure 46 How the Vergnet footpump works.
Source: WEDC

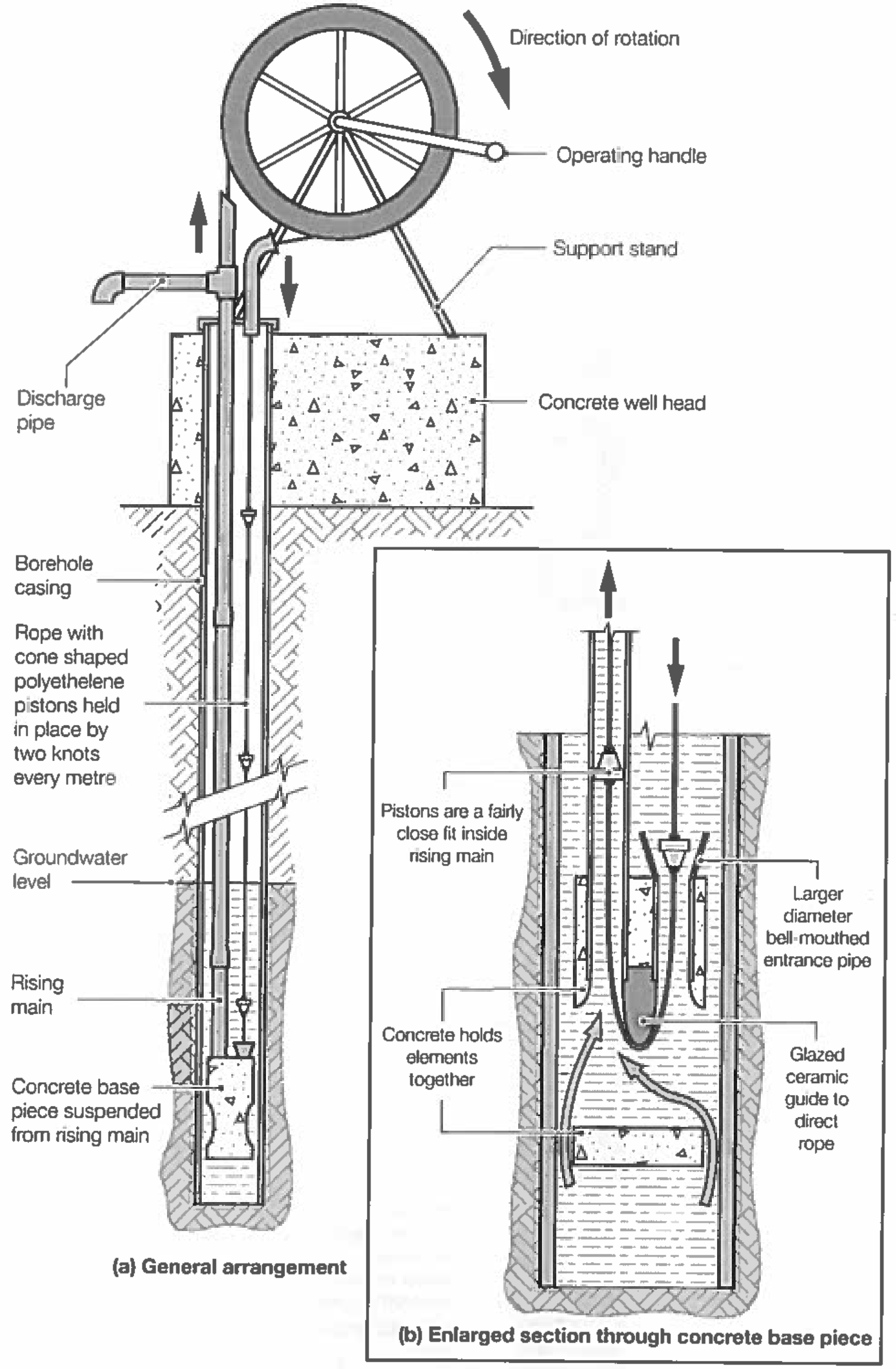


Figure 47 A rope and washer pump used in a borehole.
Source: WEDC

Before choosing a wind powered pump it is necessary to check whether the wind blows regularly enough and at sufficient velocity to give a reliable supply of pumped water. The average wind speed needs to be at least 2.5 m/s at the level of the rotor. It is important therefore to get expert advice.

Most windmills use a camshaft connected to a rod which drives a piston in a cylinder. This piston acts in an identical way to the piston in a reciprocating piston handpump (Figure 40). In fact a windmill may be combined with a handpump so that water can be pumped by hand if there is no wind. Alternatively, a diesel engine could be provided for when the windmill is not pumping, but this will make the scheme even more costly.

A wind powered pump will only be sustainable if skilled people are available to repair it, and the spares are readily available and affordable.

4.4 Water powered pumps

A hydraulic ram pump (Figure 48) uses the energy of a large volume of water falling a short distance to pump 1–10% of it to a much higher level. Water flows from the source to the pump in a large diameter drive pipe. The pumped water leaves it in a smaller diameter delivery pipe. Both pipes need to be able to cope with high pressure and are usually made of steel.

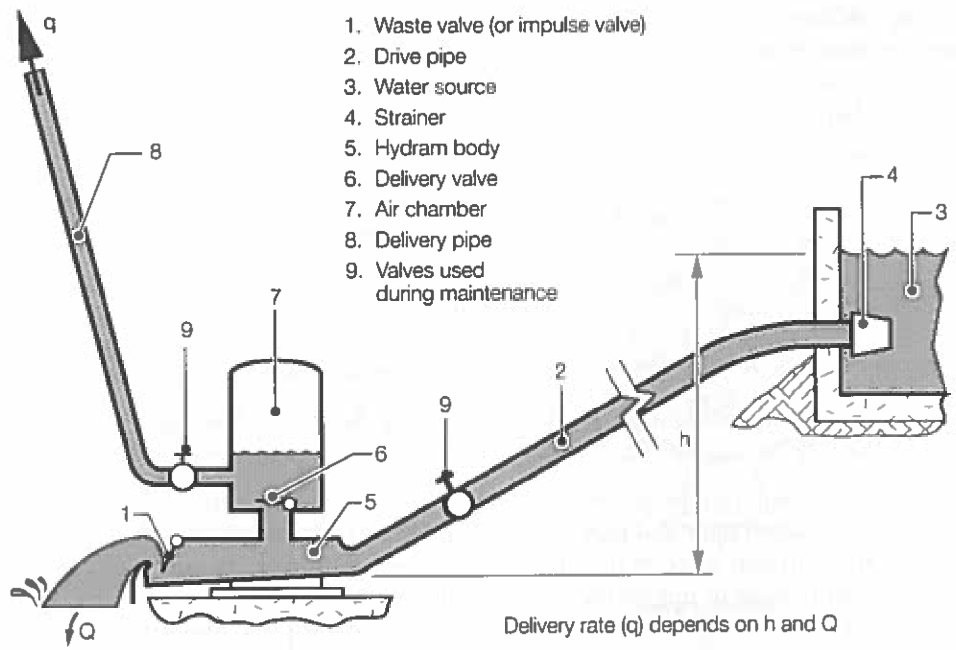


Figure 48 A hydraulic ram pump.
Source: Fraenkel (1997)

A waste valve at the pump allows much of the water from the drive pipe to flow to waste. A hydraulic ram pumps water by utilizing the pressure waves caused by the sudden opening and closing of this valve. The closure of the waste valve stops the flow of water down the drive pipe, creating a sudden increase in pressure which is used to push water through the delivery valve and into the delivery pipe. An air chamber attached to the pump acts as a shock absorber and is an important feature of this pump.

The water which is not pumped but which passes through the waste valve is usually returned to the original stream at a convenient point below the pump. Alternatively it can be collected to power another ram pump at a lower elevation. Although ram pumps can be home-made, these are usually not very durable. In a mountainous area a ram pump is useful for lifting water from a fast flowing spring to a community living at a higher level.

Water current pumps use the movement of flowing water to power a turbine. This is connected to a mechanism that drives a reciprocating piston pump or a rotodynamic pump (see below), either directly or via a gear or pulley system. Such pumps are rare.

4.5 Engine and motor powered pumps

4.5.1 Types of motorized pumps

Where a lot of water needs to be pumped a mechanically powered pump is usually used. Most of these pumps are rotodynamic pumps although other types include reciprocating piston pumps, progressive cavity pumps and diaphragm pumps.

If it is to work efficiently the pump chosen needs to:

- match the desired delivery rate
- lift the water through the required difference in level
- overcome the pumping resistance from the system of pipes it has to pump the water through which will vary with the pumping rate (see Section 7.4.2)
- suit the amount and type of suspended solids present in the water.

Choosing the right pump therefore is a skilled job for which expert advice should be sought.

Some handpumps, particularly those which include rotating elements, such as flywheel operated pumps, or the progressive cavity pump, can be adapted to be driven directly by a belt drive from a motor or engine. This can be a useful stage in upgrading a handpump equipped water supply as the population increases or as it become more able to support motorized systems. However the borehole must be able to yield sufficient water to suit the increased rate of pumping.

Rotodynamic pumps propel water using a spinning impeller or rotor. Centrifugal pumps (Figure 49) are the commonest type, but there are also mixed-flow and axial flow pumps.

Reciprocating piston pumps have cylinders that work in exactly the same way described for the handpumps in Figure 40. The rotary motion of the engine or motor is converted to reciprocating motion using various mechanical devices. They are rarely used for rural water supply.

Progressive cavity pumps have pumping elements that work in the same way as the handpump described on page 84. The pumping element can be mounted vertically or horizontally.

Diaphragm pumps work by using a flexible rubber diaphragm as one wall of a pumping cylinder, which also has an inlet and an outlet valve. A motorized attachment, connected to the diaphragm, moves it in and out to pump the water. Diaphragm pumps are rarely used for water supply. However, they are particularly suitable for dewatering shallow wells or excavations that are less than 7 m deep. Note this type of diaphragm pump uses a completely different operating system to the hydraulically operated system for the Vergnet diaphragm pump mentioned on pages 84–85.

4.5.2 Suction limit and priming

A pump positioned above a water source cannot draw water from more than about 7 m below it, and possibly only from 3–4 m for a centrifugal pump. The actual 'suction limit', as it is called, is very dependent on the atmospheric

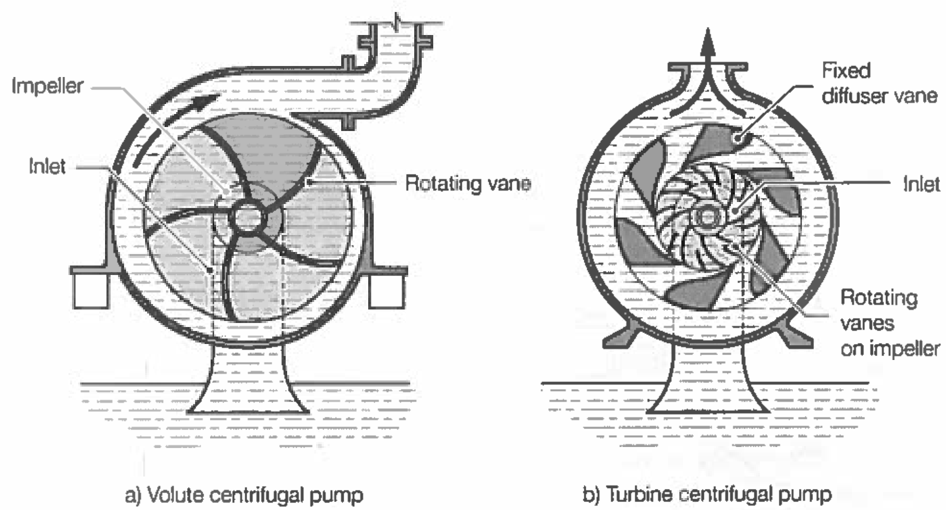


Figure 49 Two types of centrifugal pump.
Source: Fraenkel (1997)

pressure, reducing with increase in altitude (see comments under suction pumps on pages 75–76).

To start a pump that is positioned above the water level it is necessary to first evacuate the air from it. To achieve this, water is usually added to the pumping element, so that while the pump is moving, air and water are expelled from the pump and the suction pipe until they are both full of water when delivery starts. This process is known as priming. Sufficient water needs to be available to allow evacuation of all of the air in the pipe so it may be necessary to store water for this purpose in a tank which is connected by a branch pipe to the inlet of the pump. A footvalve (non-return valve) on or near the bottom end of the suction pipe (Figure 50) can make priming easier but at this position it can be difficult to access it for repairs. It should be of sufficient size to ensure that flow into the pipe is not appreciably restricted. If the valve is particularly good it should hold water in the pump for some time after it stops, so that re-priming is not necessary. The suction pipe should be airtight or the pump may never start, or will operate very inefficiently.

If the water level will be beyond the suction limit of a surface-mounted pump it may instead be placed below the water level, although the motor may still be at the surface as shown in Figure 51. Provided the pump and its motor are sufficiently powerful, and the delivery pipes are strong enough, then any water that enters the pump can be lifted to almost any height.

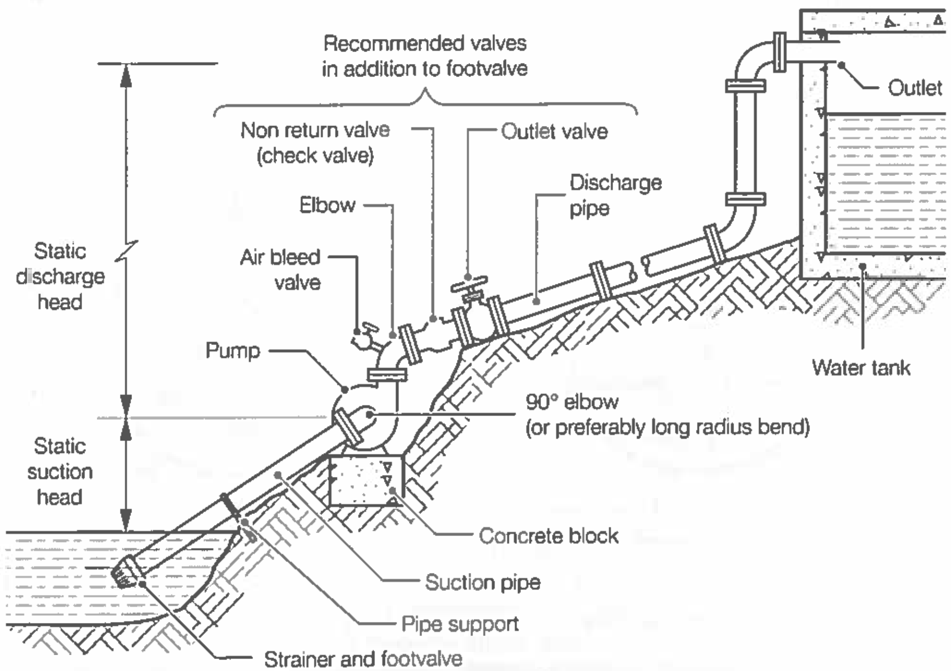


Figure 50 Surface mounted centrifugal pump installation.
Source: WEDC

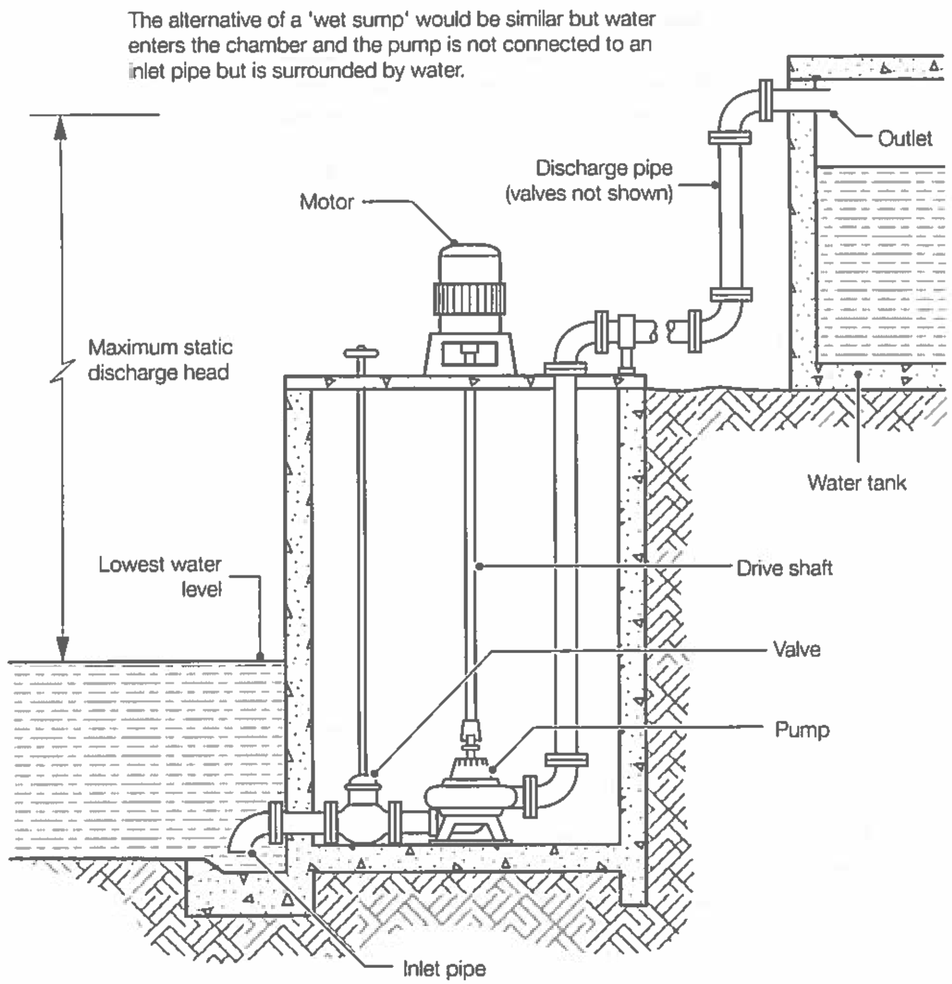


Figure 51 Below surface centrifugal pump installation in a 'dry well'.
Source: WEDC

4.5.3 Power sources for motorized pumps

Pumps can be driven either by internal combustion engines or by electric motors. The internal combustion engines are usually diesel powered although occasionally petrol engines are used. The performance of internal combustion engines is affected by air temperature and altitude. Electric motors can be powered by electricity from the mains supply, from a generator, or from solar energy converted to electricity by photovoltaic panels. Electric motors need less maintenance, are more efficient and are usually more reliable than diesel engines, so they are preferable where a reliable supply of electricity with a stable voltage is available. Generator powered submersible electric pumps capable of handling a high concentration of solids are sometimes used during construction of hand-dug wells that are deeper than the suction limit of surface mounted pumps. For safety reasons these submersible pumps should operate at low voltage (e.g. 50 V).

Matching engines or motors to pumps and arranging efficient ways of transferring power between them is a job best left to an expert. It is therefore best if the engine/motor and pump are supplied together already mounted on a baseplate by the manufacturer.

Recent developments in photovoltaic panels and solar powered pumps mean that this method of pumping water is becoming less expensive, more reliable and more popular, although it is still rarely used. Commonly the panels power submersible centrifugal pumps. These systems have low running costs but maintenance of the electrical components is a highly specialized task.

4.5.4 Sustainability of motorized systems

It is likely to be much more difficult and more expensive to maintain a motorized pump than it is to maintain a handpump so such a system should only be chosen where it can be sustained. In some areas the poor supply of fuel (especially in the rainy season), the poor reliability of electricity (e.g. variable voltage and regular power cuts), or the low level of skills for maintenance and repair will mean that such systems are most unlikely to be appropriate. The water source must also be able to provide the required yield throughout the design life of the system.

In choosing a pump, it is important to select one that a local mechanic employed by the community will understand and for which he will be able to buy spare parts. If there are already some reliable pumps in the area, it is probably best to buy similar ones, made by the same manufacturer. This also applies to the motor or engine that drives the pump.

Internal combustion engines need plenty of maintenance, and can be very expensive for a rural community to run. It is particularly important, therefore, that the community has agreed how money will be raised for operation and maintenance, which includes replacement of air filters, oil filters and fast-wearing parts, regular servicing and repairs. It is also important to decide beforehand exactly who will operate the pump, who will be responsible for repairing it if it breaks down, and from where the fuel or reliable electrical power can be obtained.

These points may appear obvious, but they are all regularly forgotten and explain many of the failures in water supplies throughout the world.