

Pump selection

IN THIS CHAPTER:

- Pumps suitable for sand-abstraction
- Operation and maintenance – principles, service and repair
- Sources of operating power

Small-scale community-based systems

Rower pump

The Rower pump is a simple handpump with applications not only suited to drawing water from most small-scale sand-abstraction well systems, but also directly from well-point systems. The pump comprises little more than a tee-bar handle with a short rod and piston and a non-return valve which all fit at the end of a delivery pipe. The pump is inclined at a 30° angle from the horizontal and as implied its name is derived from the ‘rowing’ action that is required to operate it.

In its basic form as a direct-lift bucket pump, water is discharged on the pull, or ‘up’ stroke as it flows from the open end of the pump cylinder. A Rower pump is thus unable to raise water beyond the height at which it is operated. However such a basic system does allow for quick and easy access to all wearing parts. In a less basic application the Rower pump can be converted in effect to a force pump that will deliver water to a head on the push or ‘down’ stroke.

The basic pump was developed by a member of the Mennonite community to draw water for small-scale irrigation project use in Bangladesh. In order that the pump might be tested and modified as necessary for possible use in other parts of the world the Mennonite Central Committee has not pursued a patenting right to the pump. However in spite of its extremely simplistic design and advantages such as ease of operation and straightforward

fabrication, the pump has not been adopted extensively and has not passed into the domain of the informal entrepreneur.

The pump is nevertheless well known and is still widely used on tube-wells in Bangladesh where it is manufactured and sold locally by various producers and vendors. The original design has also been refined by Richard Cansdale of SWS Filtration who manufactures the pump and sells entire pumps or pump components that can be fitted into appropriate uPVC or ABS piping. The pump does have a number of advantages for the small-scale manufacturer as each pump has only a small number of components and no welding or complex fabrication equipment is required in the assembly.

Figure 7.1 shows the simplicity of a basic Rower pump.

Joma pump

Simple components such as those used in the Rower pump may provide benefits for use in other applications. The Joma pump as shown in

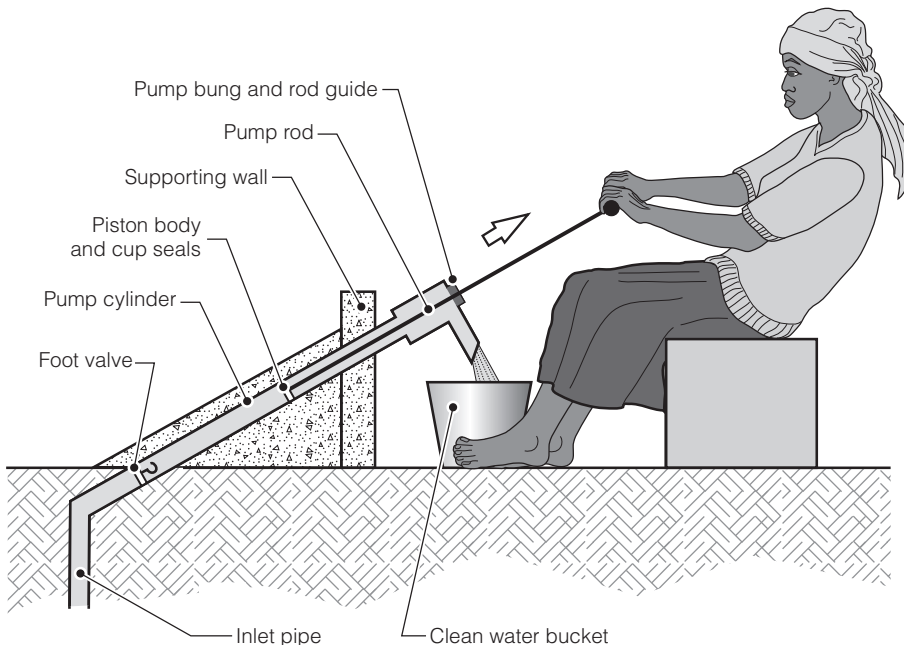


Figure 7.1. Rower pump

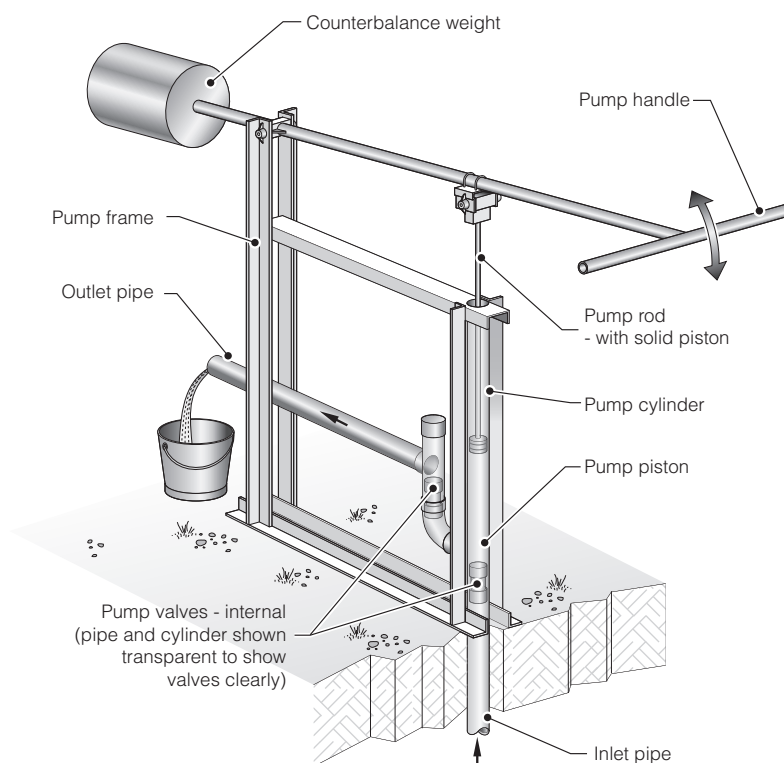


Figure 7.2. Joma pump

Figure 7.2 is a counterbalanced force type suction pump developed by Dabane Trust for use in conjunction with sand-abstraction systems. It is capable of drawing water from depths of 4 or 5 metres using atmospheric pressure and delivering water to a height of 6 to 8 metres. It has the advantage of being operated by two people simultaneously and uses simple Rower pump type valves and piston bodies. Sustained operating speeds of 30 strokes per minute have been measured and yields of 2.5 to 3.0m³ are regularly achieved. Figure 7.3 shows a simplistic representation of four handpumps that are suitable for sand-abstraction use, depending on the abstraction system to be used.

Treadle pump

The Treadle pump also known as the Tapak pump was also designed for use in shallow groundwater applications in Bangladesh and can be used in similar situations to the Rower pump. However, whereas the Rower pump is a hand operated pump the treadle pump is leg operated and consequently as leg muscles are stronger than arm muscles, this design is less tiring to use and also has a higher potential output.

The pump has two cylinders and pistons that are joined into a single suction pipe. Above each cylinder is a beam that is hinged at one end and at the other connects to a piston. The beams have a cable which connects them and passes over a pulley. The operator stands with one foot on each beam and transfers weight first to one then to the other, thus as one piston goes down so the other comes up. The result is a very simple and very effective water pump.

There are two systems of pump available. One is a basic pump that can draw water from a depth and discharge it straight from the open top of the cylinders to flow by gravity directly into a low tank or open canal. The other is an enclosed cylinder system that can raise water to a height of up to 12 metres above the operating level.

Although the construction process of both Treadle pumps is more complex than the Rower pump, manufacture has been taken up by a number of small-scale industrial companies and many entrepreneurs in a number of countries produce the treadle pump for sale. Information on the principles of the pump and its construction can be gathered from books such as *How to Make and Use the Treadle Pump* which is available from Practical Action Publishing.

Rope and washer pump

The Rope-and-washer pump is only suitable for installation on offset sand wells and collector wells that are fed by infiltration-galleries. Due to its particularly simple design and construction it is a handpump that can be produced relatively easily with no intricate equipment and only basic hand tools. There is a significant amount of experience in the use and reliability of this pump as a number of communities and service organizations use pumps that utilize this principle on shallow dug-wells.

Information is widely available on details of the pump and its construction from books and videos such as *How to Make a Rope Washer Pump* which are available from book vendors such as Practical Action Publishing.

Direct action

Handpumps such as the commercially available Canzee and Tara pumps are suitable for use on offset sand wells and infiltration gallery collector wells due to their efficiency and general reliability. Because of their narrow-bore specifications they are particularly suitable for installation on tube-wells that draw water from shallow alluvial aquifers where the required lift is 6 to 15 metres.

Direct lift borehole pumps

Such as those in the India and Afridev ranges are best used in applications where there is a need to raise water from 20 to 100 metres rather than from the shallow lifts associated with sand-abstraction wells for which they are over-designed. However because of their widespread use and the general availability of spares such pumps might be considered for use on offset sand wells and infiltration gallery collector wells. These pumps can generally be purchased commercially but the design of pumps such as the India, the Afridev and the Bushpump, the Zimbabwean designed hand operated borehole pump, are each in the public domain.

Diaphragm pumps

Are akin to both the Rower and the Treadle pump in terms of installation, use and application. There are a number of designs of diaphragm pump and a variety of models, with manufacture occurring in several countries. Commercial models generally comprise a casting, to which a diaphragm, an inlet and an outlet valve are attached.

Unlike the Treadle and even the Rower pump, manufacture of the pump is not conducive to small-scale manufacture. The relatively large surface area and the distance through which a diaphragm is expected to flex makes for a point of weakness, particularly where a diaphragm is subjected to the additional pressure of raising water to a delivery head and may lead to rupture. Simplified designs of diaphragm pumps that use materials such as old car tyres tend to be as defective as they are effective.

Progressive cavity pumps

In handpump form are suitable for use on wells and tube-wells where the helical pump unit can be installed directly in water. They are particularly useful in high lift applications where water needs to be pumped to heights of above 10 metres.

Large-scale commercial systems

Progressive cavity

Larger mechanically-powered pumps are also very suitable for sand-abstraction applications, particularly on multiple well-point and manifold systems. Surface operating progressive cavity pumps designed for horizontal use require a priming tank on the suction side of the pump with an approximate capacity $2\frac{1}{2}$ times the combined volume of the manifold, connecting pipe and well-points. The top of the priming tank must be above

the top of the pump intake so that when full the pump will also contain water. The pump will draw water from the priming tank and in so doing reduce the air pressure in the tank to the extent that atmospheric pressure will, within the limits of pump efficiency and altitude, force water through the system. Water will then be conveyed from the well-points and manifold into the priming tank and pump from where it can be pumped away.

Although helical rotor and stator pumps have the ability to pump air it is imperative that both components remain lubricated with water at all times to prevent overheating to the detriment of the pump. The volume of the priming tank must be greater than that of the sealed system to ensure that there is sufficient water for the pump not to run dry before water is moving through all the pipework. On shut down the priming tank will require re-priming before the system can be used again.

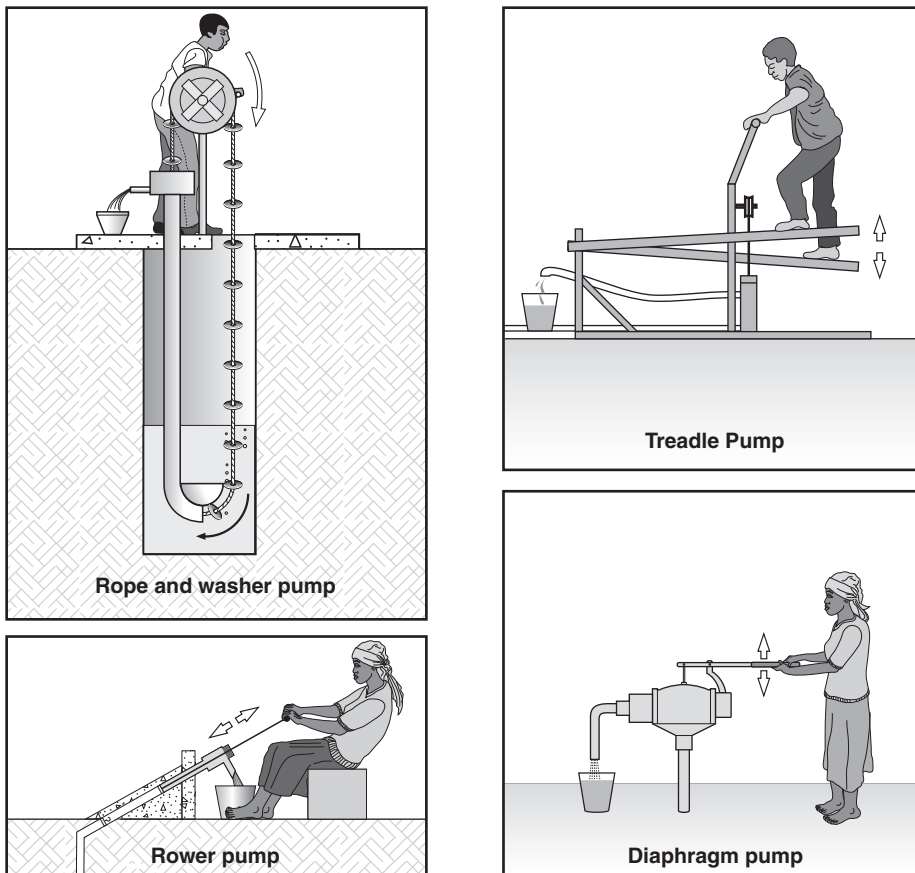


Figure 7.3. Handpumps suitable for sand-abstraction use

A progressive cavity borehole pump can be installed into a priming tank in much the same manner. A borehole pump requires installation in a sealed system that combines a pump casing/priming tank unit, a manifold and well-points. The priming tank is installed below the level of the manifold and also requires a capacity $2\frac{1}{2}$ times the combined volume of the well-points, manifold and any connecting pipes. The borehole pump draws water from the priming tank which similarly reduces the air pressure in the tank so that atmospheric pressure will force water through the well-points and manifold into the priming tank from where it is pumped to the surface. Both Mono pump/Dresser and Orbit manufacture progressive cavity handpumps, deep well borehole pumps and horizontal water and sludge pumps.

Centrifugal

High-speed mechanical pumps can be equipped for surface installation in the same situations that progressive cavity surface pumps can be installed. Centrifugal pumps do not have the same positive displacement attributes as progressive cavity pumps and are thus more efficient in installations that maintain as direct a connection as possible between the well-points and manifold and the priming tank.

Multi-stage submersible

Electrically powered pumps are typically high yielding borehole pumps and are thus primarily suited for use on large-scale schemes. Submersible pumps are best installed either on collector wells that are charged by infiltration-galleries as in Ranney well systems or installed direct into large diameter well-screens where the rate of abstraction is lower than the rate of recharge and drawdown and where it can be assured that the system will not be damaged during river flow.

Photograph 7.1 shows the above ground level set up of three submersible borehole pumps that are installed in steel borehole casing that connect to manifolds and a matrix of well-points in a commercial scheme installed in the Limpopo River, Nottingham Estate, Beit Bridge, Zimbabwe.

A limited list of manufacturers of pumps suitable for sand-abstraction use is included in Appendix 2.

Table 7.1 provides an assessment of a typical range of static head, output, power requirement and efficiency of pumps that can be used to draw water from sand-abstraction systems. It can also be used in conjunction with Table 6.1 to help select the type of pump best suited to a specific abstraction system.

Photograph 7.1. Commercial tube-well and infiltration scheme using submersible pumps.



Table 7.2 provides a comparison of handpumps that are suitable for sand-abstraction use.

Pump operation and maintenance

Valves

A system is required that will keep water moving forward through a pump. A valve is a pump component that opens as water flows through in one direction but closes as the flow of water ceases. This allows water to move forward and not to move back in a pump. Valves may be opened and closed by the flow of water or by springs. The flaps that close the pipe may be made of flat brass or metal sheet, balls or hemi-spheres or rubber sheet.

Simple self-closing valves can be made from rubber sheet such as that used in vehicle inner tubes. Such material is easily obtained, is effective in low technology applications and is simple to fabricate for easy maintenance or repair.

Table 7.1. A typical range of static head, output, power requirement and efficiency of pumps					
Operating system		Head range (m)	Flow range (m³/hr)	Input power (kW)	Efficiency (%)
Syphons		1 - 6			
Direct lift Pumps – Shallow well pumps	Bucket and Windlass	5 - 50	1	0.04 - 0.08	10 - 40
	Rope and washer	5 - 20	5 - 30	0.02 - 1	50 - 80
Displacement Pumps – Well and borehole pumps	Piston pumps	3 - 200+	1 - 100+	0.03 - 50+	40 - 85
	Diaphragm pump	1 - 2	2 - 20	0.03 - 5	20- 30
	Progressive cavity	10 - 100	2 - 100+	0.5 - 10	30 - 70
Velocity Pumps	Centrifugal	4 - 60	1 - 500+	0.1 - 500+	30 - 80
	Submersible	10 - 300	1 - 100	5 - 500+	30 - 80
	Jet pump	10 - 30	50 - 500	5 - 500+	20 - 60

Priming

Suction pumps work by removing air to create a vacuum so that atmospheric pressure can fill the subsequent void with water. As water is moved through the pump and piping so more water is drawn into and through the pump. However, a suction pump can only pump water and will not work when there is any air in the system. Even a small ‘bubble’ of air will mean that the pump is unable to move any water at all. As air can be compressed, so it can also expand, thus air in the system will inevitable mean that a suction pump will be unable to draw water through the pipes to be replaced by more water.

It is thus important to remove all air from a suction pump and replace it with water before pumping starts. It is also important to prevent any leaks that will allow air to be drawn into the pump and cause the flow of water to stop.

Table 7.2. Handpump suitability				
Type or trade name	Point of manufacture /repair	Operation	Appropriate use	Suitability
Rower	Village level assembly and repair	Rowing action	Well-points Collector well Offset sand well	Good
Treadle	Artisan workshop	Leg operated beams	Well-points Collector well Offset sand well	Good
Rope and Washer	Village level construction	Rotary	Collector well Offset sand well	Good
Canzee / Tara	Commercial	Direct action	Collector well Offset sand well	Good
Bucket	Artisan workshop	Windlass	Collector well Sand wells	Low yield
Blair bucket	Artisan workshop	Direct action	Collector well Sand wells	Low yield
Bush Pump	Commercial	Reciprocating piston	Collector well Offset sand well	Over designed Limited use
Afridev	Commercial	Reciprocating piston	Collector well Offset sand well	Over designed Limited use
Mono	Commercial	Hand operated rotary	Well-points Collector well Offset sand well	Good

In order to optimize any power system, pump efficiency must be high. Any loss of water from the pump reduces the overall output or requires the power source to operate for longer periods or to pump more water in a given time. Ineffective or inefficient systems are wasteful of both the water resource and the operating system. To ensure efficiency it is imperative that the maximum volume of water is delivered in the shortest possible time allowed by the pump and power source.

Service and repair

Satisfactory operation and maintenance will also determine pump efficiency and an optimum supply of water. In order to ensure satisfactory performance a pump is required that is easy to operate, has few components and is simple and straightforward for end-users.

Although many pumps and maintenance systems are referred to as ‘Village Level Operation and Maintenance’ (VLOM), for such a system to be effective it is imperative that the following points are agreed on:

- Suitable rules and regulations for effective management and user responsibilities. Agreements should cover; quantities of water that can be drawn at any one time, when water can be drawn, the use to which water can be put and who can draw water.
- Suitable people will need to be identified and trained in pump operation and maintenance. Training appropriate to the water supply and the abstraction and pump technology must be provided.
- Agreements will be required as to who will pay for maintenance and/or repair materials and who will undertake the work. If pump users are not prepared to contribute in cash or kind to maintenance/repair work even the most reliable water supply facility will ultimately become a failure.
- A comprehensive supply of ‘fast-moving’ spares will need to be assembled and stored or a reliable supplier or manufacturer of spares identified

Power options

Pumps require power and as with the pumps themselves, there are a number of systems that can be applied:

- Human energy – usually referred to as hand-pumps
 - Activated by hand and body
 - Activated by leg
 - Direct, walking action*
 - Cycling, chain or gears*
- Animal-powered engines
- Fuel powered engines
- Electric motors
 - Mains electricity
 - Solar energy

Human power

The most basic method of operating a pump is by ‘hand’, effecting movement on a pump piston by way of a rod and handle. This can be

either direct (direct lift) for low lift/low volume pumps or with a mechanical advantage through a fulcrum and pivot or a rotating wheel (direct action). Each system uses the relatively small muscles of the arms and back and can be very tiring.

A more efficient method is to use the larger leg muscles of the human body. A reciprocating action can be achieved through a walking motion, as in the treadle pump and rotary motion through the use of a crank and pedals with a chain wheel and gears. A useful mechanical advantage is achieved through pedal power and is used to drive appliances such as small grain grinding or plate mills. Although not commonly used to power pumps the system could be used in rotary applications such as progressive cavity pumps.

Hand power is a simple and straightforward pumping procedure. Little or no training or skill is required to operate a handpump system and there is little financial cost. There are no equipment purchase and installation costs and no apparent fuel, service/maintenance costs. With no obvious technical constraints and low financial operating costs, sustainability is generally high.

The disadvantages of handpump systems are a low output of water, the comparatively hard work required to maintain continuous pumping and the long periods of time needed for pumping which reduces the time available for other ventures and responsibilities. To compound this, human muscle power is inefficient in the conversion of the calories obtained in food into kW's of energy produced.

Although during short, strenuous periods muscle efficiency may be as high as 20-30% which compares favourably with an internal combustion engine, the continuous daily muscular work capability of a person is approximately 0.2 to 0.3kWhr/day, which is a low 7-11% efficiency of food energy conversion to mechanical energy. Thus although commonly used, human muscular energy is not cheap. People with a low income are forced to use human power as the actual cash investment is low and many are unable to afford anything else, however almost any other source of power will, volume for time, pump water more cheaply. As human work output is only some 0.25kW/day it will require four days work by one person to produce 1kW, which equates to the output of a small engine in an hour. Only when factoring in other costs and considerations such as procurement and the availability of fuel and spares and the power requirement for the generally low yields of water that are required does

human power become acceptable at a community water supply level. At a higher output commercial farming level human-powered pumps are not viable.

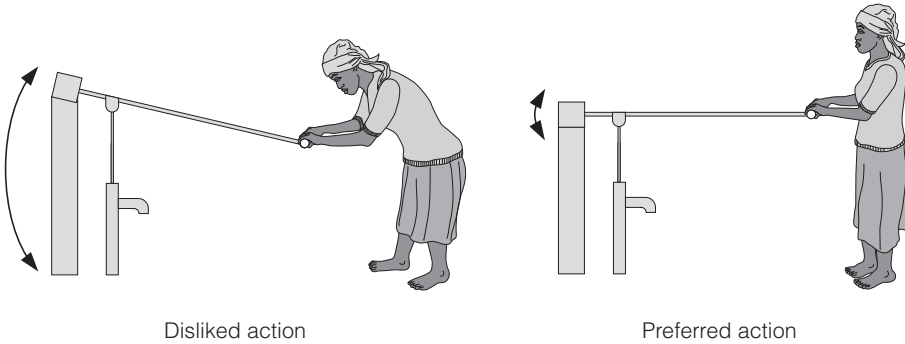
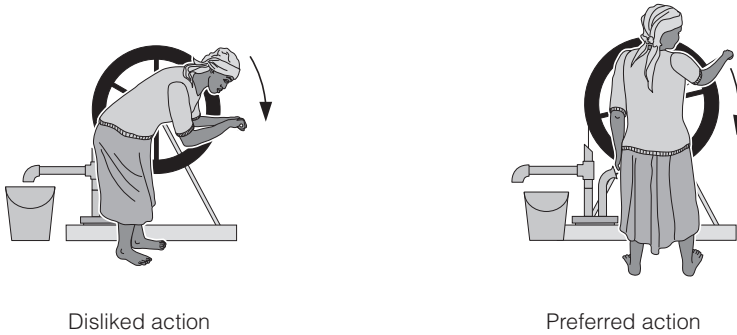
Improvements to the efficiency of human power can be made through ergonomics and the use of selected muscles in a suitable action at a correct speed through a light but strong mechanism. The human body exerts 50% more power by pedalling, utilising the legs than by pushing a handle up and down with the arms. Dynamometer tests indicate that the average cyclist works at 0.75kW when cycling at 18km/hr, if this output is fully utilized in pumping, the flow rates in Table 7.3 could be achieved.

As they are powered by larger leg muscles, foot or leg operated pumps are considered more effective for irrigation than hand or arm operated pumps and as irrigation pumps require operation for several hours a day such efficiency is crucial. However, acceptability and operator's personal preferences for pump action must also be considered, as well as the pump application. Hand operated devices may be more convenient to use than leg operated pumps thus it may be more appropriate to use smaller pumps with a lighter action to pump smaller quantities of water over a longer period of time.

The criteria for defining a good human-powered irrigation pump to pump a relatively large volume of water are likely to be significantly different from those for a suitable low volume domestic water supply pump. Thus consideration of the pump requirement, as well as the pumping method is important in the selection of a suitable manually operated pump. The efficiency of hand pumping may be improved through the use of counterbalance weights, such as shown in Figure 7.2, which are able to adjust a pump to the proportion of energy required between drawing water into the pump, and discharging it.

Figure 7.4 indicates the basic handpump actions and typical pumping preferences.

Table 7.3. Pumping rates that can be theoretically achieved by pedal power					
Pumping head (m)	0.5	1.0	2.5	5.0	10.0
Delivery (m ³ /hr)	27.5	13.8	5.5	2.2	1.1
World Water magazine					

Reciprocating handpump actions**Rotary handpump actions****Figure 7.4.** Handpump actions and pumping preferences**Animal power**

The use of animal-powered 'engines' declined with the advent of the steam engine and the internal combustion engine. Because there was limited demand for large quantities of water when animal-powered engines were in widespread use there was little application made of them for driving displacement type water pumps. However pumps such as the continuous rope and washer, the Persian wheel and water scoop wheels have long been animal-powered.

The use of animals to pump water is appropriate in remote dryland areas where engines and fuel are both expensive and difficult to obtain. However, in order to optimize the efficiency of draught animals, additional fodder may be required.

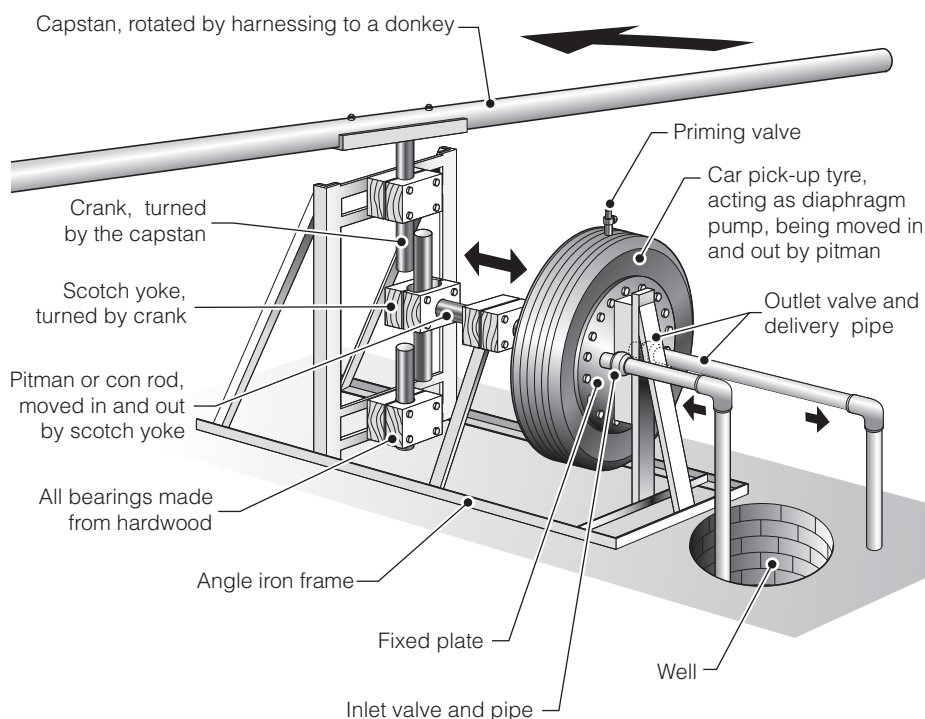


Figure 7.5. Experimental animal-powered diaphragm pump

Although the increasing availability of relatively low-cost, ‘throw-away’ stationary engines means that animal power is seldom used, opportunities do exist to use animals to drive pumps. The slow moving diaphragm pump in particular is suited to animal power applications. Figure 7.5 shows an experimental animal-powered diaphragm pump that uses a car or pick-up tyre that is sealed with steel plates. A crank which is turned by two donkeys extends and retracts a pitman that increases and decreases the interior volume of the tyre, drawing water in as it expands and pumping out as it contracts. Unfortunately in this model the rotation is so slow, approximately only 3.3 r.p.m, that the valves do not bed sufficiently accurately to maintain an airtight seal and the prime is quickly lost.

Internal combustion engines

There is presently little demand for steam engines or for external combustion engines. Due to its versatility the internal combustion engine

is probably the most commonly used source of power for pumping water. Piston engines can be used to power pumps whether the requirement is rotary or reciprocating and can be used in any sand-abstraction application. Engines range in size from small <1kW portable self-priming pump/petrol engine units to large diesel engines of several hundred kW that provide fixed power to multiple well-point systems capable of irrigating hundreds of hectares.

Motorized self-priming centrifugal pump units are capable of making handy and efficient small-scale irrigation and livestock water systems. Small petrol or diesel engine pumps, stationary or portable, coupled to one or several well-points sunk into the river alluvium provide a simple and effective system of water abstraction. Such units are able to pump significantly larger volumes of water with considerably greater ease of operation and without tedium than can be supplied by hand pumping.

The disadvantage is the increased cost of operation and maintenance, which is considerably compounded where there are problems associated with obtaining fuel and service materials. A knowledgeable and skilled operator is required as is a competent mechanic to undertake the service and repair of the unit. The sustainability of engine powered pump units is often questionable and there is sometimes the added drawback that small engines may be stolen

Large, fixed plant schemes with large engines are capable of providing high volumes of water over long distances or to great heights if required. As with smaller engine powered units, operation is easy and requires little physical effort. However, although larger volumes of water can be pumped, such systems are expensive to operate and maintain. Supplies of fuel and service materials can be a real problem and a competent mechanic is certainly required.

Electric motors

Where either mains electricity or series of solar panels are available electric motors may be used in any application where an internal combustion engine can be used. As with internal combustion units, motor/pump units range from very low output to very large output systems

As with all fast moving machinery, any exposed shafts, pulleys and belts require safety guards. In addition, electric motors, if not properly safeguarded, have the further limitation of potentially lethal electricity.

Wind power

Wind power has relatively little application with sand-abstraction systems. Windpumps are dependent on the velocity of the wind in relation to the size and efficiency of the rotor, the volume of water to be pumped and the pumping heads. Consequently wind power is only practical on collector well and offset sand well systems where pump priming is not required. A further limitation is that wind speeds tend to be reduced in valley bottoms where sand-abstraction systems are located.

Table 7.4 indicates the advantages and disadvantages of four distinct power systems.

Table 7.4. Pump power systems		
Application	Advantage	Disadvantage
Human or hand power	<ul style="list-style-type: none"> • Simple and straight-forward • Little or no financial outlay to operate • Low maintenance costs and not difficult to repair 	<ul style="list-style-type: none"> • Inefficient - poor return on inputs • Can be hard work – long and tiring • Mechanically inefficient, may be frequent breakdowns
Animal power	<ul style="list-style-type: none"> • Animals work for a longer period of time than humans – more cost effective • Not complex, low maintenance costs and not difficult to repair 	<ul style="list-style-type: none"> • Animals may require additional feed • Technology not commonly used or understood
Internal combustion engines	<ul style="list-style-type: none"> • Both engines and power transfer systems widely available • Efficient pumping for a protracted period of time 	<ul style="list-style-type: none"> • Costly in outlay and in operating, service/ maintenance, repair and replacement costs • Inputs; fuel, oil, spares may be costly or difficult to obtain • Skilled operator required
Electric motors	<ul style="list-style-type: none"> • Efficient • Can be used by unskilled operators 	<ul style="list-style-type: none"> • Limited to availability of mains electricity or solar panel displays • Efficiency impaired where there is intermittent power supply or over-cast weather
Wind power	<ul style="list-style-type: none"> • Low running costs – although maintenance is required 	<ul style="list-style-type: none"> • Not suited to widespread use • Costly, windmills tend to be as expensive to purchase as internal combustion engines • Suitable sites may be difficult to find

Hand powered pumps are suitable for:

- Low-cost, low volume requirements
- VLOM systems that are relatively easily maintained and repaired
- small-scale rural/community water supplies

Animal-powered pumps are suitable for:

- low-technology pumping applications
- low lift applications
- some application with some pumps designed primarily for use with internal combustion engine/electric motor power

Engine and electric motor powered pumps are suitable for:

- fixed plant equipment (engine pump and base) schemes
- commercial water supply systems –
 - domestic, livestock and irrigation schemes
 - commercial farms, ranches and irrigation schemes
 - supplies to towns

Chapter summary

An appraisal is made of the suitability of specific pumps for both small-scale community based sand-abstraction systems and larger scale commercial systems. Simple suction pumps are generally the most suitable and versatile pumps as they are simple to operate, relatively straightforward to service and repair and are generally suited to all small-scale sand-abstraction pumping requirements.

The principle of suitable pumps is explained together with appropriate sources of operating power. Full VLOM systems of pump operation and maintenance are advocated with end users being encouraged to accept complete responsibility for pump operation, service and repair systems. As one of the advantages of basic sand-abstraction is the simplicity of the system, ideally rural communities should be encouraged to undertake well-point and handpump fabrication and installation work for themselves.

It has to be acknowledged that technical solutions are only a part of the answer. As well as the relatively straightforward process of selecting a suitable abstraction and pump system if an independent, long-lasting, community sustainable water supply scheme is to be ensured it is imperative that consideration be given to the difficult issue of ownership and responsibility for equipment.