How to Make a Rope-and-Washer Pump

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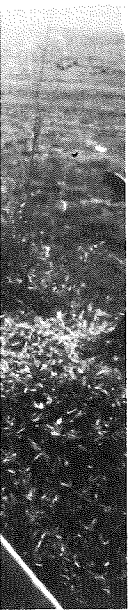
Contents



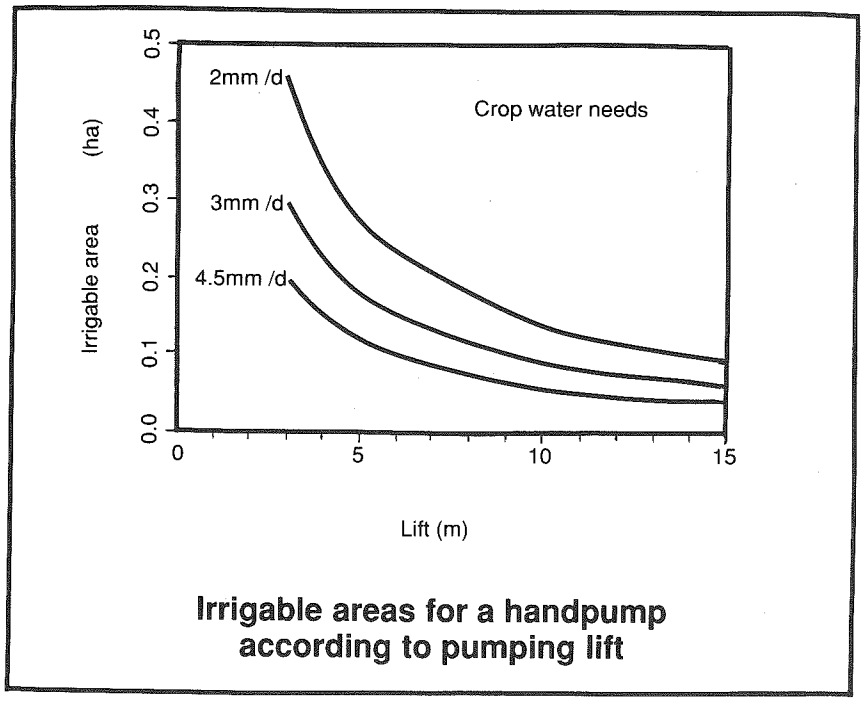
SECTION 1

Introduction

In many parts of the world, the cultivation of small plots, such as gardens, provides a substantial amount of food to the rural population and is particularly valuable for vegetable production in the dry season. During this season, vegetables may be grown only through the use of some form of irrigation. In many cases this involves drawing and carrying water by bucket or watering can from a well to the crops. However, irrigation may be just as important during the rainy season. The ability to provide supplementary irrigation to crops such as maize at critical periods of growth can greatly increase the possibility of a good yield. In addition, when gaps in the rainy season occur, the ability to irrigate may make the difference between a good crop and total failure. The job of irrigating may be divided into two parts: the first is to raise the water out of the ground, and the second is to distribute that water to the crops.

Raising the water

Raising the water out of a well in the ground can be speeded up by the introduction of a simple water-lifting device. The design of the rope-and-washer pump described in this manual has evolved with experience in Tanzania,



Irrigable areas for a handpump according to pumping lift

Figure 1

Zambia and Zimbabwe. It is cheap and easy to make and can be operated, maintained and repaired with the simplest of tools. The materials needed for manufacture are widely available in market-places in most parts of the world.

In many situations, because of the high cost of lining a garden well, it is desirable to be able to pump water from an unlined open well, with the pump sited on the bank. It is also desirable that the pump be portable so that it can be used in a number of wells and taken to a secure place when not in use. The main design described in the following pages is intended for use in gardens with unlined shallow wells. With some simple modifications the pump may also be used in deeper, lined wells. These modifications are discussed in Section 5.

The output of the pump and the effort required to operate it compare favourably with other low-lift hand-pumps costing much more. At lifts of up to five metres an output of one litre per second can be sustained and areas of about 0.25 hectares may be irrigated, as shown in Figure 1, assuming that the pump is operated by one person for twenty hours per week.

What follows is a detailed description of the materials required and processes involved in making the pump. Many alternatives exist and may be more suitable in different circumstances.

Distributing the water

Distributing the water efficiently is just as important as raising it efficiently to the surface. Perhaps the cheapest distribution system is a small furrow which takes water from the well to the crops. However, this method has a number of disadvantages:

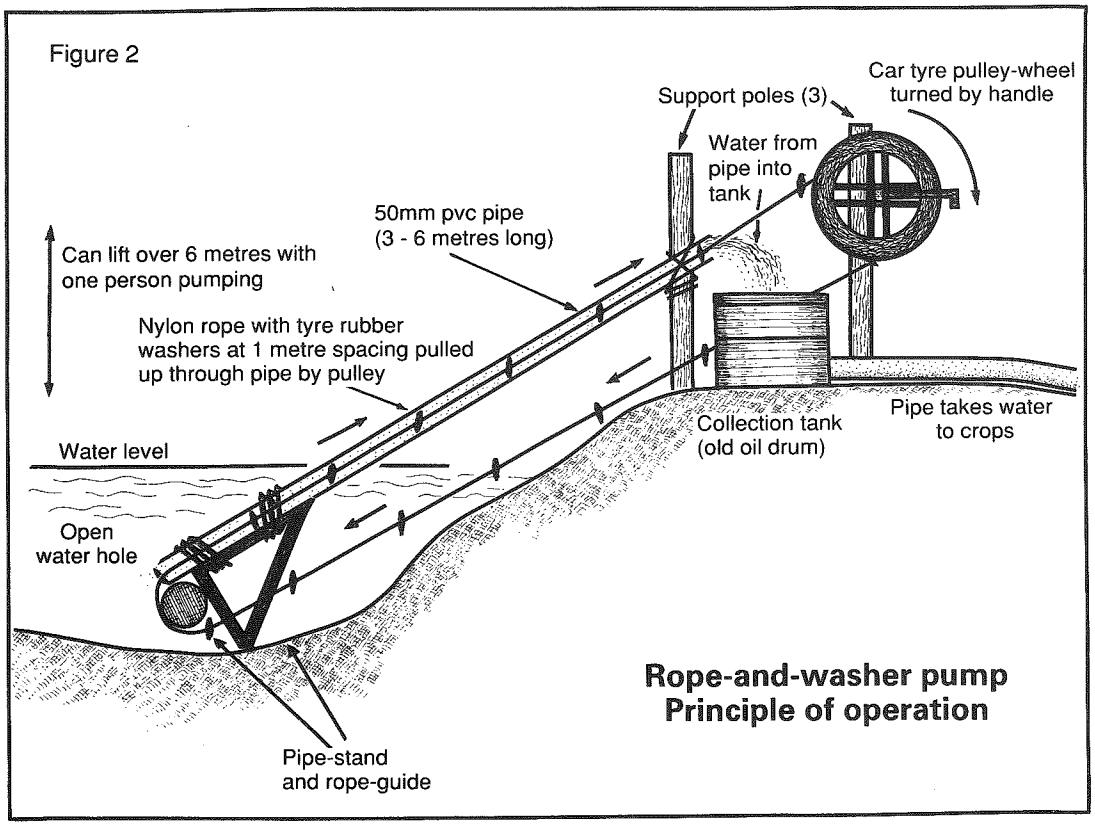
- in sandy soils seepage of water into the ground may be high. Having expended a lot of valuable human effort in raising the water to the surface it is important not to waste it.

- construction of the furrow and channel requires accurate levelling and a knowledge of simple hydraulics. This requires a certain amount of training and adds to the difficulties of introducing a new technology.

- such furrows may often conflict with the need to have raised beds in the rainy season which are required to prevent waterlogging.

Nevertheless such a furrow system may be appropriate in many situations. An alternative is the use of a small tank-and-pipe system. Black poly pipe, when available, is ideal for the job. If the well is situated in the centre of the plot, a tank made out of an old oil drum and 50 metres of piping can irrigate a maximum of about 0.50 hectares — about the maximum that can be irrigated with one hand-pump.

Figure 2



Principle of operation (see Figure 2)

The rope-and-washer pump is a water-lifting device capable of lifting relatively large volumes of water from a water-hole or well to its own height. It is not capable of lifting water above its own height so it is important that the well and pump are located in such a way as to allow the raised water to flow by gravity to the crops. During operation, a rope is pulled up through a pipe by means of a pulley-wheel. Fixed to the rope are flexible rubber washers whose diameter is slightly less than the internal diameter of the pipe. When the bottom of the pipe is inserted in water and the rope and washers are pulled upwards through the pipe, the water is drawn up and discharged at the top of the pipe. The rope and washers pass around the pulley-wheel and return to the bottom of the pipe completing the circuit.

There are two very important considerations in the design of the pump:

- avoiding slippage of the rope on the pulley
- preventing the washers getting caught as they enter the pipe.

To overcome the first problem a simple pulley-wheel made from cut-away old tyres is used. This vee-pulley, made from rubber, gives an excellent grip on rope or chain. In addition, the flexible rubber washers are gripped tightly by the pulley.

To prevent the washers getting caught and to support the pipe above the bottom of the well, a suitable pipe-stand and rope-guide is necessary.

The pump has no valves and can cope easily with mud, silt and weeds. Because of the circular action there are no changes in direction of major moving parts and this, combined with the slow speed of operation, results in low stresses on the working parts. The simplest of wooden bearings may therefore be used.

A small amount of water will leak between the moving washers and the pipe wall, resulting in some loss. However, it is unwise to try and compensate for this by making the washers fit the pipe too closely, as the pump becomes difficult to operate due to friction between the washers and the pipe. A little loss of water is preferable to a lot of effort in pumping. Other friction losses occur at the bearings, as the rope enters the pipe and as the rope returns down the bank of the water-hole. A well-rounded axle that is regularly greased will minimize the first, correct design of the rope-guide will minimize the second, and keeping the path of the rope clear will minimize the third.

SECTION 2

Tools and materials

Tools

Only the simplest of carpentry tools are needed and are illustrated in Figure 3. A very sharp knife is needed to cut the tyre. A pair of pliers is useful for tying wire and a hacksaw for cutting iron bars. A hammer, wood-chisel and a woodsaw are also required. Other useful tools include a wood rasp and a bit and brace.

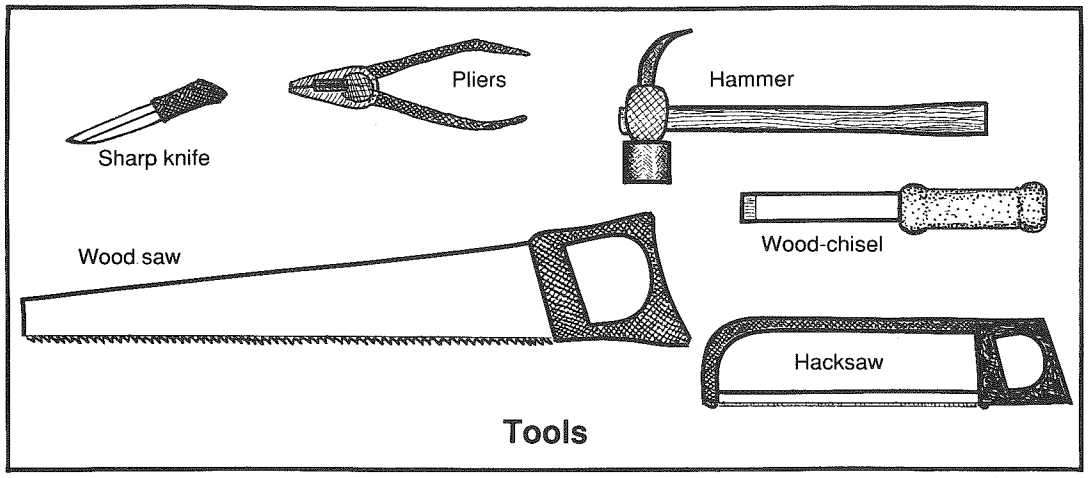


Figure 3

Summary of materials

A wide variety of materials may be used in the manufacture of this pump. The materials described here have been used with success, are cheap, widely available, require basic skills and are durable.

- **Pipe:** 1 pipe (length suited to well) 50mm rigid uPVC or galvanized iron.
- **Old Tyre:** 1 old tyre, 30 to 50 cm internal diameter.
- **Rope:** Nylon rope is best, 8mm diameter. The rope should be three times as long as the pipe.
- **Old can or log:** At least 30 cm long and 20 cm in diameter.
- **Wire and nails:** Strong tie-wire and nails 4 to 5 cm long.
- **Rubber strips:** These strips can be cut from an old inner tube.
- **Round bar:** A total length of 8.5 metres of round bar, 8 to 10 mm in diameter.

- **Steel piping**: Two lengths of strong steel piping of minimum diameter 20 mm for the handles.
- **Timber**: Two 30 cm lengths and one 2 metre length of 75 × 75 mm timber.
- **Poles**: Three treated poles, 2 metres long and 120 mm thick.
- **Drum and piping**: An old drum, of capacity 200 litres, cut in half is an ideal collection vessel. For piped distribution, black poly piping with a minimum internal diameter of 40mm is recommended.

Materials description (see Figures 4 and 5)

Pipe

Almost any rigid pipe is suitable. The cheapest pipes which are widely available are made from uPVC. It is recommended that a rigid PVC pipe be chosen with the minimum strength being Class 6. A PVC pipe 50mm in diameter is recommended. The length depends on the depth of the water-hole and the angle of the pipe leaving the water. It is important to remember that this pump will cause the level of the water to fall fairly quickly, so allow for this in estimating the length of pipe. PVC pipes are commonly sold in lengths of 6 metres. One of these lengths is generally more than adequate for unlined wells. For greater lifts a pipe of smaller diameter may be required (see Table 1 below).

Old tyre

An old tyre provides the raw material for the pulley-wheel and the washers. A large tyre, 30 to 50 cm in internal diameter is desirable. If the tyre is too small, the pump output will be reduced. If the tyre is too big then it may be difficult for one person to operate the pump alone but the output will be high. For higher lifts, a smaller tyre and pipe should be used (see Table 1).

Table 1. Pulley and pipe sizes for different lifts

Lift	Maximum Internal diameters	
(m)	Pulley (cm)	Pipe (mm)
0-3	50	50
3-5	50	40
5-8	30	40
8-12	30	30
12 and over	30	20

Rope

Nylon rope is ideal for this pump. It should be about 8 mm in diameter. Smaller diameters will not have as long a working life and may be a little stretchy but they can be used. If nylon rope is not available then any rope may be used provided it does not stretch too much when wet. Strips of car tyre, which with careful cutting can be cut in one section up to 20 metres long, can also be used as the rope. If you try this, it is best to use the fibre reinforced section. The strips should be about 20 × 10mm in cross-section.

To calculate the length of rope required, double the length of the pipe and add 5 metres. Thus a 6 metre pipe will require (2 × 6) + 5 = 17 metres of rope.

Old can or log

A short log is ideal for making the rope guide, being very slippery when wet. As the rope will be continually sliding over this log it should be as hard as possible. An old can may be used instead of a log. Several large holes should be punched in the ends to allow it to sink quickly into the water when the pump is being installed and to allow the water to empty quickly when the pipe is being withdrawn.

Wire and nails

Strong tie wire is required for joining the steel bar: about 5 metres will be sufficient. About twenty nails, 4 to 5cm long are needed for joining the two halves of the pulley-wheel.

Rubber strips

Rubber strips cut from the old inner tubes are cheap and invaluable in making this pump. Each pump will need about 5 metres.

Round bar

Round mild steel bar, often sold as reinforcing rod, is used in making the pipe-stand and the pulley-wheel. The recommended diameter is 10mm, although 8mm or 12mm may be used, as available. Eight lengths of bar are needed for the pulley-wheel. The length of the bars depends on the size of tyre used. For a tyre with an inner diameter of 50cm, a rod length of 55cm is needed. The pipe-stand requires three bars, two 150cm long and one 40cm long, bringing the total length of bar required to about 8 metres.

Timber and poles

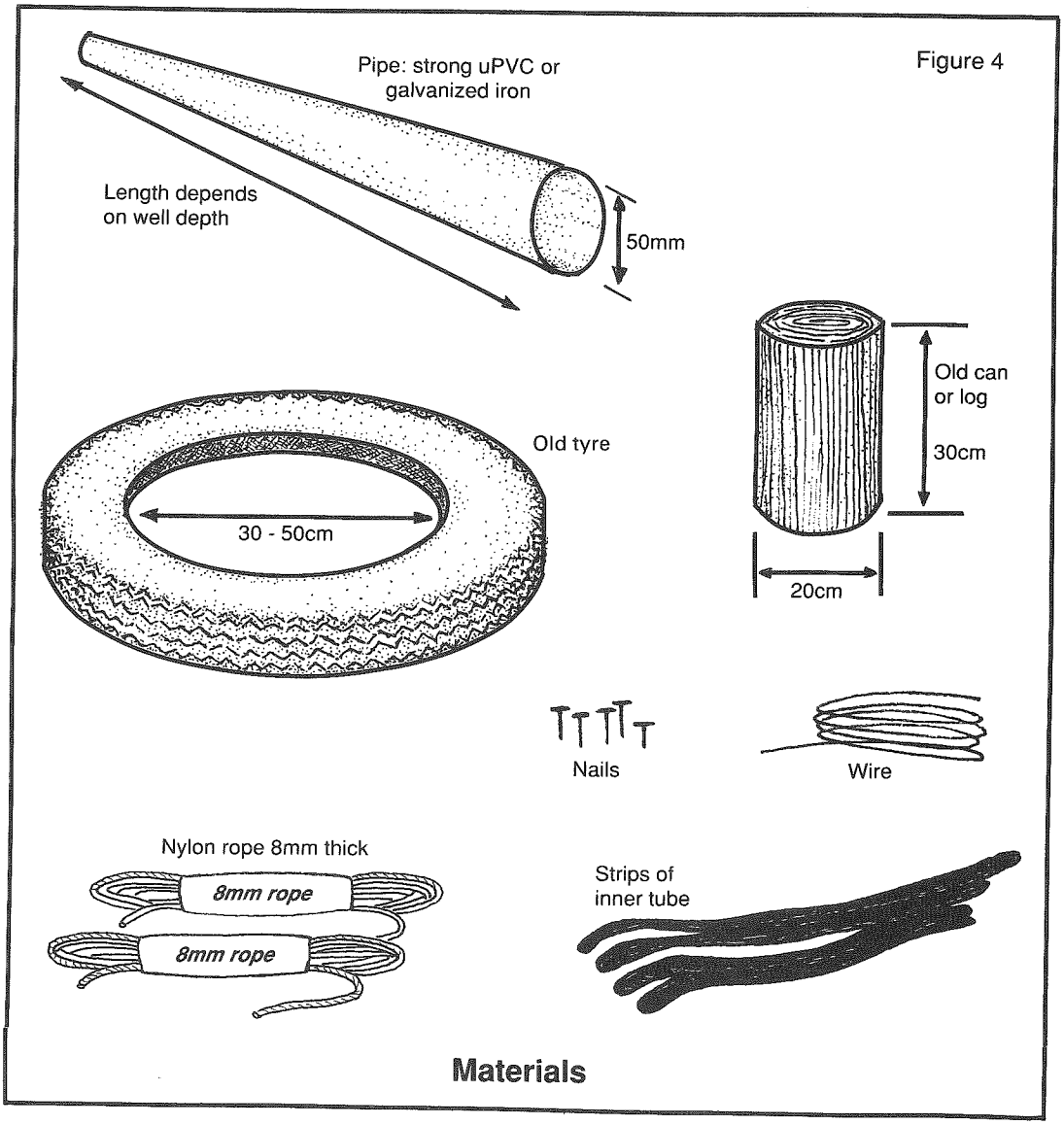
Timber is used for the axle and the bearings holding the axle to the poles. The timber for the axle should be strong and free of knots as these cause weakness. The axle should be 1.5m to 2.0m long with a minimum cross-section of 75 ×

75mm. Holes should be drilled near each end to take the handles (see Figure 8). The same size timber can be used for the two bearing blocks, each being 30cm long. Three poles, 2 metres long by 12cm diameter, are needed to support the pump at the well site.

Drum and piping

A 200-litre drum is cut in half to form the collection vessel for the water coming out of the pipe. In the side of the drum near the bottom, a piece of steel piping is fitted, to which the distribution piping may be attached. This piping should be in short sections, 5 to 6 metres being a useful length. These sections can be moved easily around the field, and connected together using strips of inner tube. Long sections of pipe which are full of water are very difficult to move.

Figure 4



Materials

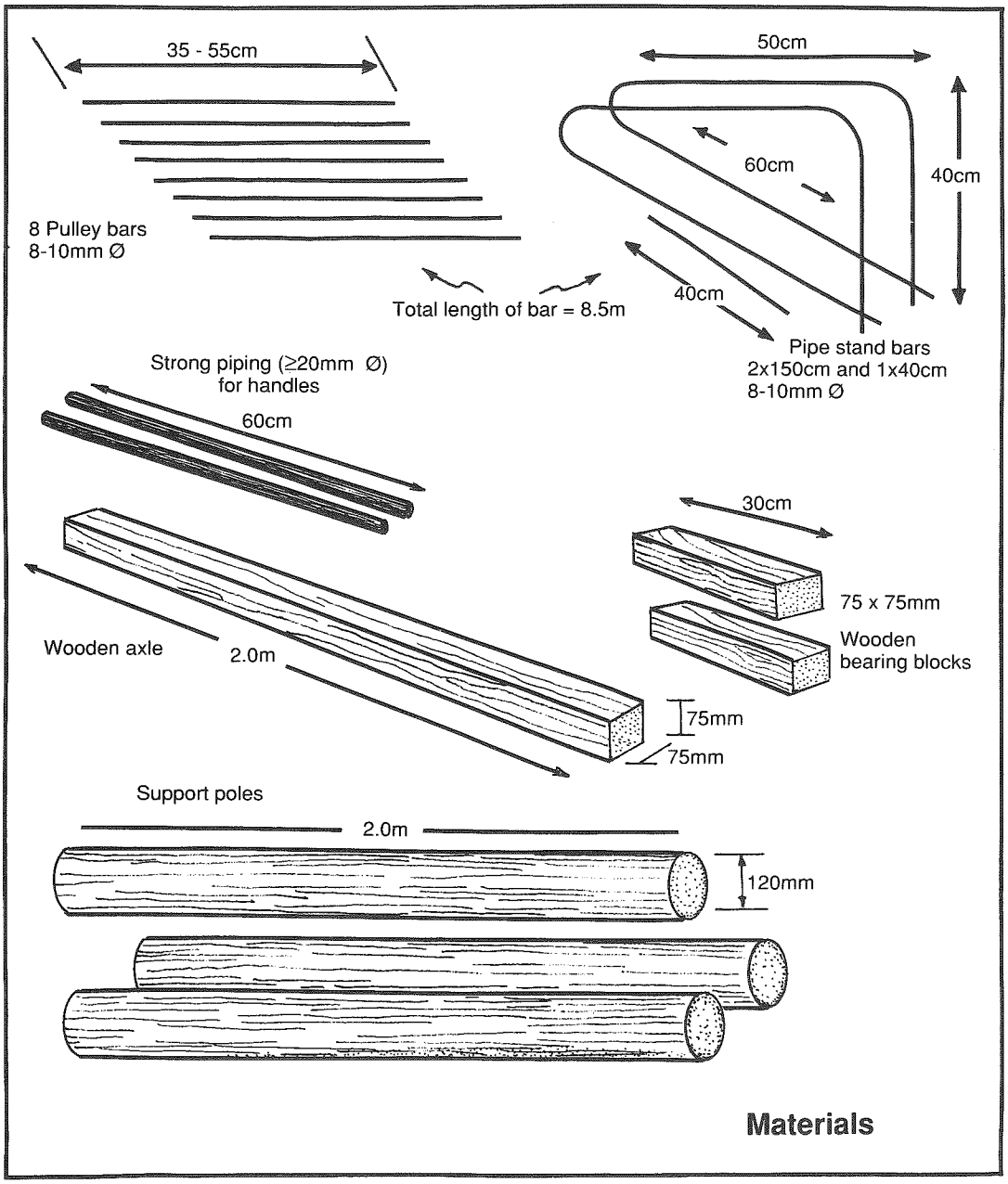

35 - 55cm
8 Pulley bars
8-10mm Ø
Total length of bar = 8.5m
50cm
60cm
40cm
40cm
Pipe stand bars
2x150cm and 1x40cm
8-10mm Ø
Strong piping (≥20mm Ø)
for handles
60cm
30cm
75 x 75mm
Wooden
bearing blocks
Wooden axle
2.0m
75mm
75mm
Support poles
2.0m
120mm
Materials

Figure 5

SECTION 3

Making the pump

SAFETY NOTE: In making the pump a very sharp knife must be used. As with all tools, take great care when using the knife and always keep it out of reach of children.

Making the pump involves cutting and joining various pieces of car-tyre, cutting, bending and joining steel bar, and a small amount of wood carving. Some welding may be undertaken but is not essential.

The pipe

Measure the pipe at the well. Cut it to the required length and file the ends smooth. It is best not to cut the pipe until the final assembly has been completed. It is better to have a pipe that is too long than one that is too short.

Cutting the tyre and washers

The inner walls of the tyre are cut out as shown in the diagram (Figure 6). These form the two halves of the pulley (Figure 10) and should be a minimum of 5cm wide. The remaining outer part of the tyre is used to make the washers, as shown in Figure 7. This part is cut into strips 6 to 8mm thick. The outer part of the tyre has fibre-reinforced ply layers which may be separated with a sharp knife. The required thickness of ply may be obtained as follows:

- cut the outer part of the tyre into strips
- slit along each side of the strip at the required thickness.
- at one end of the strip, slit the ply completely away from the tread to a length of about 150mm.
- the strip of ply may now be pulled away, by hand or with pliers, from the tyre strip.

The washers are cut to give a good fit in the pipe. A small section of pipe can be cut off and used for measuring the washers. A clearance of 1mm between the washers and the pipe is about right. Test each washer by allowing it to fall through the short section of pipe. If it gets stuck, trim it accordingly.

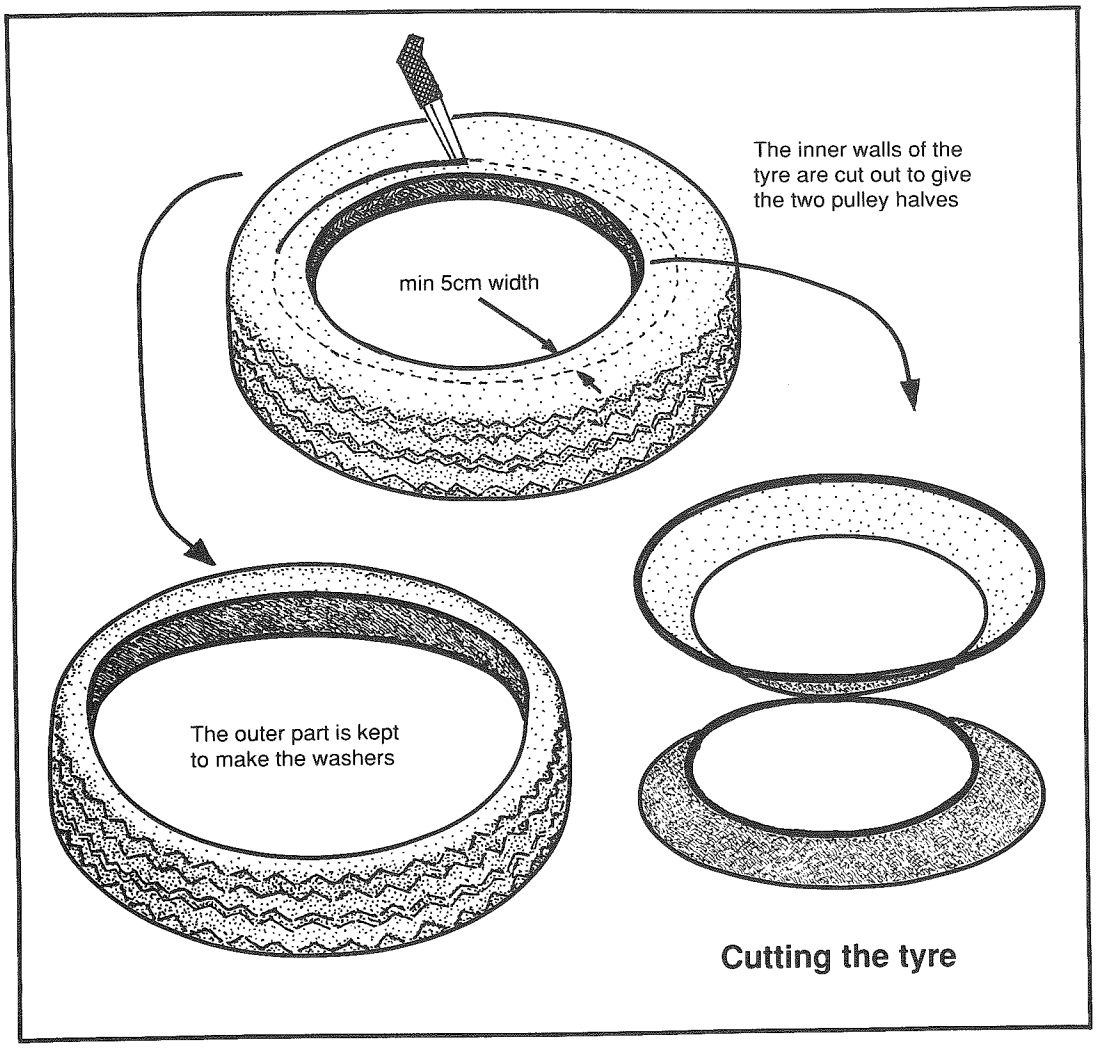


Figure 6

Fitting the washers

A small hole is cut in each washer just big enough to allow the rope to be pushed through (see Figure 8). The washers are fixed at one metre spacing. To keep them in position the rope is knotted tightly on each side of the washer. An alternative method is to wrap thin strips of inner tube tightly on the rope on each side of the washer. To join the ends of two pieces of rope, overlap the ends by about 20cm. Wrap tightly with a thin rubber strip. This will give a very tight, non-slip connection that is easy to open. Knotting nylon rope so that it won't slip is not easy, but once it is knotted it can be very difficult to open.

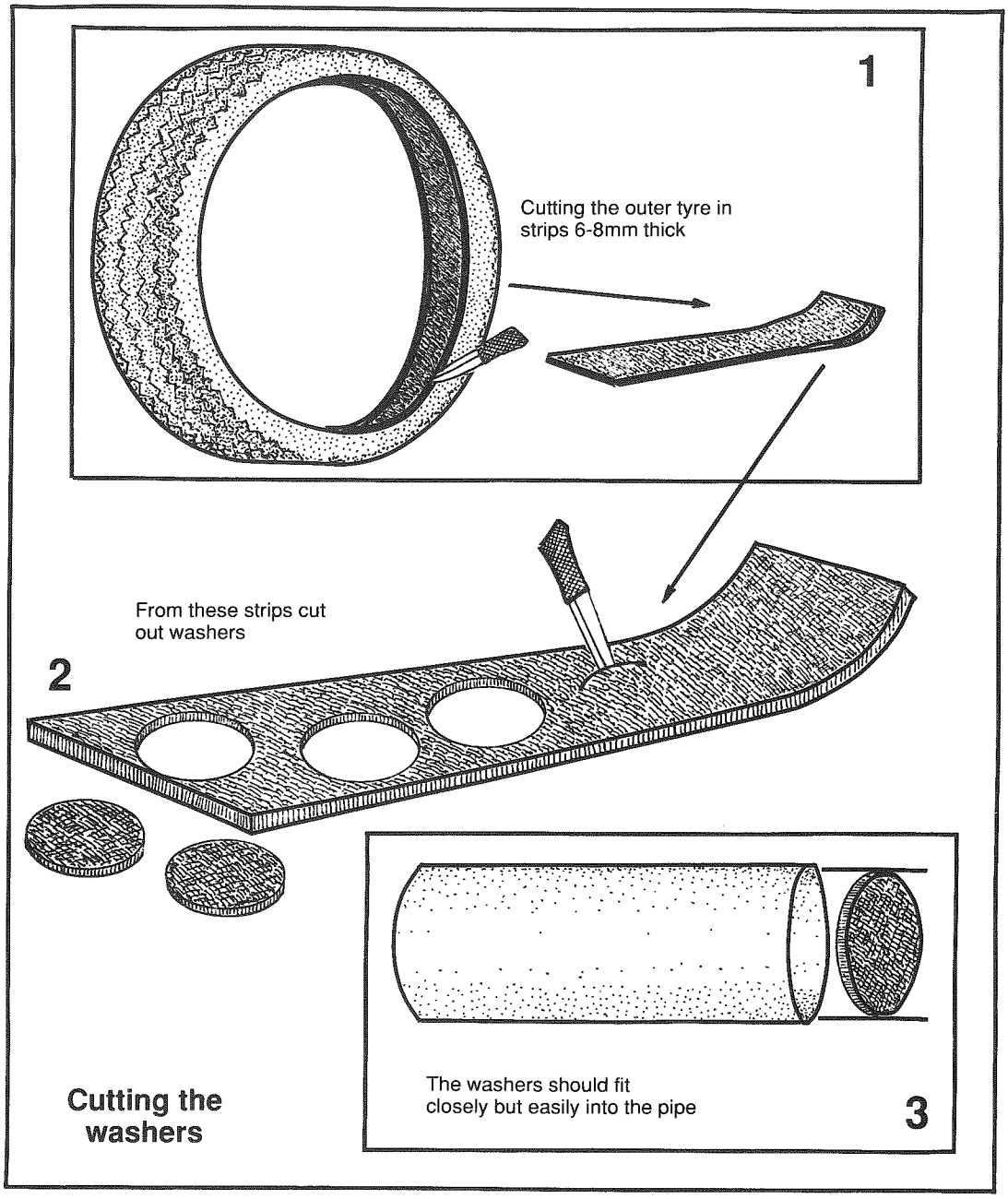

1
Cutting the outer tyre in strips 6-8mm thick
From these strips cut out washers
2
The washers should fit closely but easily into the pipe
3
Cutting the washers

Figure 7

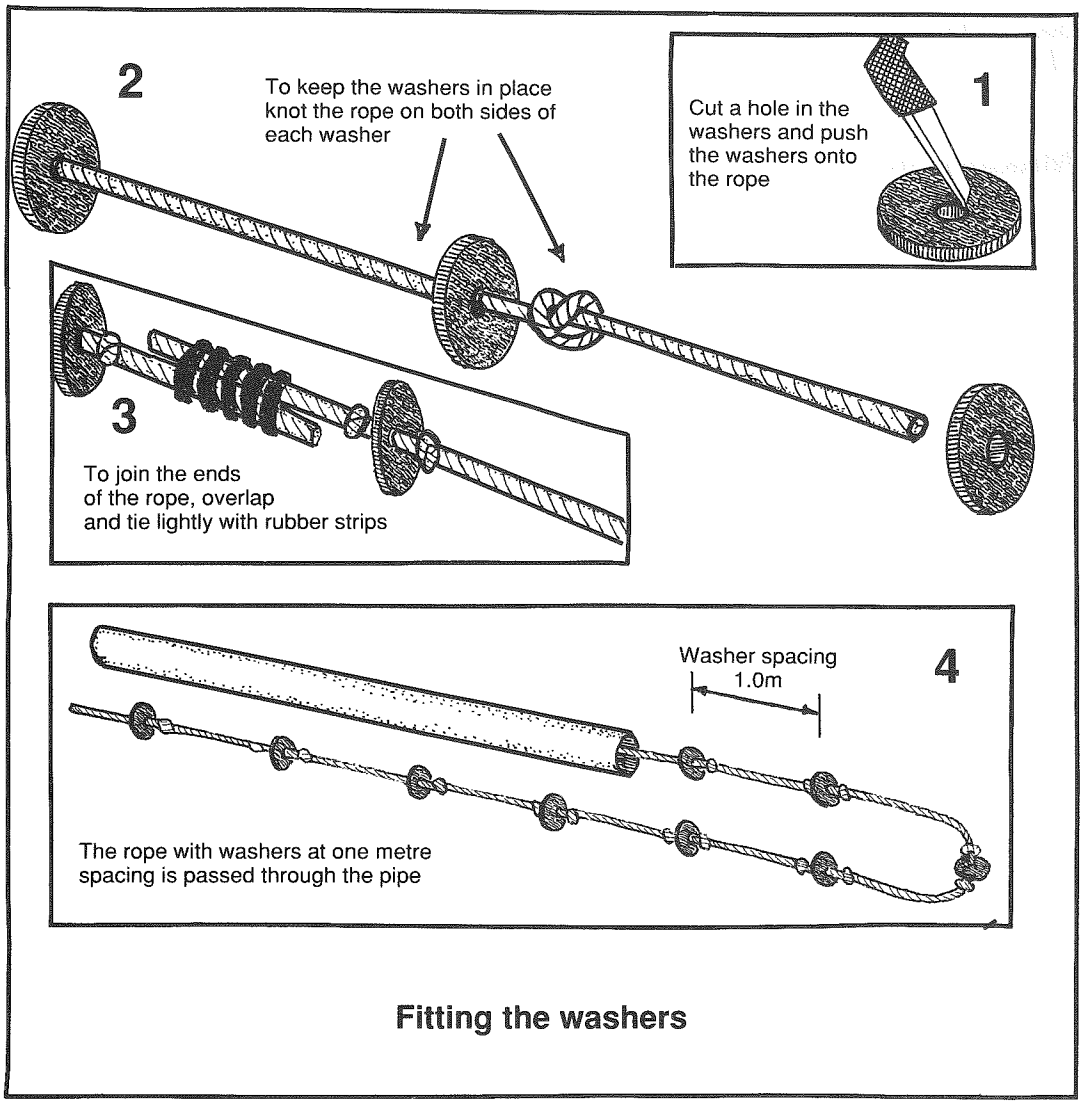


Figure 8

Making the handles

The easiest way to make a handle is to bend a piece of strong steel tubing, as shown in Figure 9. Flatten the end of the tubing with the hammer and insert it into the hole in the axle as shown. To prevent the handle twisting in use, drive in some wooden wedges around the handle. The axle should be tightly bound with wire on each side of the hole, to prevent the wood from splitting. If welding facilities are available then a handle may be welded using steel tube and

box-section as shown. Two short lengths of pipe, plastic or steel, each 150mm long can be fitted to the handles to reduce wear on the hands.

Making the pulley

The inner walls of the tyre are first joined together by nailing (see Figure 10). At the first attempt this may seem difficult, as many tyres have wire-reinforced inner rims. However if the nail is pushed into the rubber close to the inside edge and then hammered it will go through. The nails carry out two functions: holding the pulley halves together while the bars are being fitted and stopping them from sliding against each other.

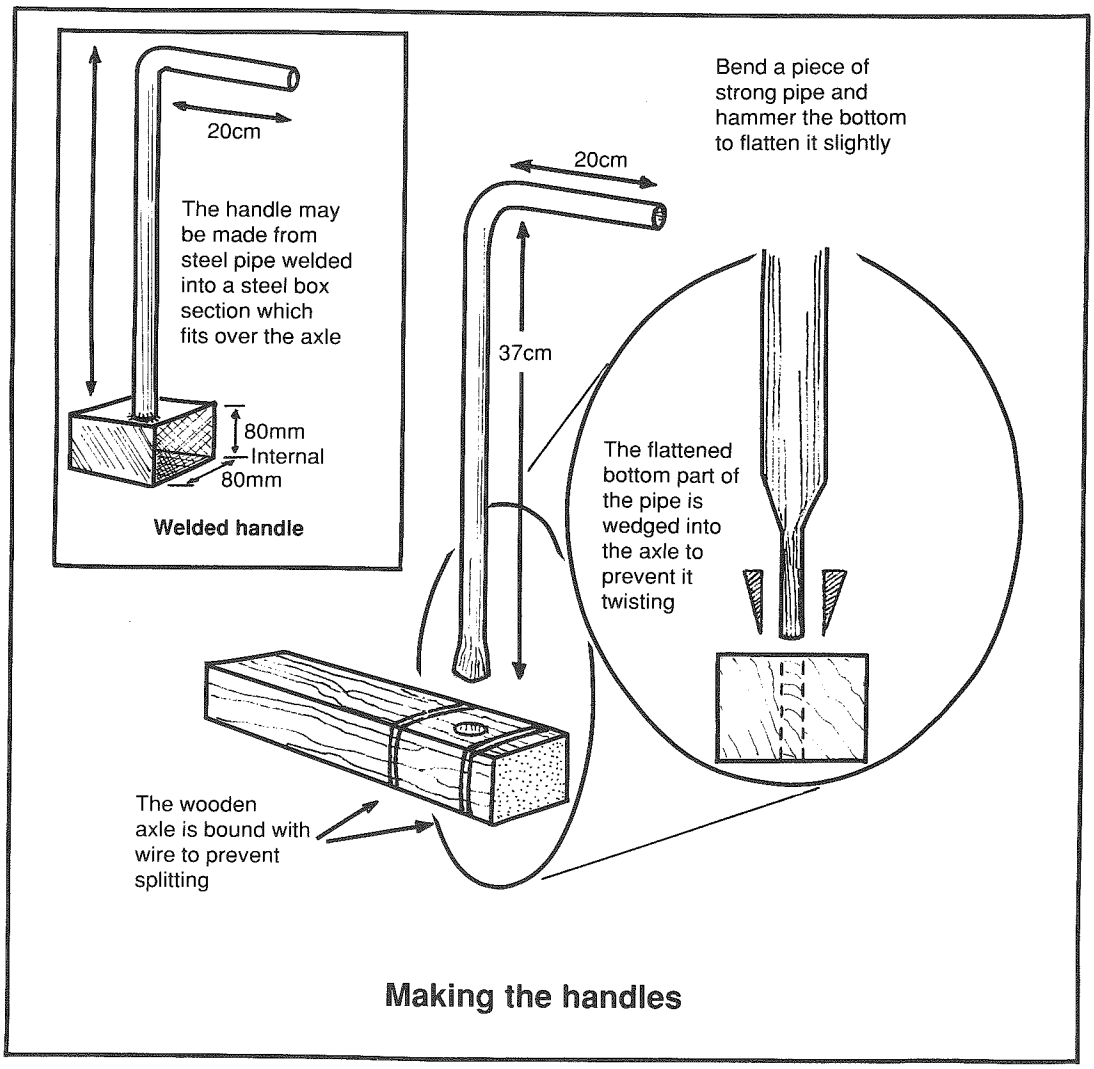


Figure 9

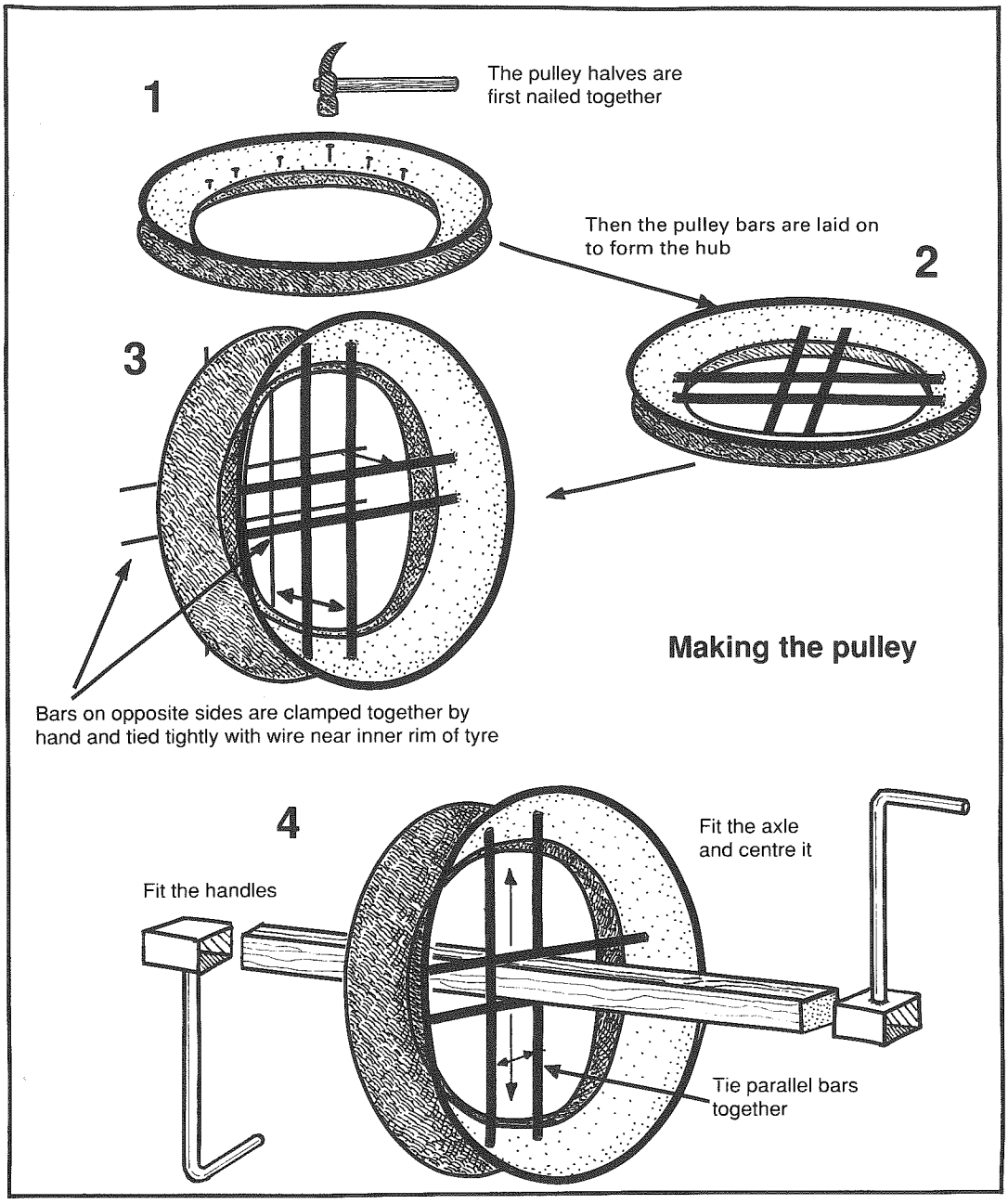
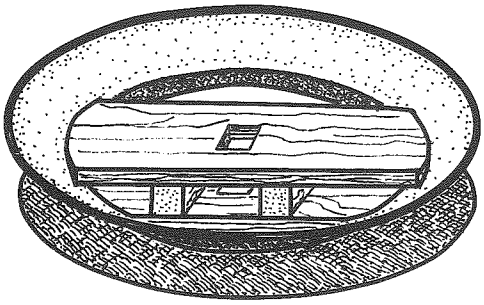


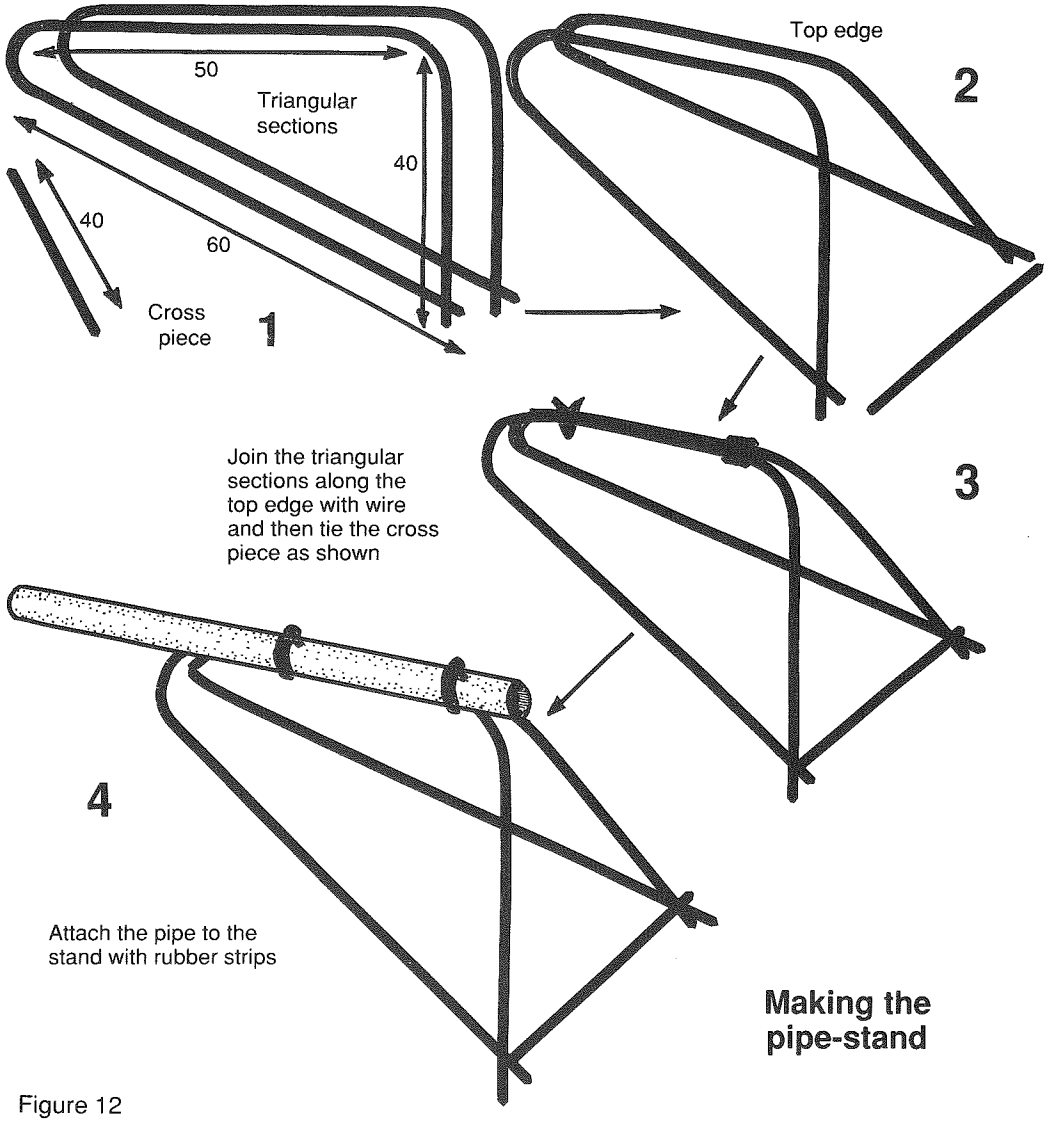
Figure 10

The strength of the pulley comes from the method of making the hub. The hub of the pulley may be made in a number of ways: using iron bars, strong sticks or timber planks. The method using iron bars is described in detail here. The first four bars are laid on top of the pulley to form a square hub at the centre. Then the second four bars are laid underneath the tyre and each bar is tied to its partner above, close to the rim of the tyre. Before the final tightening, the hub should be centred and the axle fitted.



Pulley with wooden hub

Figure 11



Making the pipe-stand

Figure 12

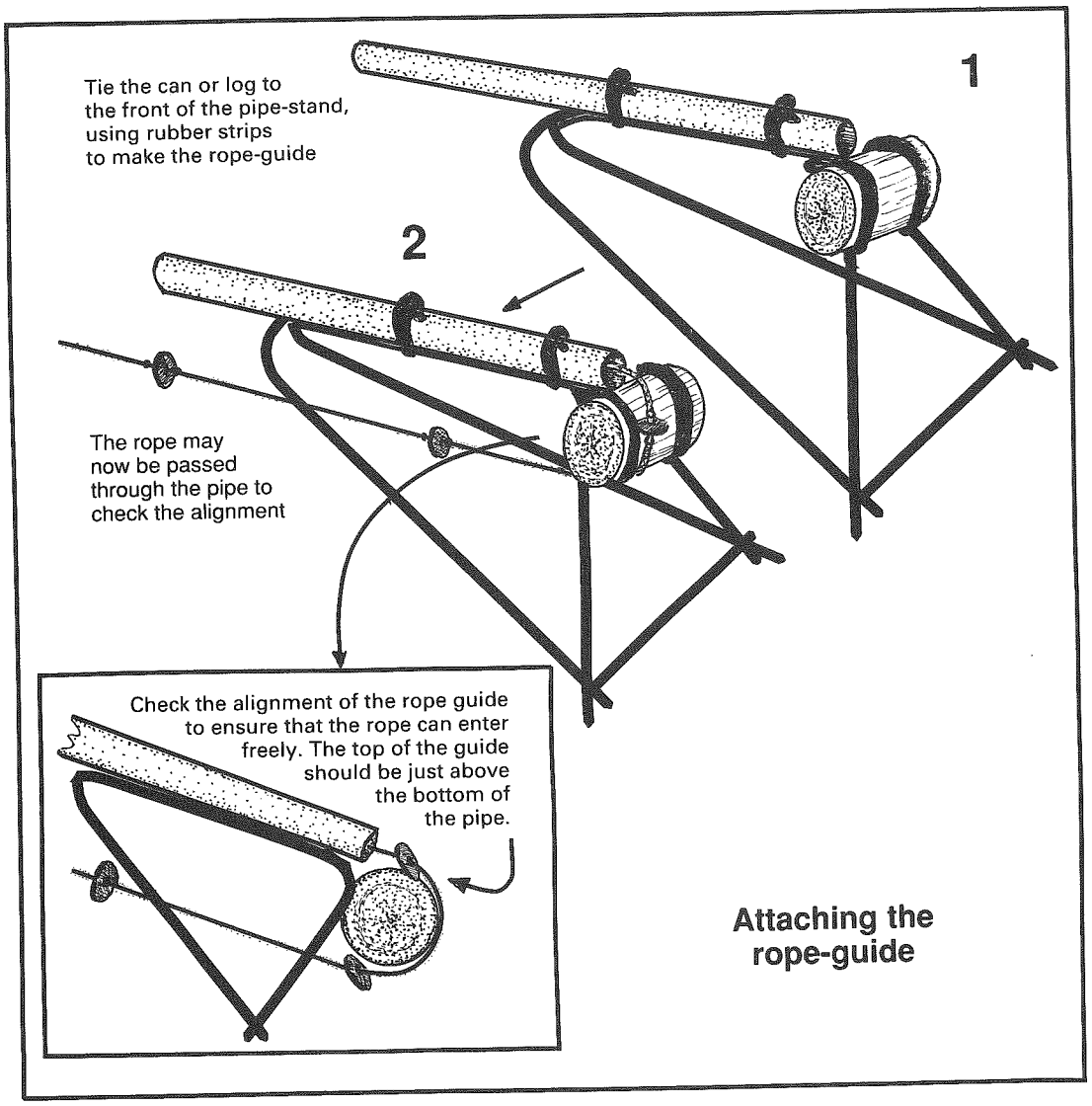


Figure 13

To prevent the bars from being pushed apart when the axle is being turned, parallel bars on each pulley face should be tightly tied together. The final tightening of the wire is done while the bars on each side of the pulley are clamped together by hand. Figure 11 shows a pulley with a wooden hub.

Making the pipe-stand and rope-guide

The two 1.5m lengths of bar are bent into right-angled triangles 60 × 50 × 40cm (Figure 12). These triangles are tied with wire along the top edge. The cross-piece is then then added to give a pyramid-type structure. This is the pipe-stand. The pipe may be tied to the stand using rubber strips. The end of the pipe should extend slightly over the end of the pipe-stand.

To form the rope guide, the log is now attached to the stand, again using rubber strips and the rope is passed through the pipe (Figure 13). To pass the rope through the pipe, first pass a piece of string, with a stone attached, through the pipe. The string can now be used to pull the rope through. The log is aligned to lift the rope up over the lip of the pipe so that the washers do not catch. As the washers slide over the log they are flattened slightly and so enter the pipe at an oblique angle, which prevents them from catching. Correct alignment of the rope in the centre of the pipe is ensured by keeping the rope under tension.

A trial-run out of the well is recommended. Pull the rope by hand through the pipe to check the alignment of the rope-guide. Note that the lubricating action of the water is crucial to smooth operation, so it is wise to wet both the rope and the log with water during the trial.

An alternative rope-guide and pipe-stand may be made from a section of log (see Figure 14). A hole is cut near the bottom of the log big enough for the washers to pass through. The entrance to this hole is expanded so that the washers can enter without catching on the corners. At the top of the log and on the opposite side, the pipe is recessed into a groove cut in the log. The pipe is bound tightly to the log in this groove. As the pipe is recessed into the log, the rope and washers may enter without the washers catching on the lip of the pipe. The log may have to be weighted with a stone to make it sink.

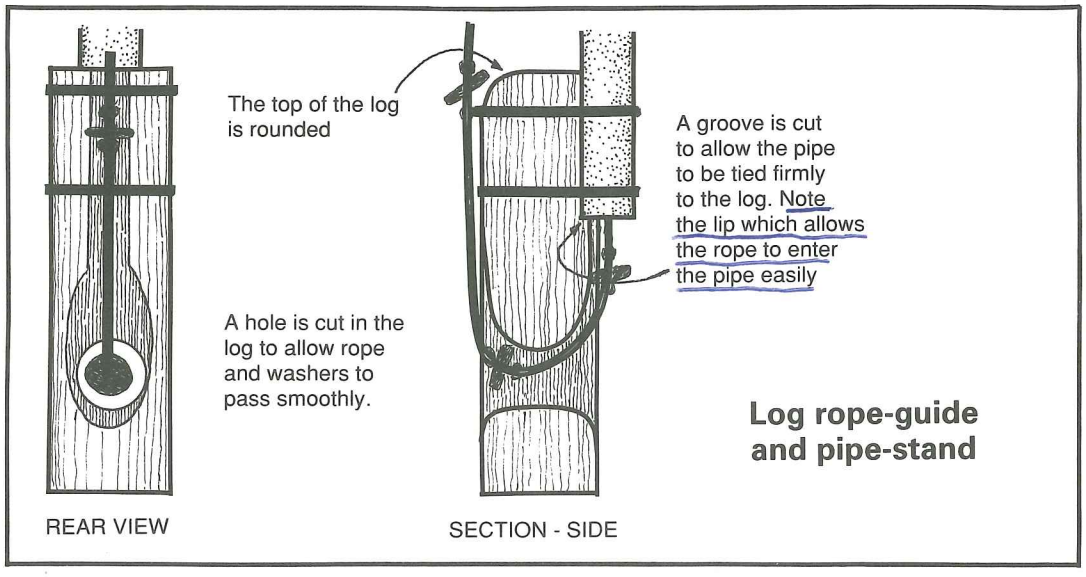


Figure 14

SECTION 4

Assembling the pump

The site

The pump should be sited on the bank of the well, high enough so that the pumped water can flow by gravity to the area to be irrigated. If necesssary an earthen platform 4 metres long by two metres wide should be levelled as the pump site. The bank of the well should be as steep as possible. Weeds and long grass should be removed.

The poles

Three poles are set firmly in the ground, as shown in Figure 15. The pipe support pole is set 1.5 metres in front of the axle support poles which are 1.2 metres apart. The poles should be set as close to the edge of the well as possible. It is important that the poles are solidly set in the ground. The holes should be at least 75cm deep and backfilled carefully with a heavy clay (anthill, for example, is very suitable). The backfill should be rammed every 10cm until the hole is full. There is no point in ramming the top of the backfill if the bottom has not been made very secure, as this will only allow the poles to pivot and shake loose.

Mounting the pulley and axle

The axle is clamped to the poles with wooden bearing blocks at a height of about one metre above the ground. If the axle is too high then only the shoulder and arm muscles are used. For sustained operation it is important that the muscles of the lower back and the legs, which are the body's most powerful muscles, are brought into play. The ideal height is the hip and waist height of the usual operator, who should be present at installation. A 20cm section near each end of the axle must be shaved with a chisel to give a circular section which rotates in the bearings. Semicircular notches are then cut in the pole and the bearing blocks, taking care that the axle is horizontal. The axle is clamped to the pole using the bearing blocks and the handles fitted. The axle should be free to rotate with a minimum of play (Figure 16). Rubber strips are ideal for clamping the bearing blocks to the poles. Later on, they may be replaced with wire if desired. Nails tend to split the wood and should be avoided.

Mounting the pipe

The pipe, with the stand attached, is lowered into the well. It is helpful to tie a length of string to the bottom of the pipe as this allows someone standing on the opposite side of the well to assist in positioning it correctly. The pipe is lashed tightly to the support pole using rubber strips (Figure 17). Thin-walled

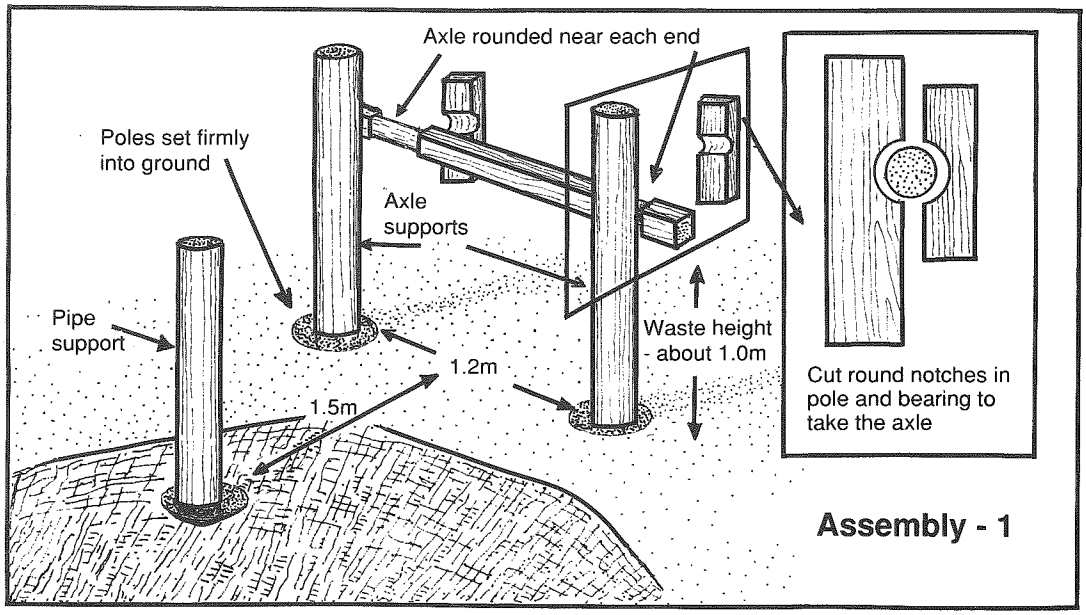


Figure 15

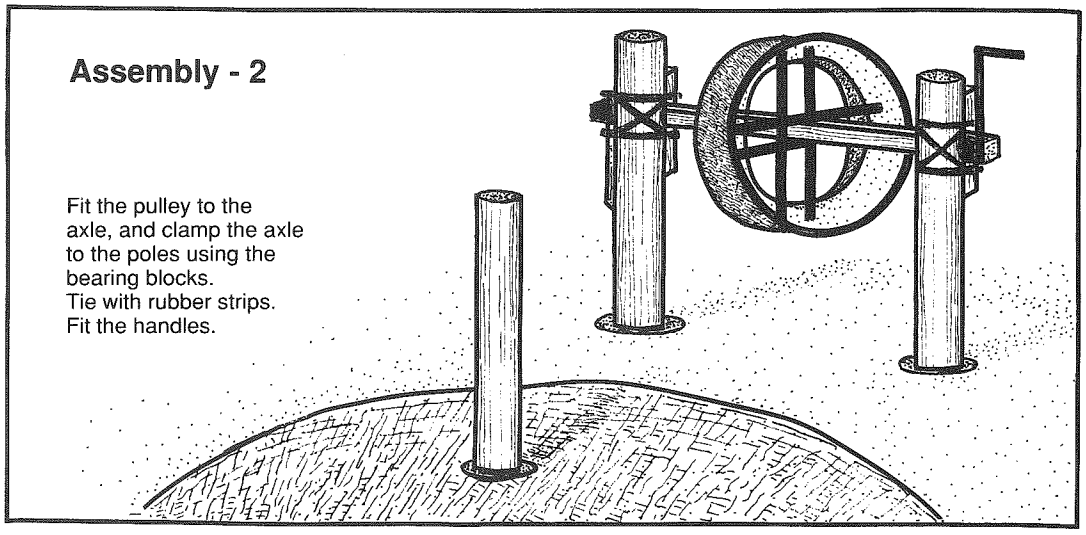


Figure 16

uPVC pipes may be squeezed out of shape if lashed too tightly, resulting in the movement of the washers being impeded. During operation of the pump the rope will be exerting a force on the pipe so as to pull it up out of the water. This force is resisted by tying the pipe to the pole. The height and alignment of the pipe on the pole is adjusted so that the rope passes over the edge of the pulley without touching the lip of the pipe. Long pipes may need two support poles (see Figure 19).

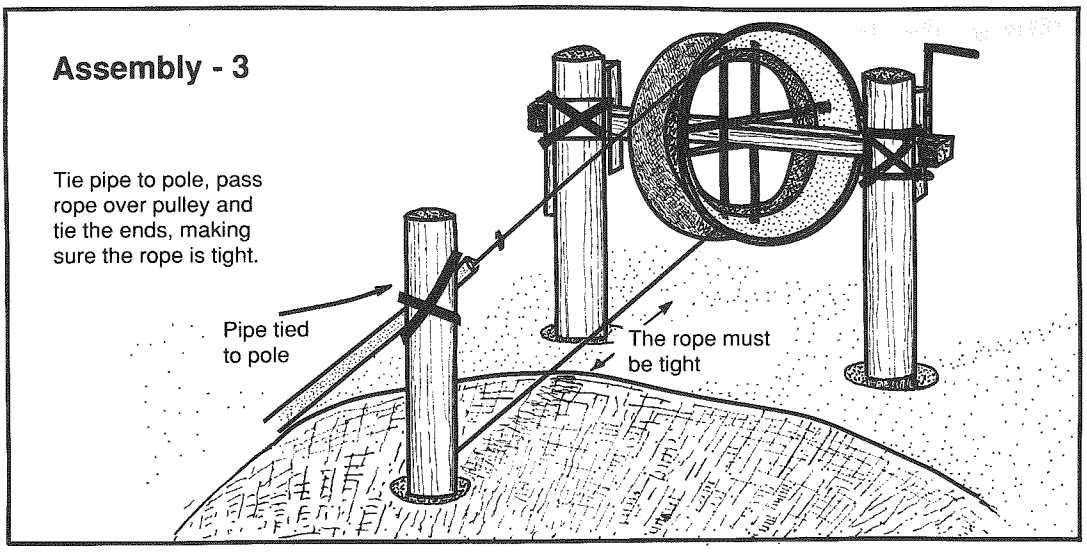


Figure 17

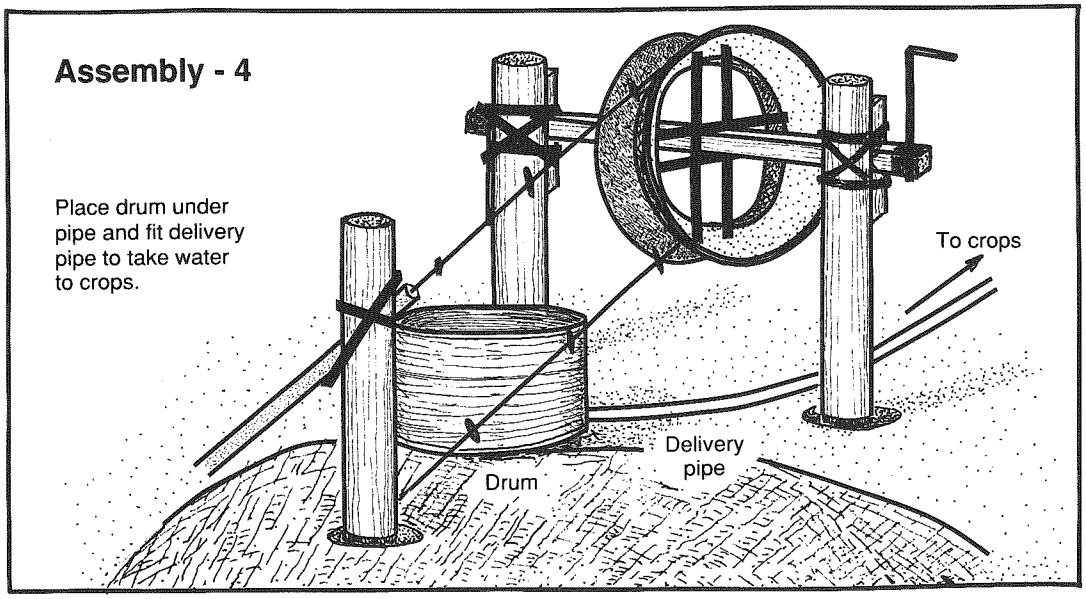


Figure 18

The ends of the rope are joined using rubber strips, as described earlier (Figure 8), so that when the rope is fitted over the pulley, it is tight. When the pump is first operated the rope tension may have to be adjusted once or twice as the knots tighten up and the poles settle in.

Fitting the drum

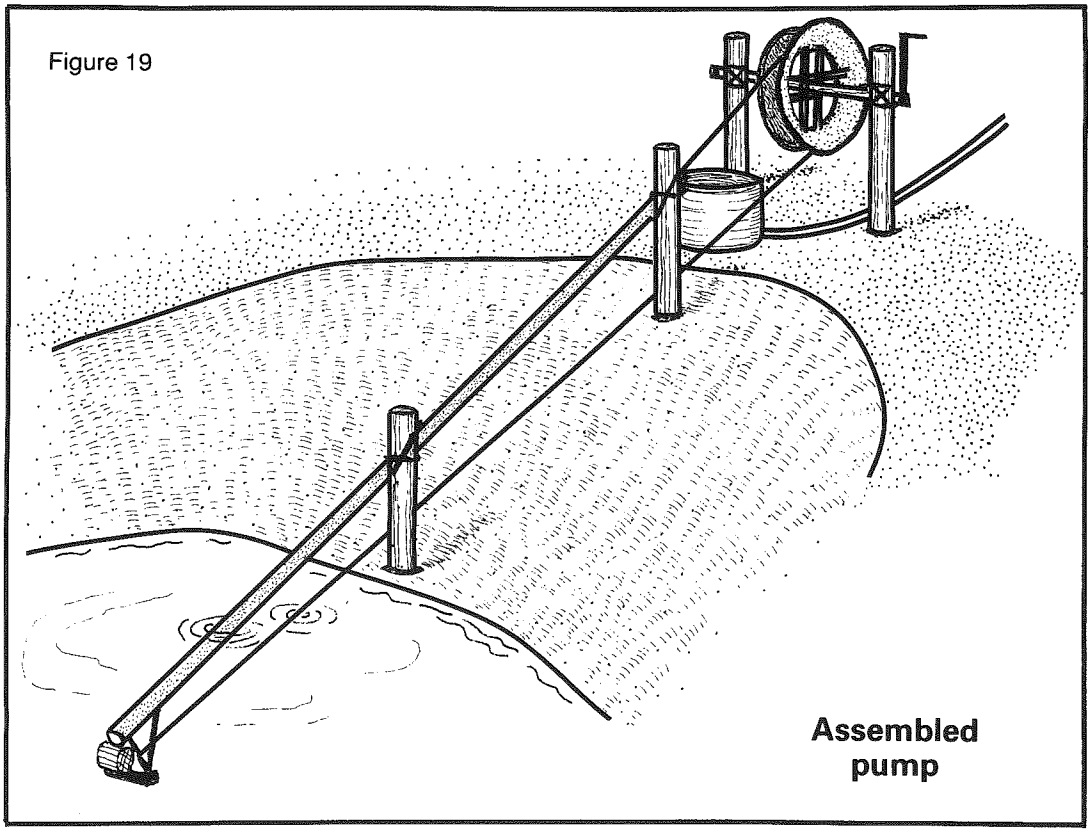
Finally, the drum is placed under the mouth of the pipe to catch the discharging water and the distribution piping is fitted to carry the water to the crops (Figure 18).

Operation

The pump is now assembled and ready for operation (see Figure 19). It is operated by turning the handles so that the rope is pulled up through the pipe. A little grease on the axle in the bearings will make for freer and quieter operation. A few adjustments may be necessary in the initial stages if the pump fails to operate. The rope will slip if it becomes loose or if the washers have jammed. A loose rope may be remedied in a number of ways:

- rope too long (maybe because all the knots have tightened); untie it and rejoin at correct length.
- pipe slipped up along support pole; check and adjust.
- pipe support pole and axle poles being pulled together by the tension of the rope: the poles were not placed firmly enough in the ground; they may be stiffened by bracing with stakes.

Figure 19



Assembled pump

If the washers have jammed at the bottom of the pipe there may be a number of reasons:

- the pipe stand has fallen over; check that the stand is sitting correctly on the well bottom.
- the log has shifted on the pipe stand, or is incorrectly attached; check and adjust.
- the washers are too big; there may be 'rogue' washers that are oversized. Trim to correct size.

Provided that the washers do not get stuck and the rope tension is maintained the pump will operate smoothly.

Maintenance

As the pump is used the washers will slowly wear, and eventually one or two may need replacement, although wear on one washer will affect the pumps performance in only a small way. Replacing a washer is very easy, and involves removing the rope, untying it at the point nearest the worn or broken washer, replacing the washer and retying the rope. Regular greasing of the axle at the bearings is desirable. As every moving part of the pump is easily visible, repair and maintenance requirements will become immediately obvious. The most likely part to fail is the log used for the rope guide, as this is subject to continuous rubbing and is under water. This is easy to replace.

SECTION 5

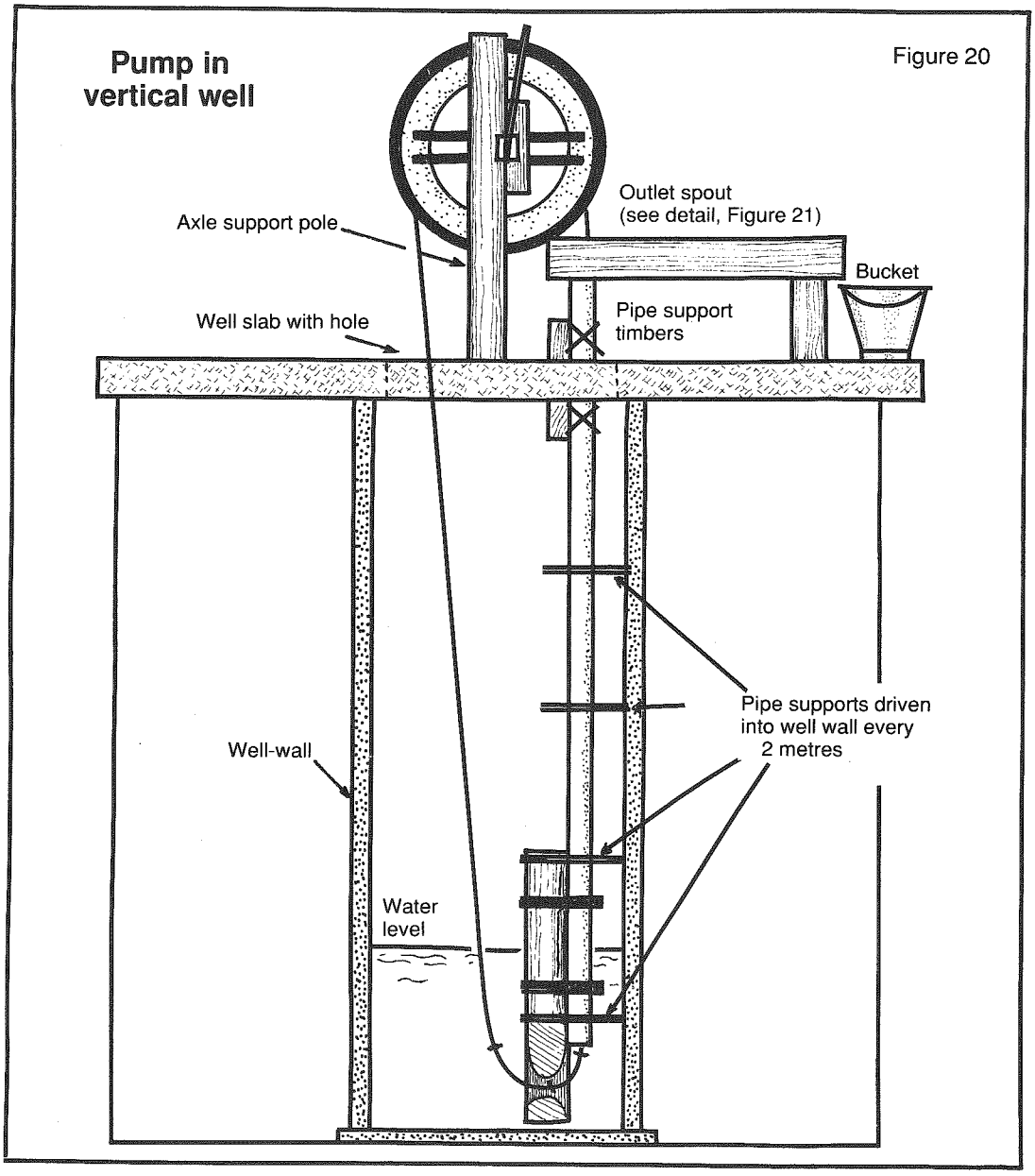
Pump in a vertical well

Installation

Although this design is intended primarily for use in open unlined wells, the rope and washer pump is also suitable for operation in a vertical lined well as shown in Figure 20. The most important modification is the addition of a

Pump in vertical well

Figure 20



suitable outlet spout (Figure 21). A trough, 1.0m long, 20cm wide, 10cm high and open at one end, is made from wooden boards or sheet metal. A hole is cut in the bottom near the closed end of the trough. The pipe is passed up through this hole, protruding by 2 to 3cm. A rubber strip is bound around the pipe above and below the hole to prevent leakage. When the water emerges from the pipe it spills into the trough and flows out the open end into a bucket or other vessel.

At installation, pipe support rods should be driven into the well wall at 2-metre intervals. The pipe is lashed to these supports using rope or rubber strips. Two support timbers are lashed to the pipe above and below the hole in the well slab. These prevent vertical movement of the pipe, either downwards due to the pipe weight when not in operation, or upwards because of the pull of the rope during operation.

Well protection

In the interests of safety and if the pump is to be used to supply drinking water then the well will need protection. Good protection can be achieved by building a brick wall surround as shown in Figures 22 and 23. A slot is left in the side walls so that the axle may be inserted and removed. The wall can then act as the axle support, resting on a wooden bearing block. The slot above the axle may be filled using another wooden block. A removable lid should be fitted on top of the brick surround.

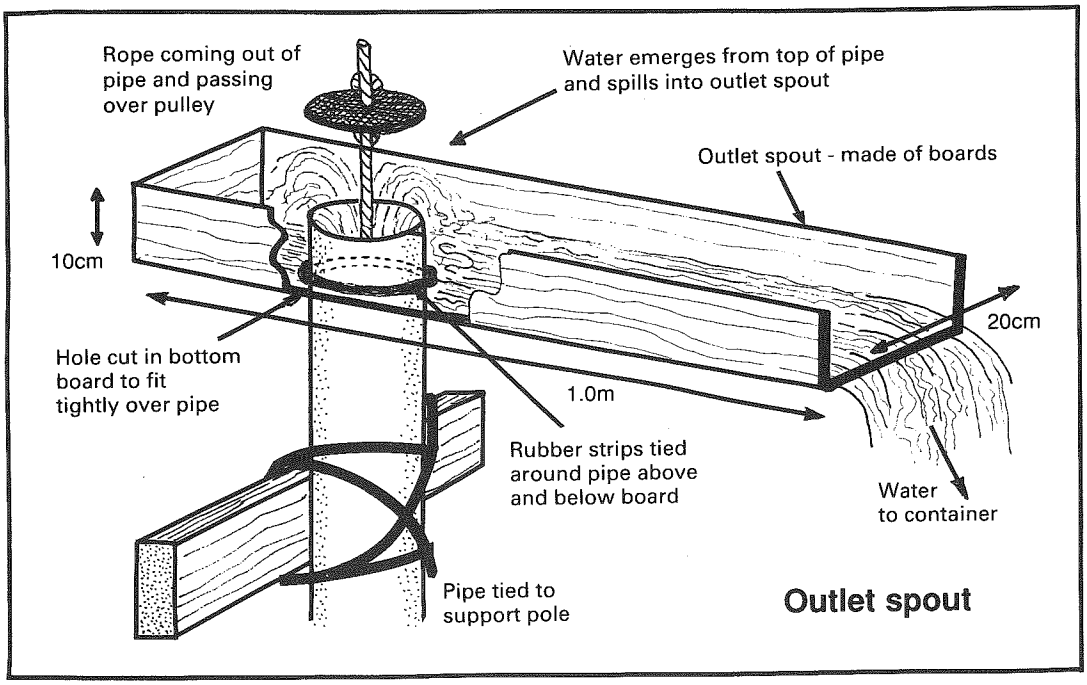


Figure 21

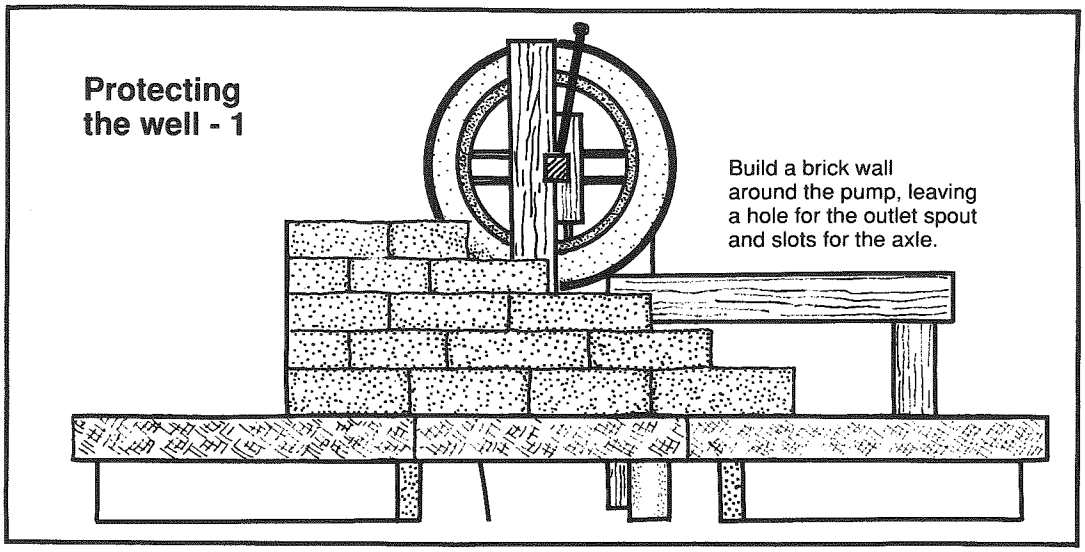


Figure 22

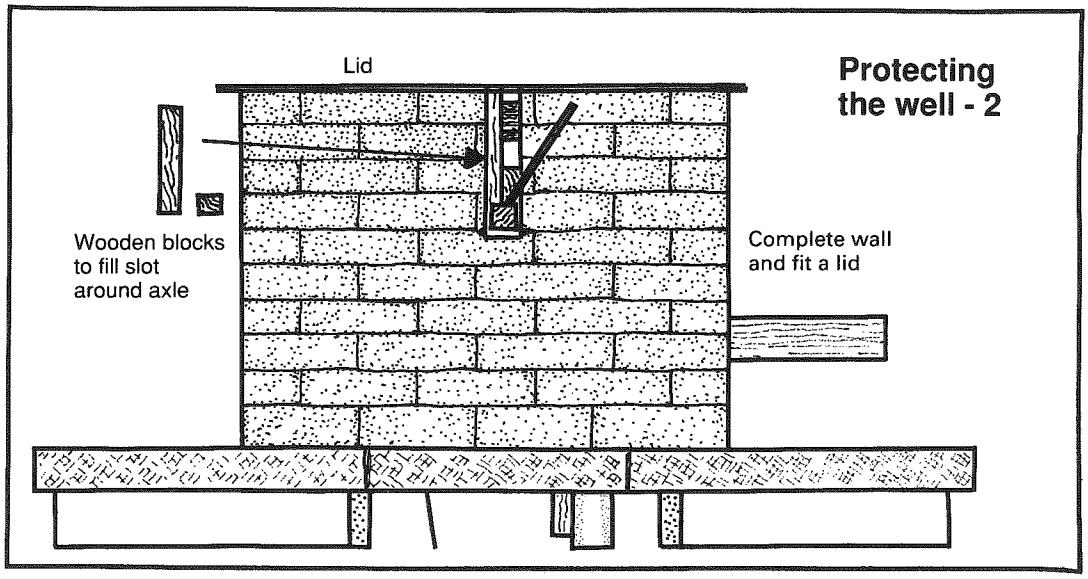


Figure 23

SECTION 6

Cost

As a guide to the cost of the pump, the following example may be used as an illustration. Prices are in Zimbabwe dollars and were current in 1989.

Materials		Cost (Z$)
Pipe: 6m length @ Z$3.00/m		18.00
Round bar, 8.5m @ Z$1.00/m		8.50
Rope, 12m @ Z$1.10/m		13.20
Old tyre, for washers and pulley		1.00
Timber		7.50
Wire, rubber straps, nails		5.00
Sub Total (pump only)		Z$59.20
Including a 10% contingency		Z$65.00
TOTAL PUMP MATERIAL COST	say	**Z$70.00**

(NOTE: In 1988 Z$1.00 = UK£0.30 = US$0.50 approximately, and so the total cost of the basic materials was, in this situation, UK£18 or US$30.)

In addition poles will be needed to support the pump and if a drum and pipes are used for distribution, then these items must also be bought or procured.

The cost of labour has not been included.