Hand drilling a shallow tube-well in Zimbabwe and fitting a simple “Bailer-bucket” for water lifting

Peter Morgan

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**Introduction**

The construction of the lighter duty, simple hand operated drilling rig has been described in another manual and was designed for drilling shallow tube wells in softer soil formations, which occur in some areas of Zimbabwe. Currently the drilling stems extend to a maximum of 12m. Staff members of the Ministry of Health and Child Welfare are familiar with local shallow ground water conditions in Zimbabwe. A depth of 12m is suitable for the use of this simple rig in combination with simple water raising devices like the “Bailer-Bucket” Pump and Blair Pump.

This manual describes the test drilling of a tube-well in Epworth, near Harare, Zimbabwe and the construction and fitting of a PVC casing and filter mechanism. It also describes the construction of a simple “Bailer-Bucket” pump and the head works at the head of the tube well. Of particular significance is the part played by the family itself by making the water raising device – a tubular bucket fitted with non-return valve and handle. The design of the “pump” is very simple and easily made within the home. The chances of continued operation and maintenance are this considerably improved.

The well head (head-works) has been designed in such a way that the PVC casing can be withdrawn when the water table drops and the tube-well deepened. The best time to dig wells and drill tube wells in Zimbabwe is in late November, when the water table is at its lowest. However this is not always practical. The ability to deepen the tube-well is therefore important. Wider diameter wells can be deepened at any time if the water table falls, since access is easy through the head works. This has not been the case for the great majority of hand drilled tube wells, which are generally abandoned when they dry. The revised method is described here.

The tube well – bucket pump combination has particular significance since the quality of water should be high. This is because the well chamber is narrow and buried deep. The high rate of change of water in the system means that fresh water enters the well chamber from the aquifer at a fast rate and is immediately discharge through the tubular bucket at the surface. This method deserves far greater attention.

**Peter Morgan**  
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**Acknowledgement**

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Stages of construction

Before the tube-well is drilled certain preparations need to be made. These include:

1. Preparation of complete drilling rig components
2. Preparation of suitable lengths of 110mm class 4 PVC casing
3. Construction of bottom filter unit for PVC casing
4. Construction of tubular buckets made from 90mm class 10 PVC, fitted with foot valve, handle and rope
5. Collection of PC 15 cement and bricks to make head works
6. Construction of upper concrete cone (mounted around upper PVC pipe)
7. Construction of lid for the tube-well
8. Provision of short chain and locks (if system is to lockable)
9. Collection of components for family to make spare buckets

Siting

The location is agreed by the family and health official and a suitable distance (30m) from pit toilets. The soil should be soft and penetrable by the light duty rig. An approximation of the water depth should be known. This should not be greater than 10m for this initial testing period for the concept. This can be judged from existing wells in the area. Maximum drilling depth should be 12m.

Demonstration sites

It is advisable to make a demonstration site which is able to show prospective families the type of technology. With the bucket pump, there is the simpler option where the bucket is raised directly by rope, by hand. This is the simplest and cheapest. Then there is the option which raises the bucket on a windlass system. This is mounted on treated gum poles which are mounted in a concrete base. The bucket pump can be upgraded from one system to the next.
Preparation of casing and casing filter

Depending on the final depth, 12m of PVC casing will be required. In addition the casing filter unit must be made.

The casing filter unit.
This is a short 50cm length of PVC casing which has been drilled with many 4mm holes in the side and filled with washed 6mm gravel. The base is fitted with a concrete plug and the top with a stainless steel screen. This filter allows water to enter the casing from the bottom. Water flows from the aquifer, into and through the gravel pack and up into the base of the casing.

Construction

50cm length of 110mm PVC casing and a short 20mm section. The short section is filled with high strength concrete 1 part PC 15 cement and one part washed river sand. This is allowed to set and will form a plug to be bonded into the bottom of the casing.

Another PVC ring is cut and a circle of stainless steel screen also cut about 130mm in diameter.
Using a bonding agent like “Pratleys white” the stainless steel screen is inserted into the top of the PVC pipe and held in place by the PVC ring.

A measured quantity of 6mm granite chips is then washed and dried. This is then inserted into the PVC casing leaving enough room for the concrete plug to be inserted.

The concrete plug is then inserted into the PVC tube. If the plug is tight, the end of the PVC tube will require heating carefully before the gravel is introduced, then the plug is introduced being bonded again by a product like “Pratleys white.” The filter unit forms the lowest part of the PVC casing which will later be inserted into the tube-well drilling.
Preparation of the bailer/bucket

A 50cm length of 90mm PVC pipe (class 10) is cut with an extra ring cut the same length as the brass non return valve. 1/2 inch, ¾ inch and one inch brass non return valves can be used for the bucket pump.

The valve is placed inside the cut piece of PVC pipe and the space between the valve and pipe filled with a very strong mix of concrete – one part PC15 cement and one part washed river sand. This is covered and left overnight.

The following day the valve plug is left to harden under water for a day and then the PVC ring is cut and the concrete plug removed and allowed to dry.
Using a bonding agent like Pratleys white (an epoxy cement) the plug is pushed into the base of the pipe. The pipe will require gentle heating over a flame to soften it so the plug can be introduced. The bonding agent is applied to the plug before being pushed into the pipe. Tests are being conducted where the concrete plug is pushed into gently heated PVC pipe without bonding.

The ring of PVC pipe used to mould the valve plug is cut so it will fit inside the top of the PVC pipe. It is then bonded to the inside of the bucket pipe with PVC solvent cement or an epoxy cement. Two holes are drilled (or burnt with a steel nail) through the thickened end of the bucket pipe.

A suitable handle made of wire is now prepared. This can be made of thicker wire or doubled up thinner wire. Together with the rope or strapping used to raise and lower the bucket, the “pump” or water raising device is now ready.
Preparations at the drilling site.

The tripod is set up by first attaching two of the legs to the upper tripod, then raising the tripod on 2 legs, then fitting the third leg in place. The third leg is held in position with a stout wire. The “upper stem” is passed through the hole in the upper tripod ring, and can sit, whilst not in use, on the hook attached to one of the legs.

Method of linking the stems together. The stems (and legs) are made of 40mm steel box tube, a cheaper material than steel pipe. The stem connectors are made of 50mm box tube, with inserts to reduce the gap between box tubes.
The connectors are held in place by bolts as shown.

Method of attaching cross bar to stem. The cross bar attachment is made of a strong U bracket welded to a 50mm steel pipe. Holes are drilled in the bracket through which bolts are passed to hold the unit in place on the drilling stem. The 40mm cross bar fits through the 50mm pipe. Holes are drilled through the stem at about 30cm intervals, so the position of the cross bar can be adjusted.

The auger stem is placed directly under the centre of the tripod (a plumb line is useful). The upper stem is then lowered over the auger stem, the connecting bolt fitted and the cross bar fitted as shown above. The drilling can then begin.
Each time the auger is filled with soil, it is raised and the cuttings extracted in a pile nearby. A rod or grass cutter is a useful tool for extracting the “cuttings.”

As the depth of drilling increases extra stems are added to the lower auger. The upper stem remains the same length. At first the lower stems can be lifted by hand but as the stems increase in length and become heavier, the pulley system will be required. This has a rope, 2 pulleys and a D shackle for attachment to the drilling stem through a small strong rope tied in a loop. The rope passes around a nail passed through holes in the drilling stem. When changing stems, the lower stems are supported by a plate (initially wood, later steel) with a slot cut in it. A 150mm steel nail passes through holes in the stem, and rests on the plate. The upper stem is detached once the lower stem is secure and stored on the hook attached to one of the tripod legs.
Photos showing pulley system

Family and community effort

Members of the family and community can participate in the drilling activity. At least one experienced rig operator is required to supervise the drilling process. Care is required at all stages of the drilling, which will be a very new concept for most people. The stems are numbered, so the sequence can be followed.
The cross bar adaptor can accept long and short cross bars made of 40mm box tube. The cross bar and adaptor are held up by 15cm steel nails placed through holes made in the stem. Spare nails and spare bolts are held in a tubular container attached to one of the tripod legs.

**Entering the water table**

As soon as the auger becomes wet the water table has been reached. Drilling continues as normal.

Keep going as far as possible through the water table. In this case the sandy soil is also filled with clay which holds the cuttings within the auger. A bailer may be required to penetrate looser formations.

**Preparing the casing**

Sufficient 110mm PVC casing is prepared beforehand to line the anticipated tube-well. Connectors for the casing are also required.
Using PVC solvent cement, the filter is attached to the lower end of the casing. The bottom of the lower casing is expanded to receive the filter.

The total depth of the tube-well can be measured with a string and weight. The total length of the casing can then be estimated with a generous allowance above ground level (0.5m). The casing rises above ground level to pass through the head works and upper supporting concrete ring (see later).

A small basin full (about 5 litres) of washed 6mm gravel is then poured carefully down the tube well to form a gravel pack at the base of the drilling. The full length of casing has been prepared.
The casing is then lowered slowly and carefully down the tube-well. A 10li bucket full of well washed gravel is now poured down the sides of the casing. This forms a gravel pack around the section of casing drilled with holes. In this case, the gravel pack is not extended up the full length of the well. The aim is to make the casing extractable when further well deepening is required.

The concrete plate which has been protecting the drilling is now removed and replaced by an upturned plastic basin with a hole cut in it. A weak mortar made of cement and pit sand is made up and covers the basin.

At an earlier time a concrete slab 1.3m in diameter has been cast with a 40cm diameter hole cast in the middle. This will be used as the well slab. Before the slab is fitted two courses of bricks are raised in a ring to support the slab.
The space between the brickwork and the casing is filled with soil and the slab mounted on the ring of brick work.

More soil is added under the slab and then a mix of pit sand and cement is added to the level of the slab. When the tube-well is deepened later, this mortar will be removed to gain access to the casing and tube-well.

The upper casing support ring (made earlier) is now placed on top of the newly mortared slab. This has been made with two chain links which will allow the well head to be locked when not in use. The casing is now cut off level with the top of the support ring.
The annular space between the support ring and the casing is now filled with weak cement mortar.

Bricks are now laid to form the well slab outer wall and the water run-off channel. The following day work on the head works continues. Note the lid covering the casing. This will be protected with a chain and padlock.

The finalised head-works and locked tube-well lid.
A lemon tree is planted at the end of the water run-off

Testing the tube-well – bucket pump system.
Initial testing and use
Once the head-works has been finished and the tree planted, the tube-well-bucket system can be put to use. At first the water contains a lot of clay. This is to be expected. Clay is present within the sandy layers and must be cleared. When the bucket hits the water, it creates a shock wave in the well chamber and this loosens the clay. Eventually the sandy soil around the well chamber is cleared of clay and the water becomes completely clear. A combination of ½ inch and one inch non-return valves were tested on this site and this revealed how much more quickly the tube-bucket filled when the larger valve was used. The 25 litre container shown in the photo above could be filled in 2.5 minutes. That is a delivery rate of water of 10 litres a minute. 25 litres of water is sufficient for a family of 6 for drinking and cooking, with extra required for washing, gardening, and other cleaning activities.

Teaching family members now to make the bucket pump.
The bucket pump is a very simple device and its construction is easily taught to families. It is accepted that the PVC tube and non-return valve are not commonly available in the rural areas, but if systems of this type are promoted, then provision should be made for extra buckets to be left on site as spares. A small “kit” of parts could also be left on site.

This family training as part of the procedure is considered important. Compared to the simple bucket, the bucket pump has only one extra part – that is the non-return valve fitted into the base of the bucket tube. Family members, especially school children, can be trained now to make the complete bucket pump, with a few components provided. At least one spare bucket should be made and preferably two. The following photos show how a family in Epworth was trained in the construction of the bucket with valve.
Items required for the demonstration of “bailer-bucket” construction

1. 50cm long 90mm class 10 PVC tube
2. Brass non return valve (1/2”, ¾” or 1”). Preferably 1”.
3. Shorter section of the same tube, cut to the height of the valve.
4. Small quantity of Portland cement
5. Small quantity of river sand
6. Wire for handle
7. Large nail for drilling holes through PVC
8. Hack saw
9. Pliers
10. Knife for mixing and adding cement
11. Small bottle of PVC solvent cement
12. Rope or chord to attach to the bucket

The bucket construction in photos

The parts are assembled. A wood fire is lit nearby, as in one part of the procedure, the PVC pipe must be heated to soften it. A small mix of river sand and Portland cement is made in equal proportions (1:1). A small measuring “cup” is used. Water is added to the mix to make a paste, which is then added to the space between the valve and the short length of PVC pipe.

The space between the PVC and valve is filled with the strong cement mix. As the space is filled, it is rammed in place with a small stick. Finally the cement fill is smoothed off with a knife. This is left to harden overnight, and the following day it is placed in water to assist curing. The longer it cures, the stronger it becomes.
Once the concrete has set hard the PVC can be removed by cutting with a saw.

The block of concrete with the valve inside can then be removed from the PVC and placed on the ground.

The end of the PVC pipe is carefully heated over a fire to make it slightly softer. The softened pipe is then pushed over the plug of cement holding the valve inside.
The short length of PVC pipe is now cut in 2 places so it will fit inside the top of the longer tube. This increases the wall thickness at this point. This is where the wire handle will be fitted.

Using PVC solvent cement, the short length of PVC is bonded to the inside of the PVC tube. The cement is applied to the inside of the long pipe first and then the outside of the short pipe. Then the short pipe is placed inside the top of the long pipe and pushed in and rotated. This makes a good bond.

A large nail is heated on the fire, then pushed through the tubes half way down the thickened section. This makes the hole, through which the wire handle will fit.
The wire handle can be made of thicker or thinner wire. The best is thicker wire. If thinner wire is used, the wire should be doubled up. The wire is inserted through the holes and secured.

The home-made buckets (2 were made) are now complete. Suitable ropes are now attached to the handles off the buckets, which are now tested on the tube-well. The bucket fitted with the larger 1 inch valve was more popular as it filled up more quickly. Whilst in use, the free end of the rope is attached to the chain link inserted in the concrete upper ring fitted around the PVC casing. When not in use, the bucket and rope is stored in the house and the lid fitted and locked in place.
Deepening the tube-well

The standard method of casing tube wells in Zimbabwe has been to drill down into the water table as deep as possible, fit a slotted casing and then introduce a gravel pack around the casing from top to bottom, plugging the top half meter or so with a sanitary seal of concrete. This method makes it impossible to withdrawn the casing in order to deepen the drilling. In order to deepen a smaller auger is required to cut within the existing casing. Such augers have not been used in the Zimbabwe program and fitting new smaller casings deeper down is difficult and also the diameter may be too small to introduce the bucket bailer pump.

In this case a filter has been fitted at the base of the PVC casing and penetration of the existing casing to deepen is impossible.

In consequence of these restrictions, the method of casing and introducing a gravel pack has been modified to make extraction of the casing possible when the tube well dries up. Many tube wells have been drilled at times of the year when the water table is not at its lowest.

The gravel pack was placed around the PVC casing around the bottom half metre only, which the rest of the casing fitting inside the drilling without a surrounding gravel pack in the annular space. This is possible because the filtering mechanism is already fitted to the lowest part of the casing.

The method of extraction involves breaking up the collar surrounding the casing on the head works, thus gaining access to the upper most part of the casing. To extract the casing considerable pulling power is required. This is achieved by drilling who holes in the upper part of the casing – passing through a steel rod and then using the rod to extract the casing. This method proved successful.
Chip away and remove the concrete collar surrounding the PVC casing at the head of the tube well.

Using a knife drill two holes in the upper end of the PVC casing. Pass a steel rod through and twist and pull.

The casing can be withdrawn fully
The casing is fully withdrawn. On the right the lower filter section.

The casing is stored pending the deepening of the tube well.

Further deepening
The auger bit can now be re-introduced into the existing tube-well to continue the drilling. Since the lower parts of the drilling will be filled with gravel, it is best to introduce some soil into the drilling which combines with the gravel to form a mix which is more easily held by the auger. The drilling continues until the desired level is reached. Then an extra length of casing is added to the existing casing sufficient to take up the increased length of the drilling. The head-works is then completed as before. Drilling such tube-wells is best undertaken during the months of November and December in Zimbabwe when the water level is at its lowest.