

HAND AUGERED GARDEN WELLS

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[Note there is a third edition out that contains illustrations and technical drawings of the tools. You can obtain a copy by writing to Bill Phelan, Regional Representative, Lutheran World Relief, BP 11624, Niamey, Niger.]

INTRODUCTION

Lutheran World Relief (LWR) has worked with gardeners in Niger since 1978 and has constructed more than 3000 LWR type concrete wells. Many other organizations are currently using similar well construction methods to provide water to villagers for dry season gardening. Even with these massive construction efforts, the demand for wells is greater than the capacity to construct them. Many gardening sites still suffer from a lack of water even though it is often less than 10 meters below the surface. In 1987, LWR began looking for a technique that would allow wells to be constructed more rapidly and at a lower cost than the now common LWR type concrete wells.

In the past 10 years the availability of PVC well casing has increased in West Africa and it is now the accepted norm for lining small diameter wells. PVC is lightweight, durable and easy to work with. LWR began investigating methods for installing PVC well casing for shallow wells in 1987. In early 1988, several hand augered wells using PVC casing were installed in the Magaria Arrondissement. In May 1988, two wells were constructed at a site near Niamey and are currently being used for dry season gardening. Following the publication of the first edition of this brochure in February 1989, interest in the technique has grown resulting in the construction of more than 150 wells throughout Niger. The technique has also been demonstrated by LWR in Chad and Mali. The first part of this brochure describes the current method of installing a hand augered well and the second part gives a description of the tools and detailed plans of how to make them.

INSTALLATION PROCEDURE

Description of the System

The technique that has evolved is similar to methods used to hand drill tube wells for village water supply in other parts of Africa. The major difference between the LWR system and other systems is that the equipment used is lightweight and designed for augering shallow garden wells. Specialized augers have been developed to make the construction procedure easier. The LWR system uses hand augering techniques with direct installation of a PVC well casing and a specialized bailer to remove water from the well. A nylon or polyester filter covering the slotted PVC well screen eliminates the need for a gravel pack. This combination yields a durable, low cost gardening well that can be installed in less than six hours.

Small diameter wells have almost no storage capacity and therefore function best in an aquifer with a high hydraulic conductivity. For this reason they are best suited to former watercourses where the soils contain large quantities of sand and fine gravel. Aquifers with high clay or silt content and corresponding low hydraulic conductivity may be better suited to large diameter wells which incorporate greater storage capacities. Adverse soil conditions can make the installation of hand augered wells difficult or impossible. Stones, laterite or hard clay can prevent the augering of the well. If these conditions are encountered near the surface they may be broken-up, using a mining bar or pick and shovel, allowing augering to continue. However, if they are encountered deeper they often prevent the well from being completed. A possible alternative for hard formations is the hand percussion method described by Koegel (1975). Although LWR has not yet experimented with this method it seems promising for use either

on its own or in a combination with augering. For sites with sandy soils, clay loams or silt loams, hand augered wells provide an excellent alternative to large diameter, concrete lined, hand dug wells, at a fraction of the cost. The advantages of the small diameter well are numerous and include: 1. Ease of construction. A hand augered well 6 to 12 meters deep with 3 meters of pipe below the water table can be constructed in less than one day by one trained well digger and two laborers.

2. Cost of the Well. The cost of a hand augered well consists almost exclusively of the cost of the PVC well casing, which currently costs approximately US\$ 15 per meter in Niger. Additional costs including labor, filter cloth, well cover, and bailer add another US\$ 15 to the cost of the well.

3. Cost of Equipment. The tools needed to construct a hand augered well are simple and can be made locally at a cost of less than US\$ 200. These tools are lightweight and are easily transported to the site and can be used to drill a large number of wells.

4. Space Required. The well occupies almost no space in the garden - an important factor where space is limited.

The well, when completed, consists of a 140 mm diameter PVC well casing which penetrates at least 3 meters into the aquifer. The bottom 3 meters of the casing are slotted and covered with a nylon or polyester filter cloth. This filter prevents the entry of fine sand into the well and eliminates the need for a gravel pack. Some of the sands encountered in Niger are extremely fine, similar to finely ground flour, and pass through all but the finest weaves. The weave of the filter cloth is matched to the particle size of the sand in the aquifer. The use of filter cloth is an important feature of the system as used in Niger.

Method of Construction

The construction procedure is simple enough that villagers can learn the technique in several days. Construction begins with the augering of the starting hole, using a 180 mm diameter auger. The choice of auger is based on experience and dependent on the type of soil. In sandy soils a conical auger is used while in very hard soils a small diameter clay auger is used to drill a pilot hole which is then enlarged to 180 mm using either the conical auger or a large clay auger. Often a combination of several augers yields the best results. In extremely unstable soils some water must be added to the surface soil to prevent the hole from collapsing. After the first 0.5 meter there is usually enough moisture in the soil to support the walls during construction. If there is not, a small quantity of water is added to the hole to increase the cohesion of the soil. The auger is turned until it has descended 0.5 to 1.0 meter into the hole. It is then raised and removed from the hole to be emptied. As the hole is deepened extensions are added to the auger shaft so that augering can continue. The extensions must be uncoupled as the auger is removed from the hole for emptying in order to prevent bending of the shaft. Augering in this manner continues until the water table is reached.

When the water table is reached, the bottom of the hole will begin to collapse. This can be noted from the surface because the auger will be at a higher level when it is replaced in the hole after emptying, than it was when it was removed. At this point the casing must be installed.

The 140 mm diameter PVC well casing is assembled, using 1.5 meter and 3 meter threaded sections, until it is one to one and a half meters longer than the hole is deep. The bottom three meters of the casing are slotted PVC well screen and covered with a polyester or nylon filter cloth. After the casing is screwed together and placed into the hole, augering continues using a smaller diameter auger inside the casing. Care should be taken when installing the casing to

ensure that it is vertical. The bottom end of the casing is open to allow augering to continue below the bottom of the pipe. The well drillers must always be aware of where their tool is with respect to the bottom of the casing because if the tool passes too far beyond the end of the casing it may become trapped and be impossible to retrieve without removing the casing.

The 180 mm diameter auger is now put aside and augering continues inside the casing using a 110 mm auger. The choice of auger is dependent on the consistency of the soil in the aquifer. Two different augers have been used with success. One is an enclosed auger which is specially designed to work beneath the water surface in saturated sands. The second is a clay auger and works best in non-flowing soils with a higher clay or silt content.

The casing clamp is attached to the casing to allow a downward force to be exerted on the casing during augering. In sands the augering continues in a repetitive sequence of a turning motion followed by several up and down strokes, until the auger is filled. Then the auger is removed and emptied, again the extension rods must be uncoupled as they are removed from the hole. Frequently water is poured into the casing after it has been placed in the well to aid in the formation of a slurry, which has proven to be the easiest way to remove sand from the well. In heavier soils the clay auger is used with a rotary motion only.

In order to avoid losing the auger, a special cover is placed over the casing before the extensions are uncoupled to prevent the auger and remaining extensions from dropping into the well. As soil is removed from the well, the casing will descend under the weight of two people sitting or standing on the casing clamp. During this stage the well drillers are working either at ground level or on two empty 200 liter oil drums. The drums provide an elevated working platform which makes the work easier especially immediately after a new section of pipe has been added. When the top of the casing reaches ground level a 1.5 meter long section of pipe, is added to the casing. Augering continues until there are at least 3 meters of casing below the water table.

This procedure normally takes 4 to 6 hours to construct a well 6 to 12 meters deep in suitable soils. Augering of the starting hole in sandy soils frequently takes less than 1 hour. In heavier soils, augering proceeds more slowly and may take several hours. Augering after the water table is reached is more time consuming, 1.5 meters per hour is the average rate.

Ideally the lower end of the casing is embedded in an impermeable clay layer to seal the open bottom. Frequently this is not possible because the depth of penetration of the pipe into the aquifer is limited by the friction between the pipe and the soil and the inflow of fine sand through the bottom of the pipe. In fine sands as much as 0.3 or even 0.5 meters of sand may remain in the casing after completion of the well. If an impermeable layer is not reached a small sack made from the same material as the filter cloth is filled with gravel and placed at the bottom of the completed well to prevent further inflow of sand. If sand were to continue to enter the well it could cause the well to fill with sand and cease to function. Alternatively, if the entering sand is continuously removed with the water, the well will continue to function. However, this could lead to the formation of potentially dangerous cavities which may spontaneously collapse causing injury to persons or damage to the well.

The top of the well, which is between 0.3 and 0.5 meters above ground level is capped with a locking cover and integral protective ring. Made from 8 mm diameter rerod, the ring protects the top edge of the casing from abrasion caused by the bailer rope. The locking cover prevents children from throwing debris into the well. When it is not in use, the bailer can be left in the well to protect it from damage. A loop welded inside the cover can be used as an attachment point for the bailer rope.

SPECIAL TOPICS

Water Lifting

The hand augered well is adapted to a variety of methods of drawing water including bailers, hand pumps, and motor pumps. The simplest method is the bailer which has been used successfully by gardeners for small plots. The bailer is made from a 110 mm diameter PVC thin wall pipe and has a capacity of 7.5 liters. In a typical 6 meter deep well, five or six cycles are possible per minute yielding about 40 liter/min or 2.4 m³/hr. Most of the wells constructed to date have had sufficient capacity to be used with a bailer without any noticeable drawdown. The advantage of the bailer is that it is simple and can be manufactured at the village level. However, once garden size increases beyond about 1500 m², it becomes impractical.

A locally manufactured lift pump has been used on several wells with good results. The flow rate from a 6 meter well was measured to be 60 liter/min or 3.6 m³/hr. However, frequently encountered problems with lack of maintenance of hand pumps in rural areas of Niger have made LWR reluctant to pursue this option for the majority of wells constructed for subsistence gardeners.

Recent tests using a motor pump indicated that flow rates of 240 liter/min or 14 m³/hr are possible from a 7 meter deep well. Commercial gardeners have expressed interest in these wells which they plan to use in combination with motor pumps to produce onions, a high value export crop.

Potable Water

These wells can be used to provide potable water if several precautions are taken to prevent contamination of the well. If a bailer is used to draw water the cord must be prevented from dragging on the ground. Regardless of the method of drawing water, a concrete apron should be constructed to prevent ponding around the top of the well, thus reducing the possibility of surface contaminants flowing into the well along the casing. In addition, the annular area around the casing should be backfilled with a clay soil, again to reduce the risk of surface dirt reaching the aquifer. A minimum distance of 30 meters from latrines or other sources of fecal contaminants should be maintained.

Perched Water Table

Occasionally, when a perched water table is encountered before reaching the main water table, the hole will begin to collapse. This occurs when a water-bearing sand layer is encountered between two impermeable layers. If the discharge from the perched water table is insufficient to provide adequate water for the desired use, augering must continue. If the rate of inflow is small enough augering can continue. However, if the hole is refilling with sand faster than it can be removed the casing must be installed. If the 140 mm diameter casing is used augering continues inside the casing. A problem that is frequently encountered is that the casing refuses to descend because of a small lip of hard soil that remains under the edge of the casing. Two solutions are possible: the use of an eccentric auger that cuts a hole larger than its diameter or the use of a 200 mm diameter casing to prevent sand from entering the well. The 200 mm diameter casing allows standard 180 mm diameter augers to be used inside it and if the large casing is embedded into the impermeable layer it can prevent further entry of sand into the well. Augering can then continue in the standard way and when the well is completed the 200 mm casing can be jacked out of the ground. Both of these techniques are experimental and have yet to be perfected but they are presented for information.

Hard Pans

Pans of hard clay, or laterite can slow the process considerably or completely stop the drilling process. When hard clay is encountered the rate of augering reduces to centimeters per hour instead of meters per hour. One solution is to relocate the well especially if the area is known to have pockets of hard clay or laterite interspersed with formations that are more amenable to hand augering. LWR will be experimenting with the use of hand percussion in combination with augering to try to penetrate hard pans.

Fine Sand

A phenomena encountered in saturated fine sands is the tendency for the sand to suddenly flow a meter or more up into the well casing. This often occurs when the well is nearing completion. The auger is removed to be emptied and when it is replaced the level of sand inside the casing is found to be a meter or more higher than it was when the auger was removed. Adding water to the casing before removing the auger has helped in some instances but patience and persistence are usually required. These wells require the use of a gravel plug to prevent further sand from entering via the open bottom of the casing. The gravel plug should be installed when as much sand as possible has been removed from the casing. There may be as much as half a meter of sand still in the casing when the plug must be installed. Using a looped rope, the plug should be lowered slowly to prevent it from becoming wedged in the casing before reaching the bottom. Once the plug has reached the bottom the rope may be removed and the plug tamped gently to expand it tightly against the walls of the casing.

PVC Casing Removal

If for any reason the well runs dry or requires other major repairs the casing can be easily removed and reinstalled. The procedure for removal is to attach the casing clamp to the casing and to use two jacks to lift the casing out of the ground. This method can be used even after the well has been in the ground for several years. With threaded casing there is no loss of pipe, while for glued casing the loss is limited to the portions of the pipe that have been glued. Frequently the filter cloth is lost or damaged during the removal of the casing.

The ease of salvaging the majority of the materials is another advantage of a hand augered well over a concrete well. In the case where the well is unsuccessful there is little lost investment. The pipe can be removed and reused.

MATERIALS

Well Casing

LWR uses commercially available 140 mm diameter PVC well casing and well screen. The well screen comes with 1.0 mm wide slots cut perpendicularly to the axis of the pipe. The pipe is threaded at both ends with the depth of the threads being only one-half of the pipe wall thickness, resulting in joints that are flush inside and out. Having a smooth interior surface is especially important when using a bailer to draw water because the bailer has a tendency to catch on any protrusion. The 3 meter long sections of both solid and slotted pipe are standard, but the 1.5 meter sections need to be ordered specially. These short lengths allow the well drillers to work at ground level or on two empty 200 liter drums, whereas 3 meter sections would require a drilling platform 2.5 meters high.

An alternate method is to use a reusable section of 1.5 meter pipe that is unscrewed and replaced with a 3 meter section when the top of the short section reaches ground level. This method requires that a joint 1.5 meters below the surface be unscrewed and another pipe screwed in. Care must be taken not to unscrew a lower joint by mistake.

The well casing can also be made from 6 meter lengths of pipe cut into 1.5 meter lengths. This requires forming bell joints or the use of couplings so the sections can be joined together. Bell joints are made by heating an end of the pipe in hot oil until it is soft and then inserting another piece of pipe into the softened end to form a bell. The pipe is then cooled in water. Pipes using bell joints or couplings must be glued together at the site. Under hot weather conditions the glue dries very quickly which leads to weak joints and subsequent joint failure.

Filter Material

A good filter material must be permeable to water but must prevent the entry of fine sand into the well. LWR has used both nylon and polyester cloth for this purpose. It is important to use a 100% synthetic fabric that will not decompose rapidly in the soil. Polyester is resistant to deterioration in the soil as long as the soil pH is between 5 and 9. Another factor in the choice of fabric is its resistance to tearing, weaves that do not tear or run are required. Using 100% polyester thread, the cloth is sewn into tubes that fit snugly over the slotted well screen. The filter is attached to the screen with wire and tape to prevent it from dislodging during well installation. To ensure that the cloth will not slip during installation grooves are cut into the casing so that the wires holding the cloth are embedded into the casing.

TOOLS AND THEIR FABRICATION

The following paragraphs contain descriptions of the tools used for hand augered well construction and how to make them. Detailed plans for the fabrication of the tools can be found in the Appendix.

Fabrication of the tools requires a competent welder with access to metal cutting tools and an electric drill. The descriptions that follow are of tools that work well under soil conditions found in Niger. When making new augers imagination plays a key role and modification of cutting angle and pitch of auger flights may make a given auger work better in one soil type than in another. Minor variations in auger shape have not proven to be extremely critical although some sets of tools have performed slightly better than others.

The most critical part of the tool-making process is the construction of the extensions. The square ends must be aligned perfectly with the long axis of the extension or it will be difficult to drill a vertical well. In addition, all the holes for the securing pins must be placed accurately. If these holes are not positioned exactly in the same place on all extensions they will not be fully interchangeable.

Conical Auger

The conical auger is a spiral, shaped like a wood screw, with the largest flight 180 mm in diameter. It looks complicated to build but by using the templates in the Appendix to cut the flights from 3 mm thick sheet steel, the fabrication becomes quite easy. The flights are then stretched and welded to the 27 mm pipe so that there are 100 mm between them.

If other size conical augers are required the templates can be designed by dividing the difference between the desired outside diameter of the auger and the diameter of the center hole by four times the number of flights. This yields the decrement for one quarter of a flight starting from the outside diameter. The template is made by plotting these points on graph paper and connecting them with a smooth curve. The diameter of the center hole is calculated with the following formula:

Enclosed Conical Auger

The enclosed auger was originally designed by Ken Hills and works very well below the water table in sandy soils. This auger combines the actions of a sand bailer and auger and is

used in a combination of rotary and up and down motions. It is similar in shape to the above auger but the largest flight is equipped with a leather flap valve. The flap valve prevents sand from flowing out of the auger as it is raised even when working two or more meters below the water table. The top two flights fit snugly inside a 450 mm long length of heavy wall 110 mm diameter PVC pipe. Once the auger is out of the hole the PVC pipe can be tapped gently and slid upward to empty the auger. The plunging motion of this auger also surges the well which increases the permeability of the aquifer adjacent to the well, thus increasing the capacity of the well.

Clay Augers

The clay augers are used in soils with high clay content. They can be used both before or after the water table is reached and cut more quickly than the spiral auger when working in clay. The closed clay auger is made from a 450 mm long section of steel tube that is of the desired diameter (either 180 or 110 mm), the bottom end of which is cut to form spoon-shaped cutters which are sharpened on their leading edges. Open clay augers can be made from strips cut longitudinally from pipe and formed as shown.

Auger Extensions and Handle

All augers are approximately 1 meter long and are equipped with a female joint made from a 35 x 35 mm square hollow section. The 1.5 and 3 meter long auger extensions are made from 27 mm diameter galvanized steel pipe. Handle attachment points are placed every meter along the length of the 3 meter extensions and at the midpoint of the 1.5 meter extension. One end of the extension has a male joint made from 30 x 30 mm square hollow section which fits into the female joint on the auger. The other end of the extension has a female joint identical to the one on the auger. The number of 3 meter extensions needed depends on the depth of the well to be drilled but each set of tools requires only one 1.5 meter extension. The auger handle is a simple tee that slips over the auger or auger extension and is secured by means of a pin connection. The placement of the holes for the pins is critical to ensure interchangeability of the extensions and augers. During use the pins are secured with short lengths of wire to prevent them from dislodging which would result in the loss of the auger and extension.

Casing Clamp

The casing clamp is placed around the PVC pipe and tightened to allow a downward force to be exerted on the casing. It is made from a 150 mm long section of steel pipe, approximately the same diameter as the casing. The steel pipe is cut longitudinally and is hinged so that it can be tightened securely. Handles are welded to the steel pipe for people to sit or stand on to provide the downward pressure necessary to force the casing into the ground. If the well runs dry or has insufficient water the casing clamp can also be used in combination with two jacks to remove the casing from the ground.

Casing Cover

The casing cover is a simple but important tool. It supports the extension rods during coupling and uncoupling and prevents the loss of the auger and extensions. It is made from a 3 mm thick piece of plate steel with a notch cut in it. The tab from the notch is not removed but is bent under to prevent the cover from sliding off the casing.

Bailer

The bailer is simple to make and simple to use. Village artisans have been taught to make and repair them in the village. It fits easily inside the well and has a capacity of approximately 7 liters.

Initially heavy wall PVC pipe was used but the disadvantages associated with higher cost and weight do not seem to be offset by significantly greater durability. Currently the bailer is made from an 0.83 meter long section of thin wall 110 mm PVC pipe that is reinforced at the top and the bottom using heavy wall PVC pipe. A lifting loop is attached to the upper end of the bailer, to provide a retrieval point, should the rope break.

Several different designs have been used with the major differences being the bottom valve. Two designs are being tested at this time, in both cases the the disk for the valve is made locally from cast aluminum. The first design is a simple flat disk with four large holes in it and a rubber flap valve attached to the disk in the center by a bolt. This design is simple to make and very durable, but it requires that the bailer be tipped to empty it. The second design was developed in response to farmers' complaints which indicated that tipping the bailer was too time consuming, especially for gravity irrigation. The "improved" model uses a poppet valve which allows the bailer to be emptied simply by placing it on a hard surface (stone or concrete slab), and the water flows out the bottom. LWR is also experimenting with a 2 meter long bailer that has a capacity of 17 liters. Its design is similar to the "improved" model but a lifting frame and pulley are required to raise it.

Additional Tools

In addition to the specialized tools described above the following hand tools are required for installation of a hand augered well: a hacksaw, a hammer, a screwdriver, two adjustable wrenches, a pair of cutting pliers, and a half round file.

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