Realizing the potential of hand-drilled wells for rural water supplies

KERSTIN DANERT

Globally, hundreds of thousands of hand, or manually drilled wells provide rural dwellers with water for agriculture and domestic use. The four distinct types of manual drilling are: augering, jetting, percussion and sludging, with variations on each. They are all suitable for niche hydrogeological environments. Different techniques are being utilized in over 20 countries worldwide. Despite its apparent affordability and suitability for local private enterprise, the full cost of hand-drilled wells can still be prohibitive for some end users, particularly if no income can be generated from the investment. There is need for much more collaboration between organizations involved in developing and promoting the technologies, and more lesson-learning from conventional drilling practices. Lack of proper understanding of groundwater resources is a barrier to full exploitation of the technology. More emphasis on monitoring the long-term sustainability of hand-drilled wells including proper diagnosis of the reasons for breakdown is required.

Keywords: boreholes, drilling, cost-effectiveness, private sector, groundwater, wells, hand drilling, manual drilling

The Joint Monitoring Programme (JMP) 2006 data estimates access to improved water supplies in sub-Saharan Africa to be 58 per cent (WHO/UNICEF, 2008). Thus some 276 million people in the region still require improvements to their water supplies to reach the Millennium Development Goal (MDG) of 75 per cent. This reality, coupled with a high dependency on groundwater means that many boreholes need to be drilled. If one assumes that only 37.5 per cent of these 276 million people will benefit from a borehole (serving 300 people) and 12.5 per cent will use a borehole with a mechanized system (serving 2,000) people, over 360,000 boreholes still need to be drilled. This equates to about 40,300 per year from 2006 to 2015. Requirements for irrigation increase this figure even further.

> To meet the MDG targets for sub-Saharan Africa, 360,000 boreholes still need to be drilled

Many stakeholders have raised concerns about the high costs, variable construction quality and the inadequate number of boreholes drilled in sub-Saharan Africa.

Manual (or hand) drilled wells cost anything from US$20 to about $3,000, depending on the location, technology used, geology and

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hydrogeology. Given that conventionally drilled wells in sub-Saharan Africa can cost from $2,000 to $20,000, manual drilling, where feasible, could provide considerable savings for the provision of rural water supplies. Despite the tremendous potential of hand-drilling technologies to provide water at low cost, they are not well known by many WASH (water, sanitation and hygiene) sector professionals, and in some cases are not considered to be acceptable. On the other hand, the apparent simplicity of the technology should not lead us to consider it as a panacea for rural water supplies.

Manual drilling, where feasible, can save money

This paper provides a brief overview of hand-drilling techniques, examines the roles and reach of the technology, and sets out the main opportunities and challenges in harnessing its potential to improve rural water supplies for both agricultural and domestic use. It draws on reports from a number of organizations, as well as the ongoing work by the Rural Water Supply Network (RWSN) to collate and document experiences of manual drilling.

What is manual drilling?

Hand, or manual drilling, comprises techniques that primarily rely on human energy. The tree in Figure 1 is an attempt to classify the

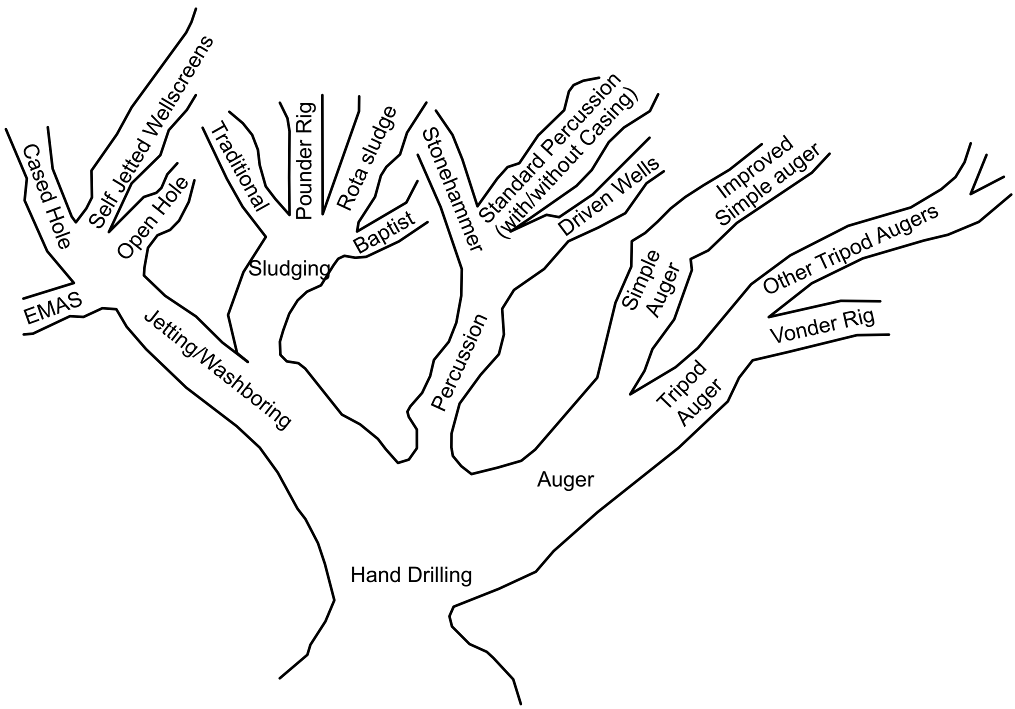

Figure 1. Hand drilling family tree

Box 1. Main methods of hand drilling

Hand augering involves penetrating the ground with a small-diameter borehole with a cylindrical or helical soil auger. This method can penetrate certain sands and silts and some clay formations.

Hand percussion and stonehammer drilling involve lifting and dropping a cutting tool suspended at the end of a rope. They are dry techniques, only adding a little water in order to remove the spoil (drill cuttings). In contrast the jetting and sludging methods use considerable amounts of water to wash out the spoil.

Jetting (also known as washboring) and the EMAS (**E**scuela **M**ovil **A**guas y **S**aneamiento Basico) technology inject water down and out of the bottom of a drilling pipe to wash the spoil up to the surface. Self-jetted well-screens are an improvement of the original jetting technique. The use of a cutting point when jetting enables more compact materials to be drilled. A tripod (or derrick) enables the technique to penetrate deeper. The EMAS technique uses a percussion action coupled with back and forth rotation of the drill bit to break the formation, whereas jetting is designed to penetrate mainly sands and silts with the force of the jetted water.

Sludging, and its more recent modifications (baptist, pounder rig and rota sludge) are all continuous drilling methods that allow the drilling fluid to flow down the annulus (i.e. the gap between the drill pipe and the drilled hole) and carry the cuttings up through the drill pipe. The baptist method, pounder rig and rota sludge have all tried to penetrate harder formations, with varying success. The pounder rig places more emphasis on drilling a vertical hole, whereas the baptist and rota sludge techniques emphasize very low cost wells. The baptist and rota sludge techniques can be combined with stonehammer drilling to penetrate harder formations (e.g. laterite) whereas the pounder rig is already designed for this.

Jetting involves injecting water down and out of the bottom of a drilling pipe to wash the spoil up to the surface

various hand drilling technologies, and thus assist the newcomer in navigating his or her way through a minefield of terms. Broadly speaking, there are four distinct types of manual drilling: auger, percussion, sludging and jetting. Over time, developers of one technology have drawn lessons from another or combinations of methods are used.

Hand drilling is only viable in certain hydrogeological formations

Hand drilling can be undertaken at very low cost but it is only viable in certain hydrogeological formations. All techniques are constrained by the limits of human energy. In cases where the water bearing formation is too deep, or too hard, conventional (machine) drilling is the preferred option. There are a number of cases where certain hand-drilling techniques have been mechanized to drill deeper and faster. As this develops further, it will be important to determine whether these techniques can drill more cheaply than existing conventional drilling equipment, and to examine well construction quality.

Description of existing techniques

Hand augering

Description. Hand augering can be undertaken with a heavy tripod and winch (such as provided by the vonder rig in Figure 2). Alternatively, very light equipment can also be utilized such as that common in Niger (Figure 3). Common to both of these rigs is the auger bit (Figure 4). Drilling is undertaken by rotating the auger into the ground, and adding additional drill pipe as the hole deepens. It is possible to auger a small diameter hole, which is subsequently reamed out to produce a larger one. With some equipment, a little water is added to the hole to mix with the loose soil (drilling spoil), forming a slurry. A bailer (a specially designed pipe or tube with a valve in the bottom) is used to remove the slurry.

The depth limit for hand augering is about 20 m

Capability. Hand auger drilling can be undertaken in a limited range of unconsolidated formations (i.e. non-collapsing sands and silts and some clays). Stiff clay, gravels and hard materials cannot be drilled unless the technique is combined with percussion drilling. Temporary casing can be utilized with some equipment. The depth limit for hand augering is about 20 m. Diameters range from 50 to 200 mm.

Locations. The Vonder rig has been used extensively in Zimbabwe and distributed widely within sub-Saharan Africa. Hand augering has been utilized in Niger, Chad, Senegal, The Gambia, Uganda, Zimbabwe, Tanzania and Nigeria and Niger.

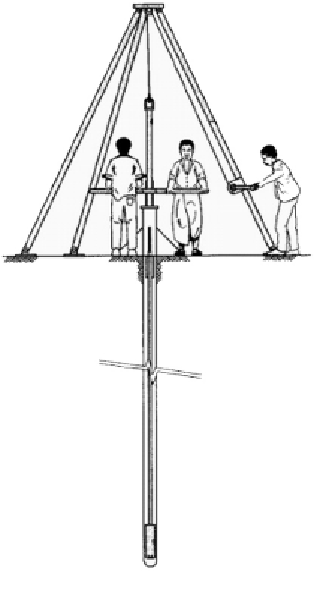

Figure 2. The Vonder rig

Figure 3. Light hand auger equipment

Figure 4. Auger bits

Equipment availability. Off-the-shelf hand auger equipment (with heavy tripod) is available from V&W Engineering (Zimbabwe), Van Reekum (Netherlands), Eijkelkamp (Netherlands) and Dormer Engineering (Australia). Lighter, but effective hand auger equipment is manufactured in Niger. For contact details see RWSN (2008).

Blankwaardt (1984), DHV (1979), Koegel (1985), Naugle (1996), Carter (2005) and Danert (2006) provide more information on hand augering.

Hand percussion

Description. Percussion (also known as cable tool) drilling refers to the alternate breaking of the formation and cleaning the hole. Percussion drilling is often undertaken with different tools: for example, a chisel to break followed by a bailer to remove the spoil. There are also clay-cutting tools available that can both cut and remove the spoil. The drilling tools and weights (referred to as the tool string) are suspended from a rope or steel cable and reciprocated through a stroke of 1 to 3 m (Figures 5). Small amounts of water are usually added to the hole to help loosen the formation. It is often necessary to line the hole with temporary steel casing to prevent collapse.

Often the hole must be lined with temporary steel casing to prevent collapse

Capability. In principle, percussion drilling can deal with most ground conditions but progress can be very slow in hard rock. Due to the limited energy inputs of hand percussion, progress is considerably slower than for conventional (mechanized) percussion drilling. If temporary casing is used, considerable time and suitable tools are needed to drive it into the ground and remove it. Depths of 20 to 30 m are possible if there is no temporary casing required, otherwise the limit is about 15 m.

Locations. Zimbabwe, Tanzania, Liberia, Niger, Nigeria, Chad, Ghana, Central America.

Availability. Hand percussion is not commonly used today. However, there are some cases of mechanized percussion, and the principles of percussion are used alongside other techniques such as sludging, or have been integrated into other combination hand-drilling techniques such as rota sludge and pounder drilling.

See Koegel (1985), Carter (2005) and Missen (2007) for more information on hand percussion.

Stonehammer drilling

Description. This technique is a variation of hand percussion drilling. An approximately 60 cm long cutting tool is fitted to the base of a drill pipe. A 70 kg steel weight (or hammer) is lowered into the drill pipe. This hammer is raised and dropped onto the cutting tool, forcing it to penetrate the formation, before being lifted out carrying the cuttings.

Capability. The stone hammer drilling method can penetrate reasonably hard formation, but progress is slow.

Locations. Nicaragua and India.

Equipment availability. No off-the-shelf technology is available, but the rig can be assembled in a reasonable local workshop. Drawings and assembly guidelines are available in the sources set out in the reference list.

A key references on stonehammer drilling is Van Herwijnen (2005a, b).

Driven wells

Description. 'Driven wells' refer to driving a well point and well screen directly into the ground using a hammering tool (Figure 6). The material is forced aside rather than excavated by this technique. This technique is sometimes used in conjunction with hand augering.

Capability. Koegel (1985) states that 25 to 30 m is probably the maximum depth for a driven well. The depth depends on the build-up of friction between the pipe and the formation drilled and the driving force available. A hand-driven well can generally only penetrate about

Figure 5. Hand percussion rig in action

1–2 m into coarse sands because of resistance. Use of machinery can enable greater depths to be reached.

Locations. Chad, Cameroon and Madagascar

See Koegel (1985) for an overview of driven wells.

For a driven well the material is forced aside rather than excavated

Hand sludging

Description. Hand sludging (also known as Asian, or Indian sludging) is a traditional technique used in parts of Nepal, India and Bangladesh. It involves reciprocating a steel pipe (of 25 to 40 mm diameter) vertically in a shallow pit, which is kept full of water (Figure 7 and 8). The reciprocating action is achieved by a lever, which is attached to a bamboo frame. One operator operates the lever while the other uses a hand over the top like a flap valve. On the up-stroke the hand covers the pipe, while on the down stroke it lifts off. This action enables the cuttings to be carried up through the drill pipe and exit at the top.

The water in the pit flows back down the drilled hole and then up the inside of the pipe, carrying the cuttings. This provides a continuous circulation of water for the removal of the spoil as a sludge (hence the name of the technique). Thickeners or stabilizers can be added to the water in the pit to prevent collapse of the hole and to reduce lost circulation (i.e. drilling fluid leaking, or draining into the formation). Cow dung and sawdust are sometimes used as thickening materials.

Hand sludging is an excellent method for drilling silts, sands and certain clays

Capability. Hand sludging is an excellent method for drilling silts, sands and certain clays. Hard layers can reduce speed of penetration or halt progress completely. Some clays can block the sludging pipe. Coarse gravels and sands can result in lost circulation and thus failure to remove spoil from the hole. Depths of up to 15 m are common.

Locations. Extensively used by private artisans (*mistries*) in India, Bangladesh and Chad.

Availability. Hand-sludging equipment is made locally in parts of India, Nepal and Bangladesh.

Ball and Danert (1999), Carter (2005) and Knight (1995) provide details on hand sludging.

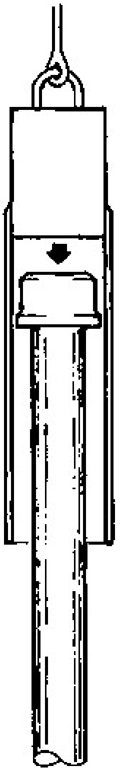

Figure 6. Well driving device (guided on outside of pipe)

Baptist drilling

Description. Terry Waller of Water for All in Bolivia developed baptist drilling in 1993. It is a hybrid of sludging and percussion drilling. The main difference is that while hand sludging relies on a person's hand at the top of the drill pipe as a valve, the baptist method uses a valve, incorporated into the bit at the bottom of the drill stem.

The drill pipe and bit are normally not removed from the borehole until drilling is finished. Drill cuttings are suspended in the drilling fluid (mud) and pumped to the surface. The percussion action is performed by lifting the drill stem using a rope and pulley attached to a simple (wood or bamboo) derrick. Drilling diameter is kept as small as possible with standard drill bits made from 1¼" (32 mm) internal diameter iron plumbing accessories. With reamer bits the hole diameter can be increased to 150 mm. The drill pipe is iron or galvanized iron for the bottom 3 m, with PVC pipe extensions to keep the equipment light. The drill is lifted with a rope and pulley and the drill can be rotated some 90 degrees. Some drillers have motorized the lifting action.

Capability. This technique works best in sand, loam, small gravel and light rock. It will not penetrate hard rock or boulders. The standard drill bits work through sticky and even consolidated clays. Optimum results in varying conditions are obtained with an array of different bits, including those without a valve. In layers of pure clay or gravel, progress is slow compared with sludging, since the clay has to be pounded into suspension and stones have to be ground to small pieces to pass through the footvalve. With the 'shipo' version of the Baptist, as used in Tanzania, stones smaller than 3 cm can be lifted in one piece because of the use of an open drill bit combined

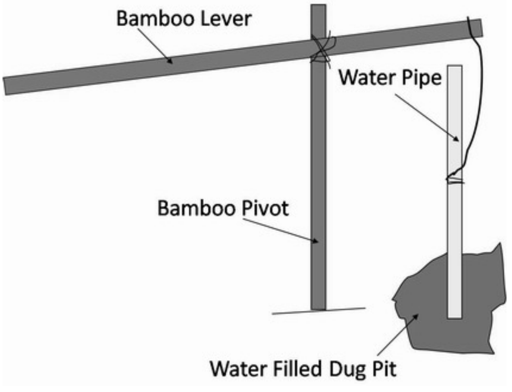

Figure 7. Sludging equipment

Figure 8. Sludging in West Bengal

Depths of over 15 m per day have been obtained in favourable conditions

with sludging. Drilling speed is variable with different soil conditions and crews, but over 15 m per day have been obtained in favourable conditions.

Equipment and cost. The core element of the rig can be made in almost any arc-welding workshop, using materials that can be found locally. A complete baptist rig, all tools included and capable of drilling up to 30 m deep, can be assembled in Nicaragua for about $150. In Bolivia, the wells cost around $2 per metre (well casing and a low-cost PVC pump and small provision for rig maintenance). Prospective well owners provide all labour.

Locations. Water for All in Bolivia provides training and advice on purchase of materials to communities (Water Clubs) that want to drill their own wells. Farmer-to farmer training is used to pass the method on to other communities. To date, over 2,000 baptist wells have been drilled in 12 countries. Most wells are in Bolivia, followed by Nicaragua, Sri Lanka and Cameroon with trials in Ethiopia, Kenya, Tanzania, Zambia, Mozambique, Malawi, Togo, Mexico, Argentina, Costa Rica, Nigeria and Mali, the Netherlands, USA and Chile.

See Fitzgerald (2007), Burrows (2006), Water for All (www.geocities.com/h2oclubs), Waller (2009), Cloesen (2007b), Stocker (2007) and Cloesen (2008) for more information,

Pounder rig

Description. The pounder rig has been derived from sludging, but has been designed to deal with the weathered overburden, also known as regolith, which lies over the basement complex. These conditions are common in much of Africa.

The principle of drilling is the same as for sludging. It involves reciprocating a steel pipe (of 25 to 40 mm diameter) vertically in a shallow pit, which is kept full of water. However, rather than a bamboo frame, a steel frame is used. This ensures that the hole is drilled vertically. A platform (part of the frame) assists in separating large cuttings out of the drilling fluid before it flows into a settling pit and is recirculated. A see-saw mechanism is used to raise and lower the drilling pipe, and a steel and leather flap at the top of the pipe (inside an upturned bucket) acts as a valve. This replaces the hand used in sludging and rota sludge. The drill pipe comprises carbon steel 'wireline' drill pipe, which is considerably stronger than galvanized iron pipe and able to resist the stresses imposed by the impact on the very hard layers. Hardened steel drill bits are used to penetrate hard rock (Figure 9).

The pounder rig can drill through gravel, laterite and limited amounts of hard rock

Capability. The pounder rig can drill through clay, sand, silt, gravel, laterite and limited amounts of hard rock. The limitations are primarily due to the slow progress in hard formations.

Locations. Uganda.

Figure 9. Hardened steel button bit

Equipment availability. One rig has been manufactured and is currently in Uganda. See Ball and Carter (2000) for specifications and drawings for the pounder rig and Carter (2001) for project details.

Rota sludge

Description. The rota sludge technique is similar to hand sludging and the pounder rig. It involves raising and lowering a steel pipe, which is weighted at the bottom and fixed with a drill bit on the base to drill the hole. A simple wooden frame and lever are used to enable the reciprocating action. Water mixed with cow dung is used as drilling mud (i.e. to carry the cuttings to the surface and prevent collapse of the drilled hole). A hand, placed at the top of the pipe acts as a valve, lifting up and releasing the cuttings on the down stroke and covering the pipe on the up stroke. A pit enables the drill cuttings to settle out and thus the drilling mud to be recycled. A handle is clamped to the drill pipe. This allows rotation of the drill pipe, which assists in scraping and breaking the formation.

The stonehammer technique is used in conjunction with the rota sludge technique to penetrate hard formation.

Capability. Rota sludge drilling is capable of penetrating soft, sandy formations. Gravel and small stones within such formation can be lifted. The technique can be used to drill through more cohesive sandy formations and most clay. When very stiff clay, layers of hard rock, or boulders are encountered, these are broken using the stone-hammer attachment. However, owing to the limits of human energy, progress through such formations can be slow.

Locations. Nicaragua, Tanzania, Madagascar, Ghana, Senegal, Mauritania and Niger.

Equipment availability. No off-the-shelf technology is available, but the rig can be assembled in a reasonable local workshop. Drawings and assembly guidelines are available in Van Herwijnen (2005a, b). See Practicafoundation (2008) for video material of the technique.

Well jetting or washboring

Description. Well jetting, also known as washboring (and hand turning in Nigeria), is considered to be a manual drilling technology, even though it utilizes a small pump. The engineer Richard Cansdale has been heavily involved in the development of the technology. The technique involves pumping water (with a hand, or motorized pump) down the drill pipe, which is held vertically in the hole. The water passes through the bottom, open end of the pipe and carries the drilling spoil up the annulus. The drill pipe is held vertically and slightly rotated and/or reciprocated. It is the washing action of the water that forms the hole. The drill pipe is usually up to 50 mm in diameter, while the hole is 100 to 150 mm. The equipment comprises a centrifugal pump, suction hose, flexible delivery hose, elbow and swivel and jetting pipes. Temporary casing can be used, but a technique which enables the self-jetting of wellscreens has also been developed (Figure 10). In cases where the ground is very compact, a special jetting point is used (Figure 11).

> Given the right ground conditions, jetting is a very fast drilling technique

Capability. Well jetting can be undertaken in weakly cohesive sands and silts but cannot be used in hard formations. Clay can only be penetrated very slowly; gravels and other highly permeable formations will result in lost circulation. Given the right ground conditions, jetting is a very fast drilling technique. Normal depths are 6 to 10 m, but depths of 30 m (drilling through silt) have been recorded.

Locations. Nigeria, Cameroon, Niger, Madagascar, Senegal, Darfur, Chad, Zimbabwe, Sri Lanka.

Equipment availability. Although an off-the-shelf kit for well jetting is not available, it can be readily assembled from locally available materials. Self-jetting screens are available from SWS filtration (http://www.swsfilt.co.uk).

See Carter (1985), Jose (1988) and SWS Filtration (2001) for more details and Adekile and Olabode (2009) for information about jetting in Nigeria.

Figure 10. Well jetting in action

Figure 11. Jetting point

EMAS drilling

Description. EMAS drilling, developed by Wolfgang Buchner in Bolivia combines jetting with a percussion action. Drilling mud (water mixed with clay or bentonite to a suitable density) is pumped down through the drill stem using a hand-operated metallic version of the EMAS pump. The mud flows back up around the drill stem, carrying up the drill cuttings. Sand and small stones are decanted, and the drilling mud is recycled through the pump.

A percussion action is performed by lifting and dropping the drill using a lever, mounted on a drilling tower. In addition, the drill stem is rotated in half-turns in both directions, enhancing the grinding action of the bit. The drilled diameter is about 2 inches and wells are cased with cheap 1½" (39 mm) PVC pipe to accommodate a 1¼" PVC piston pump although they can be reamed to a larger diameter.

EMAS drilling can penetrate consolidated materials and light rock

Capability. EMAS drilling can penetrate loose soils, as well as consolidated materials and light rock but not hard rock or boulders. In coarse sands, progress may be slow, as sand may sink faster than it can be lifted out with the drilling fluid. In such conditions, a temporary switch is made to a sludging technique: an open-ended drill bit is installed, and a valve on top of the drill stem. The technique drills to 30 m although depths of 100 m have been reached with the use of a small motor. The entire drill stem is metallic so deeper drilling becomes heavy and several operators are needed to operate the lever.

Equipment. An EMAS drilling rig, capable of drilling holes to a depth of 30 m, can be built in Bolivia for about $600–800 (including the tower, mud pump and all essential non-common tools to operate and maintain it). All non-standard components can be built locally in most arc-welding workshops, using only materials found in ordinary hardware stores.

A similar technique, called Madrill, is under development in Madagascar.

Cost. About $6 per metre in Bolivia (including drilling, casing and PVC pump).

Locations. Primarily in Bolivia, but introduced in other Latin American, African and Asian countries.

For more details see Cloesen (2007a) and EMAS (2005).

The role of hand-drilled wells

Manually drilled wells are commonly used for agricultural water supply

Manually drilled wells are commonly used for agricultural water supply. The combination of suitable, very low cost, hand-drilling techniques (particularly sludging and jetting) with very low-cost irrigation pumps (including the treadle pump) fuelled the development of small-scale irrigated agriculture in Bangladesh, India, Niger and Nigeria in particular. Hand drilling has thus been considered as a technology mainly for the agricultural sector.

However, there has been a spillover into domestic use. Farmers do not tend to distinguish an agricultural and domestic supply and will tend to drink what is available at hand. This reality is now being recognized and has been termed multiple-use water services (MUS). Concerns are repeatedly raised by professionals concerning the biological and chemical quality of 'irrigation' water, or water tapped from very shallow aquifers. Unfortunately, there is still so little data available that the jury is still out on this key issue. It should be noted, however, that shallow aquifers are vulnerable to pollution from fertilizers, latrines and waste if the upper layers are highly permeable.

Successful adoption was facilitated by the availability of affordable well drilling *and* hand pumps

In Nigeria and Niger, local enterprises have marketed and used hand-drilling techniques to specifically drill wells for domestic (and industrial) use (Danert, 2006; Adekile and Olabode, 2009). Indigenous hand sludging, coupled with the (modified) No. 6 pump and robo screen (internally ribbed continuous slot plastic screens) enabled the uptake of millions of very cheap wells in Bangladesh in the 1990s (WSP, 2000). Notably, in all cases, the successful adoption was facilitated by the availability of affordable well drilling *and* hand pumps.

Over the last 15 to 20 years, a number of development organizations have focused on developing and promoting hand-drilled wells specifically for domestic supplies. These initiatives have generally been undertaken in tandem with the promotion of particular pumps (e.g. EMAS, rope pump, Canzee pump, modified No. 6 or other village level operation and maintenance, VLOM pumps). Ideally, the low drilling costs should be matched by low pump costs. However, some of the pumps which were designed for household use are being promoted as community pumps, with the danger that they become overused and break down frequently.

Figure 12. EMAS drilling

The reach of hand-drilled wells

Manual drilling is common in some pockets of the world (e.g. Bangladesh, northern India, Niger, Nigeria) with countless local enterprises involved. In other parts of Africa as well as Latin America, these technologies have been introduced more recently. Table 1 synthesizes known information about hand drilling in 21 selected countries. Given the fragmented nature of work in this area, it is possible that some initiatives have been missed.

Development and promotion of hand-drilled wells

Sometimes manual drilling techniques spread across borders introduced by local artisans

In some cases, manual drilling techniques spread across the border from one country to another, introduced and adopted by local artisans themselves.

The author has knowledge of about 30 organizations which are currently promoting hand-drilled wells to local NGOs, local enterprises or water users themselves. These promoters comprise international and local NGOs, individuals and private companies (which tend to consider themselves as social entrepreneurs). The geographic scope in which they work, the time spent on piloting, demonstrating and training varies widely, as does the extent of back-up support provided to water users afterwards.

In some cases the development and promotion of hand-drilling technologies has been built on a solid foundation, whereas in others it has tended to be fairly fragmented. In many cases the same lessons are learned from scratch in different parts of the world, or even within the same country. However, there are coalitions and informal networks which share information and ideas. The Rural Water Supply Network (RWSN, 2008) is one example, having been active in trying to link hand-drilling players and disseminate information since 2005. However the reality is that there is competition over scarce resources among developers and promoters.

Carter and Bevan (2008) point out the importance of promotion of hand drilling through the indigenous private sector. This is echoed by Danert (2006), Adekile and Olabode (2009) and Ikin and Bauman (2004) and the practices of some of the promoters of the technology. Some argue that there should be no subsidies, while others believe that water users cannot afford to pay, and in fact should not pay the full cost of these water sources. Some organizations do not focus on the private sector and profit, but rather on self-help. These different approaches can be particularly problematic when they are practised in the same vicinity.

Whether a well is drilled by machine or hand, there are good practices in terms of gravel packing (or the use of geotextiles) and well development that ensure good flow into the well and prevent silting. These are ignored by some programmes. As an example, PRACTICA Foundation (2005) notes that the lack of attention to gravel packing in hand-drilled wells drilled in Chad in the late 1960s and early 1970s led to failure of most of the wells and installed pumps after 3 to 6 months of use due to the inflow of fine sands. Proper well sealing and correct pump installation are essential to provide sufficient clean water and not contaminate the aquifer. Unfortunately not all hand-drilling programmes follow these good practices, which can not only give the technology a bad reputation but also create major problems later for the water resources as well as the water users.

Proper well sealing and correct pump installation are essential to provide sufficient clean water

Keeping the drilling diameter to a minimum contributes to low drilling costs and the installation requirements of the pump determine casing diameter. Some handpumps (e.g. Tara, No. 6) can be directly installed (i.e. the rising main doubles up as well casing), thus considerably reducing the drilled diameter over other pumps.

The overwhelming success stories, in terms of numbers and sustainability of hand-drilled wells are to be found in Bangladesh, Bolivia, Vietnam, Nicaragua, Nigeria and Niger in particular. In all these cases, the drilling techniques were highly suitable for the hydrogeology, large numbers of artisans were able to make a living from selling the wells, or there was a strong self-help ethos, pumps were cheap and readily available and end users were able to afford to buy them. There is clearly much that can be learned from the successes and failures in the promotion of hand drilling around the world.

Sustainability of hand-drilled wells

Lack of good documentation (a very common issue among implementing organizations) makes it difficult to form a global picture of sustainability of hand-drilled wells. Promotion and piloting tends to focus on service delivery rather than on long-term viability and monitoring. Providing water tends to excite donors the most as does training to a certain extent. Long-term follow-up and monitoring is relegated to the back row if it is considered at all.

Long-term follow-up and monitoring is relegated to the back row if it is considered at all

The successes in terms of widespread uptake in Bangladesh have been eclipsed by its arsenic problem. Rocks rich in arsenic were eroded and arsenic was deposited with the sands, gravels, silts and clays in low-lying areas of West Bengal and Bangladesh. These were buried, and form the aquifers now tapped in many places. The extent of the problem took a decade to be realized and the extent of similar problems in other areas is not fully understood. This should serve as a reminder to us that our understanding of groundwater resources in many developing countries is still fairly limited and requires attention.

Table 1. Summary of extent of hand drilling in selected countries (X = 10s of wells, XX = 100s, XXX = 1,000s, XXXX = 10,000s)

Country	*History*	*Techniques*	*Scale (number of wells)*	*References*
South Asia				
Bangladesh	Sludging is an ancient tradition	Sludging	Millions	WSP (2000)
India	Sludging is an ancient tradition	Sludging	Millions	Ball and Danert (1999)
Sri Lanka	Various trials	Sludging, unnamed, baptist	X	
Vietnam	Sludging introduced in the 1980s by UNICEF. In 1991 IDE introduced the treadle pump, which did not take off	Sludging	Hundreds of thousands	Ikin and Baumann (2004)
Africa				
Cameroon	Well jetting spread from Nigeria to Cameroon in the mid-1980s. Baptist drilling was introduced more recently	Well jetting, baptist	X	
Chad	Manual drilling was undertaken by local enterprises in the 1980s. However, quality problems led to loss of confidence in the sector. Apparently hand drilling is once again on the rise and 20–30 manual drilling enterprises are active	Sludging, jetting	XXX	PRACTICA Foundation (2005)
Ethiopia	Pilot only	Rota sludge, baptist	X	Communication with PRACTICA Foundation
Mali	Training of private artisans in 2008	Various	X	
Ghana	Pilot only (for irrigation and domestic)	Hand augering, rota sludge, percussion	X	
Mauritania	Some manual drilling techniques have been tested	Various	X	
Madagascar	Jetting technique introduced in the first few years of 2000	Jetted wells	XX	Communication with Bushproof (http://bushproof.biosandfilter.org/)
Senegal	Well jetting was introduced in 1991. Apparently private households in Casamance are paying for their own water supplies with this technique	Augering, well jetting, rota sludge	XX	
Niger	Training of manual drillers started in the mid-1960s. Various projects have taken place, particularly in the mid-to-late 1990s involving private artisans. An estimated 10,000 hand drilled wells have been installed for	Primarily hand augering	XXX	Danert (2006)

Country	*History*	*Techniques*	*Scale (number of wells)*	*References*
	irrigation and hundreds for drinking water			
Nigeria	Well jetting was introduced in Nigeria in 1982 as part of the Kano Agricultural Development Project to provide irrigation wells in the sand rivers of Kano State and beyond. There was widespread adoption of the technique	Jetting/washboring, augering, hand percussion, and recently baptist drilling	X	Adekile and Olabode (2009)
Mozambique	Pilot stage only	Rota sludge	X	
Tanzania	Hand augering introduced during the Shinyanga Project in the 1970s. Rota sludge was introduced in 2008	Hand augering, rota sludge	XX (estimate)	DHV (1979)
Togo	Pilot only 2008	Baptist	X	
Zambia	Pilot only 2008	Hand augering, baptist	X	
Zimbabwe	Vonder rig development and extensive use	Hand augering	XXX (estimate)	
Latin America				
Bolivia	Techniques introduced in 1993 through water clubs	EMAS and baptist	XXXX	Personal communication with Water for
Nicaragua		Baptist, EMAS	XXX	All NWP (2006)

Conclusions

Promoters and developers should pay more attention to what others have already done

There is no doubt that there is scope for further improving rural water supplies with hand-drilled wells. There are a number of techniques available, but they are only suitable in particular niche environments. The promotion and support of these technologies are just as important as finding what can work in which particular environment. In order to prevent the same lessons being learnt each time, promoters and developers should pay more attention to what others have already done. There is also much that could be learned from good conventional drilling practices and applied to hand drilling, particularly in terms of well completion to prevent silting or groundwater contamination. Lack of proper understanding of groundwater resources is one of the barriers to full exploitation of hand-drilling technologies. Much more emphasis is needed to monitor the long-term sustainability of hand-drilled wells as well as water quality and to properly diagnose reasons for breakdown or rejection by water users.

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