SOUTH AFRICAN EXPERIENCE WITH HAND AUGERED SHALLOW WELLS IN COASTAL AQUIFERS

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South African experience with hand augered shallow wells in coastal aquifers

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Abstract
The Ubombo Family Wells Programme was initiated in 1997 to investigate and demonstrate appropriate water supply options for the communities resident on the coastal plains of northern KwaZulu-Natal, South Africa. These communities are characterised by very flat, sandy terrain, a relatively shallow water table, and highly dispersed population patterns.

The early work was modelled on Zimbabwe's highly successful family wells programme. However, it was soon found that in this terrain tube wells, hand augered and fitted with bucket pumps, provided a more effective solution. Since 1998 over 550 tube wells have been installed, and most of these are owned and maintained by individual families, even though the water is generally shared amongst several families. Recently one of the early wells has been completely excavated to examine casing wear and well screen condition, in order to enable predictions to be made regarding the long term performance of these wells.

Since July 2003 work has been done developing a locally manufactured version of the rope and washer pump, and trial units are being monitored in the field. Based on these trials a further 100 wells are being constructed and fitted with rope and washer pumps.

Keywords
Bucket pumps; rope and washer pumps; shallow wells; Vonder rigs

1. INTRODUCTION

There has been considerable activity implementing community water supplies throughout South Africa over the course of the last ten years. There is also a growing concern regarding the economical sustainability of piped water supplies in the more remote rural areas (Still et al, 2004).

One such area is Maputaland, the region of South Africa which forms the coastal plain of northern KwaZulu Natal. It extends from the north of Lake St Lucia up to the Mozambique Border. To the west lie the Lebombo Mountains, to the east is the Indian Ocean. The area is gently undulating and sandy, with the water table typically located between 2 and 25 metres below the surface. The rural population of 120,000 people live in very dispersed settlements, with homesteads several hundred metres apart and large spaces with no settlement at all. Traditionally people take water from pans, lakes and shallow pits sunk a few metres into clay.

Water supply in this region has followed a similar pattern to the rest of KwaZulu-Natal. During the seventies and eighties boreholes fitted with handpumps were provided by the government, but maintenance programmes tended to be ad-hoc and as a result many pumps were out of order for long periods at a time. During this period the government also constructed concrete ring wells on the coastal plain, but these were not protected or particularly deep. These open ring wells were thus often highly contaminated, or dry.

Over the last decade the area has seen the construction of a number of large piped water schemes, which cover the denser development nodes in the region. The real cost of water on these schemes is generally in excess of R10/kl, and typically most or all of this cost is covered by government. In addition to the large schemes there are many small borehole schemes, incorporating a borehole, an engine or motor driven pump, a reservoir, a small amount of reticulation and some taps. The operation of these schemes has not been subsidised or supported and almost without exception they have hardly worked at all since installation.

There was therefore a need to find a sustainable and acceptable solution to water supply to the more remote and dispersed settlements within the region.

2. THE UBOMBO FAMILY WELLS PROGRAMME

It was against this background that the Ubombo Family Wells Programme was conceived in 1996, inspired by Zimbabwe's phenomenally successful family wells programme (it is estimated by Morgan (2001) that in the last decade a total of 45 000 Zimbabwean family wells have been upgraded with a brick lining, a tin lid and a windlass). Despite the success of the Zimbabwean programme, and the apparent suitability of the Maputaland coastal plain for a similar approach, there were a number of social, political, technical, and financial obstacles to be overcome.

2.1 Technical Description

The term *tube well* is not in common use in South Africa, but is used internationally to designate any small diameter borehole used for water abstraction. In this programme it is used specifically when referring to manually augered, uPVC cased wells. The augering is done with the simple but robust and effective tool called a Vonder Rig, which was developed by V&W Engineering in Harare, Zimbabwe in the 1980s. The rig consists of a tripod and winch, a work table that keeps the hole straight, drill rods and a number of 165 mm diameter auger bits. The rig is operated by a team of four people, and can reach depths of up to 20 metres. In fact greater depths are possible but the augering time gets exponentially slower with depth and so 20 metres is found to be a practical limit. Once the water table is reached six metre lengths of 125 mm class 9 uPVC well casing are screwed together and lowered down the hole. A bailer is then used to deepen the well further, with the casing being manually driven down behind it, care being taken to ensure that the bailer does not extend too far below the casing and get trapped (in which case both bailer and well have to be abandoned!). In practice the team has been able to sink their wells up to 4.5 metres below the water table.

Figure 1: The Vonder Rig work table and auger bit

The first, or bottom, length of 6 m casing incorporates a 3 metre long slotted screen, which is located 0.5 metres from the bottom of the well. Once there is more than 4.0 metres of water in the well, baling ceases and a cement and mortar filled geotextile cylindrical bag is rammed down the hole to plug the bottom. This is essential in order to prevent sand from entering the bottom of the well and causing it to silt up.

The well screen itself needs explanation. The fine sand of the area has an effective grain size (d10) of only 0.16 mm. A 1 mm slot size was selected for the well screen because of its general availability, low cost and relatively large percentage of open area. Ideally a gravel pack of 70 mm thickness should be constructed around the screen to prevent the ingress of fines and to keep the well from silting up. The augered hole was only 170 mm in diameter, and the well casing needed to be not less than 125 mm to accommodate the type of pump used, which meant there was not enough

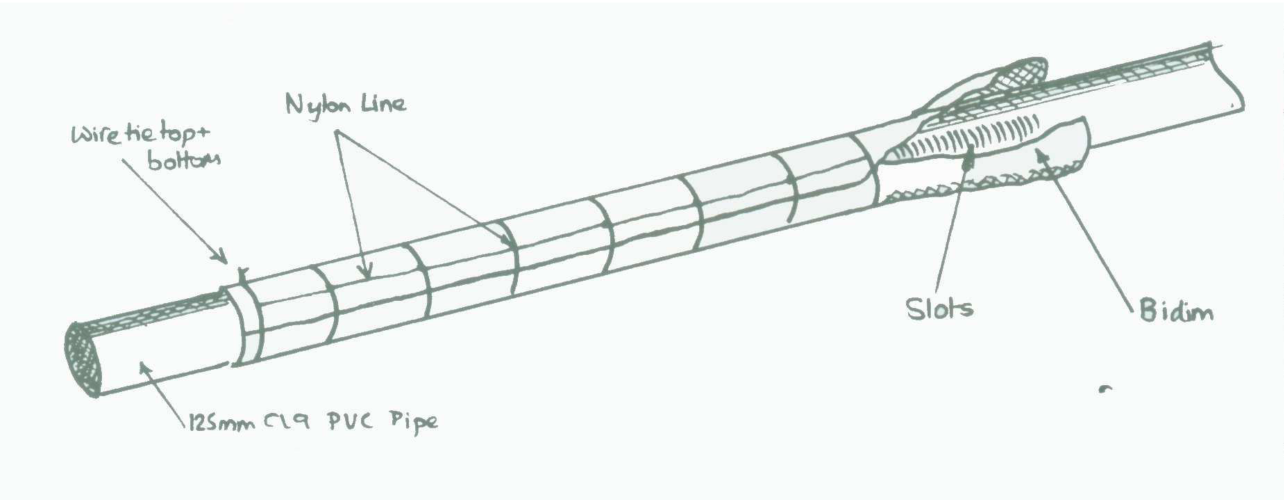


Figure 2: The geotextile filter fitted on a slotted section of casing pipe

space for a gravel pack. Instead a 150 g/m^2 geotextile fabric was wrapped around the screen and wired in place. This fabric has an effective pore size of 250 microns, which was not too small too clog up but large enough to allow some fines to wash through in order for a natural graded filter to establish itself around the well.

Once the plug is in place work can start on the superstructure. Although some of the wells have been fitted with handpumps, submersible electric pumps or even petrol powered suction pumps, the standard installation has been kept robust and simple. The water extraction device is what is called the *bucket pump*, adapted again from a V&W Engineering design from Zimbabwe. The bucket pump is simply a 100 mm diameter galvanised steel tube with a basic foot valve, which is lowered down into the water using a windlass and a rope. The bucket holds 5 litres of water, and is thus lowered four or five times to fill a standard 25 litre water container. The foot valve is of such simple design that it can be maintained with old car tyres and wire, and it is.

Figure 3: A Maputaland family well equipped with a bucket pump

The total current cost of a tube well in an area with a water table averaging 12 metres below ground level is approximately R6,000 including all overheads, but excluding VAT. Of this cost, R600 is borne by the beneficiaries, leaving R5 400 to be covered by the programme. If the average well is used by 12 persons, then the average programme cost per person is R450. For comparative purposes, reticulated supplies in this region with only a stand pipe level of service (with between 60 and 120 people sharing each standpipe) currently cost between R1,000 and R 2,000 per person served.

3. MONITORING AND EVALUATION

Due to the long term nature of the programme, the team has over the years been able to monitor key aspects of the work being done.

3.1 Performance of Geofabric Filter

A series of pump tests on one of the first tube wells, which has been in constant use serving over 20 families, was used to measure the performance of the geofabric filter (Still and Nash, 2002b). The tests took place over a period of three years, from April 1998 to April 2001. Using a submersible electric pump the well was subjected to extraction rates stepping from 0.16 l/s to 0.43 l/s. The drawdown increased from 0.2 metres to 0.6 metres over this range, with no significant difference in the drawdown observable over the three years.

Note that this well has had much heavier use than the average tube well. It was concluded from this series of tests that, with a properly constructed plug at the bottom of the well, no significant reduction in the yield of the well over time should be expected.

Subsequently some of the wells in favourable conditions have produced yields in excess of 50 kilolitres per day for irrigation projects, with no noticeable change in drawdown over time. The geotextile filter screen thus appears to be a successful adaptation for use in very fine sands. In 2003 an old well was completely excavated to check, among other things, the condition of the geotextile filter, and no clogging was observed (see section 3.4 below).

3.2 Reliability and Maintenance

Routine maintenance consists of:

i) periodically replacing a piece of wire that acts as a split pin on the bucket valve;
ii) replacing worn rope;
iii) welding repairs to the bucket.

In practice it has been observed that family well owners do take care of all of the above. In the context of rural water supply, therefore, the *family* wells can be considered to be highly reliable. As can be expected the length of downtime is noticeably higher in the case of the *community* tube wells, where time must elapse before money is collected and/or an individual takes the initiative to sort the problem out.

More recently it has been observed that the galvanised steel windlass can tend to fail from about six years due to corrosion caused by constant contact with the wet rope. The replacement of the windlass, at a cost of approximately R500, must therefore be seen as part of the long term maintenance cost of this type of pump. A cheaper alternative would be periodic sanding and treatment with rust preventative paint.

3.3 Water Quality

An argument that is used by some against wells is that they produce water of a standard inferior to that supplied by piped water schemes. The main concern seems to be that the groundwater must be contaminated because of the incidence of pit latrines in the area.

In order to assess the actual situation with regard to contamination, the programme maintained a record of water quality from a number of wells over several years (Still and Nash, 2002a). It was found that the average incidence of faecal coliforms in family wells was 6/100 ml, and that in communal wells was 34 per 100 ml. The incidence of coliforms was higher in the warmer summer months than in the colder winter months.

Samples were also taken over the same period from monitoring holes around two long established pit latrines in the area. From these it was clear that the fine sand acts as an effective filter medium, and that bacteria do not travel more than a metre or two from pit latrines in this area. The fear that the groundwater of the area is contaminated by pit latrines is thus unfounded. A comprehensive review of 21 other published case studies (Crane and Moore, 1983) confirms that the migration of bacteria from a water point source in groundwater is typically limited to 10 to 30 metres. Longer migrations only occur where there is relatively unrestricted groundwater movement (e.g. a *gravel* bed), and where large amounts of water are moving in the ground (caused, for example, by a major production borehole).

It must be pointed out that the moment there is human contact with any water source, bacterial contamination will result. Even water with zero faecal coliforms will typically become somewhat contaminated the moment it is stored in a household water container, as these containers are handled. However, in the case of a family well the risk of exposure to disease is much reduced, because only that family, who are in any case in close physical contact, are sharing in the water. Secondly any family that desires to have good quality water has only to follow certain very basic rules, which are taught with the installation of every well: keep the well surrounds well drained; put a few capfuls of bleach down the well every few days; and, practice good personal hygiene, especially the washing of hands.

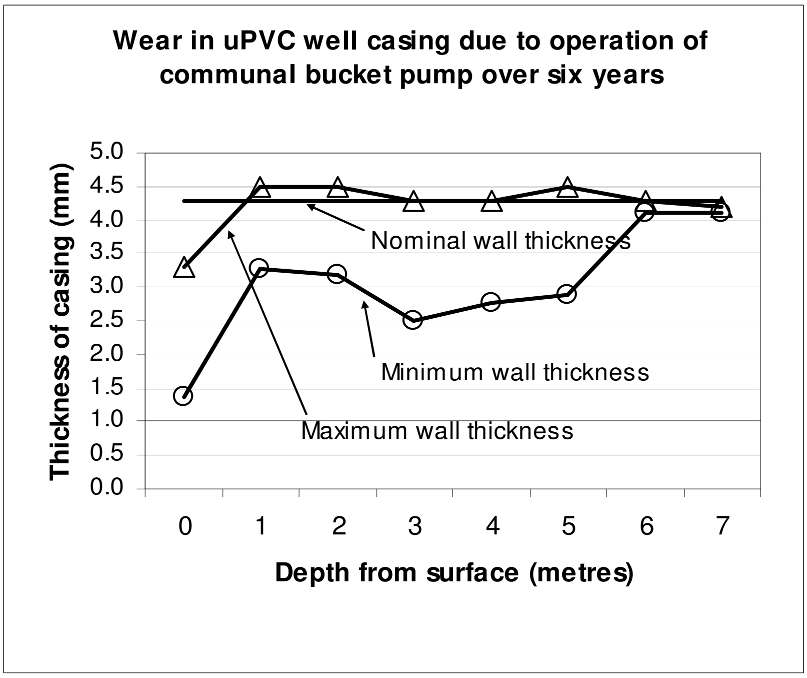
3.4 Rate of wear of well casing

It was decided to investigate whether the action of the bucket, travelling up and down over several years, would eventually wear out the well casing. A heavily used, relatively shallow, family tube well was selected. The well was 8.5 metres deep, with a water table depth of 6.1 metres. It had used by up to 30 families for over six years. Cement mortar rings (1.3m diameter) were constructed and sunk around the casing, with the sand inside the rings excavated as the rings were sunk, thus exposing the casing. It was found that the uPVC well casing had not been installed exactly vertically, and that the bucket had therefore worn one side of the casing only.

The plan was to sink the rings right into the water table so that the geotextile filter which is wrapped around the slotted screen could also be inspected. The geotextile prevents the ingress of fines into the tube well and there had been some concern that this might clog up over time. It was found that the casing had not been installed exactly vertically, with the result that the rings could not be installed all the way into the water table. However, once the rings were installed as deep as they could go the casing was extracted using a chain block.

Once the pipe had been extracted it was cut up into 1metre long sections and the thickness of the pipe was measured at one metre intervals at both the thinnest and thickest point on the circumference. Figure 4 below gives the thicknesses recorded. The worst wear was at the top of the casing where the bucket enters the well. Apart from this it was found that the casing had lost at most 1.8 mm of its 4.3 to 4.5 mm thickness. From this it could be concluded that this heavily used well would have lasted at least another six years with the same level of usage. However, from this evidence one can conclude that a well used by only one or two families would last for very much longer (presumably more than 30 years). This well also provided a worst case example, as it proved not to have been augered vertically. The project team will now excavate a further two wells to broaden the data sample.

Although the galvanized wire securing the geotextile at the top end of the screen had rusted badly, there was no evidence that there was any deterioration or clogging of the geotextile. There was, however, some sign of iron having oxidized on the geotextile and on the uPVC well screen.



It would be a relatively straight forward procedure to replace the top half metre section of pipe once it had worn through completely.

Another alternative would be to fit a pump such as a rope and washer pump where no wear on the casing is experienced – this would prolong the life of the tube well indefinitely.

Figure 4: Measured wear on George Zikhali's tube well after six years' use by several families (30 families at peak times)

4. TRIALS WITH ROPE AND WASHER PUMPS

A remarkable development of the last decade has been the rediscovery of the rope and washer pump, an ancient pumping technology. Most of the development work and the greatest success with this pump has been achieved in Nicaragua (SKAT, 2001), where it was found to be such a simple and effective technology that it could be implemented during the years when that country was being ravaged by civil war.

Figure 5: Rope and washer pump manufactured locally in Maputaland, South Africa (MacCarthy, 2004)

The pump lifts water using a rope which has washers, sometimes described as pistons, which are located at intervals along the rope's length. The rope passes over a wheel mounted above the well (see Figure 5), then down to the bottom of the well where it passes around a guide, then into a riser pipe which is connected to the spout at the top of the well. As each washer or piston enters the riser pipe, it starts lifting the section of water which is between that washer and the previous washer. The pump is robust – the failure of any single washer only slightly affects the pump's efficiency. Maintenance consists of replacing or reconnecting the rope if it comes apart. The washers can be punched from scrap car tyres or conveyor belts, although they can be moulded from plastic at very low cost if there is enough demand to cover the capital cost of the mould.

Given the nature of the Ubombo wells programme (family owned wells with a shallow water table), the rope and washer pump appeared to be a technology worth testing. Working with a Masters student from the Institute of Irrigation and Development Studies of the University of Southhampton and the South African Council for Geoscience, and with funding provided by Norad, development and testing of rope and washer pumps began in Maputaland in July 2003 (MacCarthy, 2004).

The early results are promising. Most of the pump fabrication is done by a locally based welder, and the cost is only R300 more than the bucket pump which it would replace. After nine trial units had been made and tested, a further 100 were installed at homes in the area. Work is now being done to monitor the pump's reliability, as wells as water usage from these wells. Of particular interest is to see if the rope and washer pumps do encourage higher levels of water usage and more food gardening.

Figure 6 shows the results of tests done to determine the relative ease with which water could be pumped from wells of different depths using rope and washer pumps, as compared with the bucket pumps. It was found that the time required to fill the standard 25 litre container varied only slightly in the case of the rope and washer pump, from 1 minute to just under 1.5 minutes, as well depth increased from 7 metres to 22 metres. In contrast, the time required to fill a 25 litre container using a bucket pump over the same range of well depths varied from 3 minutes to over 6 minutes.

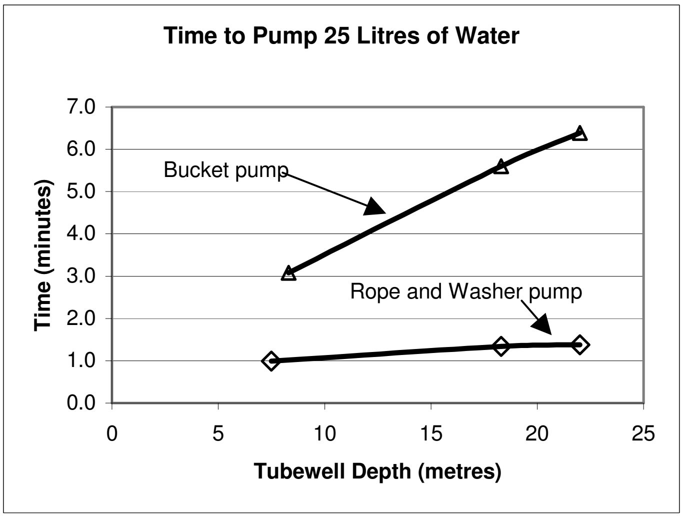


Figure 6: Relative pumping rates using bucket pump and rope and washer pump, over increasing well depth

Tests were also done to determine the importance of the washer spacing on pumping efficiency. It was found that varying the washer spacing from 1 to 4 metres had only a minor effect on pumping efficiency (measured in terms of flow rate at "constant effort") – see Figure 7. However, it is possible that the washer spacing will be a more significant parameter when the washers are worn.

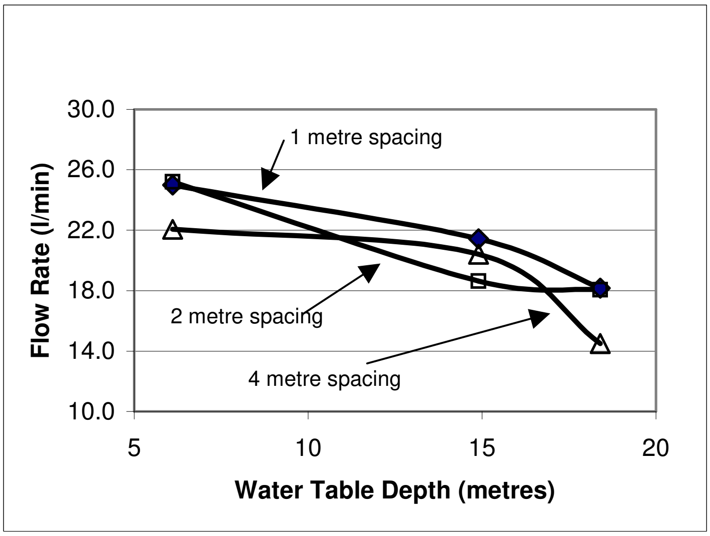


Figure 7: Effect of washer spacing on pump efficiency

5. CONCLUSIONS

Hand augered tube wells have proven themselves to be highly suitable in an area where the groundwater table is not too deep (less than 20 metres), where there is a primary aquifer, and where the soil is unconsolidated (i.e. not hard rock).

At approximately R6 000 for a 12 metre deep well equipped with a simple pumping device, the cost per capita compares very favourably with piped water supply, which typically costs between R1 000 and R2 000 per capita for a public standpipe level of service.

Until recently the Zimbabwean developed bucket pump was used for extracting water from the well. This pump is simple, robust and easily maintained at the family level. The operation of a bucket pump will, however, wear through the plastic casing of a borehole eventually. Tests carried out indicate that the life of the casing, where a bucket pump is fitted, is likely to be twelve years for a heavily used well (where the casing is not quite straight), and over thirty years for a well that serves just two or three families.

The rope and washer pump seems to be a promising alternative for shallow wells. It is only R300 more expensive than a bucket pump, but pumps approximately three times faster. It is also simple to maintain, and will not cause any wear to the well casing.

When the well is owned by a family, it is found that maintenance and well hygiene is generally taken care of efficiently. Communal wells tend to be more prone to contamination, and are out of operation for longer when the rope needs replacing or the bucket needs repair.

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REFERENCES
MORGAN, P (1990). *Rural Water Supplies and Sanitation.* Macmillan. ISBN 0333-48569-6.
MORGAN, P (2001). *Notes on Zimbabwe's Family Wells Programme: 18 June 2001.* morgan@harare.iafrica.com
CRANE S. R. and MOORE, J.A. (1984). *Bacterial Pollution of Groundwater: A Review.* Water, Air and Soil Pollution 22 No.1.
DEVERILL, P., NASH S. and STILL, D. (1999). *The Development of Hand Augured Tube Wells in Southern Maputaland*, Report to the Mvula Trust and the European Union.
MACCARTHY, M.F. (2004). *The Development of the Rope and Washer Pump for use with tube wells in Maputaland, South Africa.* MSc Thesis, Institute of Irrigation and Development Studies, University of Southampton, UK.
SKAT. (2001). Swiss Centre for Development Cooperation in Technology and Management. Proceedings: *First International Rope Pump Conference.* Managua, Nicaragua.
STILL, D.A. and NASH S.R. (2002). *Groundwater Contamination due to Pit Latrines Located in a Sandy Aquifer: A CaseStudy.* Water Institute of Southern Africa Biennial Conference.
STILL, D.A. and NASH S.R. (2002). *The Ubombo Family Wells Programme,* Water Institute of Southern Africa Biennial Conference.
STILL, D.A., Mwangi P. and Houston P. (2003). *Cost and Tariff Model for Rural Water Supply Schemes.* Water Research Commission report No. 886/1/03.