Cranfield UNIVERSITY
Silsoe

Private Sector Participation in Low Cost Water Well Drilling

Knowledge and Research (KAR) Project R7126
FINAL REPORT

Richard C Carter
June 2001

Pounder II in action in Jinja District

Government of Uganda
WES Programme – SIDA/UNICEF
Poverty Alleviation Fund (PAF)

DANIDA

Danish International Development Assistance

DFID

Department for International Development, Infrastructure and Urban Development Division

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- and last but not least those who provided funding for the work: DFID, DANIDA, UNICEF, SIDA, DWD, Mpigi, Mukono and Jinja districts, Water Aid, the PAF, and an anonymous donor in the USA.

It is our hope that the work which we have started in this short project can continue and build on the foundation provided by the many partners and stakeholders involved.

Author's note

In compiling this report, I have sought and received input from all core team members. Their comments and contributions, as with all their participation in this project, are gratefully received. Nevertheless, if factual errors or errors of emphasis still remain, I take sole responsibility for them.

SUMMARY OF REPORT

This report describes the activities, findings, implications, and future plans of a project, initiated by Cranfield University (Silsoe, UK) entitled "Private Sector Participation in Low Cost Water Well Drilling". The project was funded by DFID from July 1998 to June 2001, with additional funding partners (Government of Uganda, DANIDA, SIDA, UNICEF, Water Aid, and an anonymous donor) joining at various stages throughout this three-year period.

Recognising the importance of shallow groundwater in meeting the water needs of present and future generations, the project sought a country, and country partners, in which

- *shallow groundwater potential existed, to a degree typical of other parts of Africa underlain by Basement Complex,*
- *shallow well technologies suitable for this geological environment were lacking*
- *Government policies were conducive to the development and promotion of shallow well technology in the private sector*
- *there were potential stakeholders who would actively form partnerships with the project.*

After visits to Ghana, Kenya, and Uganda, the latter emerged as the most promising project location.

In relation to the policy context, Uganda was a particularly appropriate country for this project, because of its strategies of decentralisation and privatisation in the water sector. Debt relief through the HIPC process, and the consequent financial resources available to the sector through the Poverty Alleviation Fund, only adds to the opportunities - and the challenges - for projects such as this.

Project goals and values

The project set out to develop low-cost technology suitable for shallow well construction in the regolith, the highly variable weathered overburden which forms the top few metres to tens of metres above the ancient, hard, crystalline rocks of the Basement Complex.

Second, the project sought to promote this technology to the private sector, in the form of small commercial water-sector businesses. Uptake, in this sense, was a key component of the project.

Third, the project aimed to bring about local manufacture of the new technology, so assuring its long term ownership and availability.

The project gave high value in its operational approach to partnership, capacity building, and learning. The first was reflected in the nature of decision-making, and the extent and depth of networking with and listening to stakeholders; the second in creation of opportunities for participation; and the third particularly in the action research approach of the project. All were very demanding in terms of time.

The emphases on learning and listening, and the desire to set in train a process which would be sustainable beyond the end of the short funding period, led to an expansion of the scope of the project. Specifically,

- *the technology issues were broadened from consideration only of drilling rig design and performance, to include well design and handpump choice, well siting methodology, and water quality. In other words, not just drilling, but all the key aspects of the water point and its suitability for the end user;*
- *the private sector issues were expanded to include not only technical training with the new technology, but also business capacity. The project researched and built capacity of small water sector businesses to prepare them for their future role;*
- *much time was spent understanding and getting alongside districts (the key level of local Government), raising key issues in relation to contracts with small businesses and contract supervision;*
- *the end users of water – rural communities – entered the scope of the project, through our research on community mobilisation, and direct actions taken by us to mitigate weaknesses in mobilisation;*
- *sustainability of project concepts was addressed through networking and public workshops to create ownership, and through the establishment by two of the core team members of NGO TEMBA (Technology Mobilisation and Business Access).*

Results

In relation to the four outputs set out in the project logframe, the following results have been achieved.

Output	***Achievements***
1. New rig designed and tested, and design and operation fully documented.	*Pounder II drawings, specification, and outline operation published. Pounder I trialled 1999. Pounder II trialled 2000-2001. Further R & D is needed to bring technology to full readiness for manufacture and promotion.*
2. Manufacture and marketing initiated	*Local manufacture studies and preparations have been undertaken in readiness for take-off of technology. Wide awareness of the technology has been created, and demand is strong.*
3. Contractors trained in use of new machine.	*Two contractors have been trained and have used Pounder II to drill 14 boreholes in total. Twenty contractors have received business training.*
4. Sustainable uptake mechanisms in place.	*NGO 'TEMBA' (Technology Mobilisation and Business Access) created and registered. Directors have been active team members over last two years.*

Results relating to the expanded scope of the project are summarised below.

Key findings and outcomes

In relation to technology, science and engineering,

- *Human powered well construction demands drilling at as small a diameter as possible, because of energy constraints. Small diameter wells require handpumps to be direct installed (ie the rising main doubles as well casing, the well-screen extends below the cylinder, and the entire string of screen-cylinder-rising main are permanently installed). Groundwater corrosivity demands use of plastics/stainless steel pump components, and this requires models such as the U3M, Tara or Malda, rather than U2/U3.*
- *The low-cost drilling rig – the Pounder Rig – developed during this project has drilled 14 holes in initial trials, and another 14 in trials with private contractors. The technology shows much promise, but further technology R&D is needed before the rig can be fully promoted and disseminated.*
- *Siting of boreholes in regolith is technically problematic because of the high degree of lateral and vertical geological variability. Also it cannot be economically worthwhile to spend large sums of money on siting, in the context of low-cost drilling. It is shown that a low drilling success rate in Pounder drilling is acceptable economically, effectively using the rig itself as the exploratory or siting tool, but questions remain as to whether this approach will be socially acceptable at the level of the end users of the water point.*
- *The quality of water from completed Pounder wells has been shown to be good, from the point of view of faecal pollution (as indicated by thermotolerant 'faecal' coliforms). The iron content of Pounder well water may be high or low depending on background levels in the aquifer; in addition our monitoring results clearly show the impact of corrosion of galvanised pump components on iron content. High iron contents of well waters cause people to reject safe sources in favour of unsafe waters. The turbidity of well water is determined by geology and by the effectiveness of the process of well development. Good development is crucial, but it cannot always and entirely compensate for naturally high levels of fines (such as micas) in the regolith aquifer.*
- *While the Pounder rig is not yet ready for full-scale local manufacture, substantial work has been done on this aspect of the project. The complex issues of intellectual property, public domain ownership, and local manufacture, combined with inherent technical constraints, lead to the following conclusions: (a) a rig which can drill regolith will not be manufactured in its entirety in Uganda, for the forseeable future; (b) nevertheless the control of availability could be in Uganda's hands; (c) to bring this about, substantial future capacity building work is needed; (d) at the same time, all future technical developments should be placed in the public domain, through publication of drawings, specifications, and design and operating principles.*

In relation to three key stakeholders (small businesses, communities, and districts),

- *Small water sector businesses suffer from major conceptual, financial, organisational, and technical weaknesses. Nevertheless, they welcome and respond to training and capacity building in all these areas, when carried out with understanding and in a spirit of mutual trust between trainer and trainee.*
- *Small businesses suffer from a range of external constraints, ranging from access to credit, technology and training, to the need for 'contacts' and 'brown envelopes' in order to win contracts.*
- *Communities vary in their understanding, abilities, and willingness to respond to the demands of participation, and now public-private-civil society partnership.*

Moreover, they experience very varying levels of external support, through the Local Council system and in terms of mobilisation by sub-county and district. Unsurprisingly, therefore, the quality of post-construction operation, maintenance, and recurrent financing, not only varies, but sometimes can be poor.

- *The recent <u>policies</u> of decentralisation and privatisation, combined with the greatly increased funding made possible by HIPC/PAF, are generally recognised to be constructive steps which promise great opportunities for serving the unserved, and reaching the poor. Nevertheless, these large changes, all coinciding with one another, present great challenges to the capacity of districts and lower levels of local Government. Little is yet known about how districts are coping, nor about the effectiveness of the public-private- civil society partnership model which is now in operation. Systematic research is needed, of the type proposed by this project.*

In relation to <u>partnerships</u> developed during the project:

- *The <u>project partnerships</u>, with DWD, districts, small businesses, communities, NGOs, donors, and other stakeholders have been, without exception, constructive, enthusiastic, and backed up by real contributions in cash or in kind.*
- *<u>Project ownership</u> is very firmly planted in Ugandan soil. Well beyond the confines of the core project team, reference to the project is in first person terms ("we", "our") rather than second person ("you", "your").*
- *The final stakeholder workshop in June 2001 endorsed the work of the project, giving it a clear <u>mandate</u> to continue and extend. The primary stakeholders indicated in addition their desire for a more structured, formal, involvement in steering and decision-making.*

In relation to <u>dissemination</u>:

- *Wide use has been made of <u>written materials</u> (newsletters, news reports in journals, informative pamphlets), <u>electronic media</u> (local and international radio and TV, web), <u>open days and stakeholder workshops</u>, and <u>conference</u> attendance. All opportunities have been taken, and many created, for public dissemination of project concepts, experiences and progress.*
- *Extensive <u>documentary output</u> (some internal/confidential, most publicly accessible) has been produced. All project documents are listed in this report.*

Wider lessons

The wider lessons reinforced by this project – and which are by no means unique to it – including the following:-

- *Partnership, capacity building, and learning are all crucial to the achievement of ownership and local control. These elements all demand large commitments of time and human resources.*
- *The quality of the human relationships between stakeholders, and partnerships involving true inter-dependence, are fundamental to success.*
- *The differences in values, attitudes, and emphases between cultures and diverse institutions should not be under-estimated.*
- *Flexibility of approach, through participatory processes involving action, review, lesson learning, and re-direction of action, are vital.*
- *Technology and social/institutional aspects must be closely integrated. Neither should be pursued in isolation.*

These are well known factors in development practice, but paying them more than lip-service is extremely demanding in terms of the time, understanding, compromise and commitment of all partners.

The future

A second three-year project stage is proposed, with the following purpose, outputs, and key activities:

The Purpose of the second stage would be to "develop Pounder rig technology, manufacture, ownership, and capacity to the point at which it is self-sustaining". In this statement "Pounder technology" refers to rig, well design, and handpump installation – ie all that is needed to ensure an acceptable and sustainable water source.

The Outputs of the second stage would be:

1. *Fully developed and documented Pounder technology.*
2. *Pounder availability assured through partial local manufacture, public domain ownership of intellectual property, and standardisation.*
3. *Three to six small water sector businesses trained and using Pounder technology in three districts*
4. *Corresponding districts facilitated in private sector construction works.*
5. *TEMBA capacity built to the point of full control of Pounder promotion.*

Key Activities corresponding to each of these outputs would be:

1.1 Further develop Pounder technology through R&D and field trials through to well completion.
1.2 Fully document Pounder III technology.

2.1 Facilitate partial local manufacture of rig and well components.
2.2 Build capacity of local manufacturer(s) and agent(s).
2.3 Conduct trainings and workshops to transfer understanding of Pounder technology design and manufacturing issues.
2.4 Bring documentation to point of standardisation, using appropriate agreed model such as Uganda National Bureau of Standards (UNBS) or Swiss Appropriate Technology Organisation (SKAT).

3.1 Identify and select short-list of one or two contractors each in 3 districts, preferably all in one DWD Technical Support Unit).
3.2 Carry out participative training needs assessments.
3.3 Conduct formal and informal trainings and capacity building in business concepts, organisation and management.

4.1 Assess district and sub-county experience in private sector rural water source construction.
4.2 Conduct workshops with districts and sub-counties to raise key issues of contract management, supervision, and community mobilisation.
4.3 Liaise between DWD/TSU and districts on issues of interpretation of policy.

5.1 Develop participative SWOT analysis of TEMBA.
5.2 Identify training and other capacity building needs of TEMBA
5.3 Conduct trainings, consultancies, and workshops with TEMBA Directors and Associates.

Organisation and management

As mandated by the June 2001 stakeholder workshop, it is proposed that Cranfield University would lead the second stage of the project. However, the University would phase itself out of the project by the end of year three, with TEMBA taking an increasing lead over that duration. Cranfield would field a full-time Uganda-based project manager. TEMBA likewise would assign the equivalent of one Director full-time to Pounder project management. Technical and management support would be provided from UK. TEMBA would assign office space, secretarial and administrative support. A steering committee consisting of representatives of Cranfield, DANIDA, DFID, DWD, other donors, TEMBA, and UWASNET (Uganda Water and Sanitation Network) or an appointed NGO, would be established. Quarterly meetings are envisaged.

1 Introduction

1.1 Project Background

The last two decades of the twentieth century saw an increasing international determination to end the scandal of extreme poverty. The conditions in which approximately one fifth of the planet's people live result from grossly inadequate services, opportunities, and freedoms. One aspect of this situation is the inadequacy of water supply infrastructure, with corresponding consequences for health, as well as the excessive time and energy which women and children in particular have to devote to water collection. Universal access to safe water, near to the home, together with the practice of safe excreta disposal and changes in hygiene behaviour, are the focus of a new drive toward poverty elimination as the twenty first century begins.

Although much good practice was developed during the International Drinking Water Supply and Sanitation Decade (the 1980s), as well as during the 1990s, the problem remains: how to scale up the good practices implemented in relatively small projects and programmes, to meet the urgent needs of still rapidly growing populations. Previously inacessible funds and forces need to be released to meet the enormous challenge which still remains.

Arguably the biggest step forward in water and sanitation development in the twentieth century was the realisation that only participative and community-managed approaches would work. Governments and NGOs simply lacked the resources to meet a large and growing need. The shift in roles, of former service providers to facilitators, and of target beneficiaries to actively participating managers, is still taking place; such radical change takes at least a generation to become effective.

At the turn of the century, the private sector is increasingly being looked to as a possible means of meeting part or all of the development targets. In the water supply sector there have been some successful, and other more controversial, experiences of private sector activity in the urban environment. The potential and success of the private sector in rural water service provision is far less evident. It was the aim of this project to research private sector uptake of a new technology concept, by putting in place the means of its success, within a limited project in one country.

Project Starting Points

The project started from the point of view that private sector providers (implementers) of rural water services, particularly the small business sector, represent a relatively untapped potential. The project set out on the assumption that if small businesses receive manageable technologies and training in their deployment, training in good business practice, and other forms of support, they can be released to effectively implement water source construction at community level.

The project also assumed that the end users of rural water will be more likely to maintain and sustain their sources if they own them, with real ownership being achieved through the community (or farmer, or school, for example) paying the full cost of source construction.

The logic of this position led to the need to identify or develop affordable water supply technology – affordable by both small contractors, and by the end-users. Because of the widespread existence of shallow groundwater in the regolith (the weathered over-burden above the fresh rock (basement) at depth, and the lack of widely available technology capable of accessing it, the technology focus of the project lay in low-cost shallow well construction.

These starting points also raised questions and issues in relation to the entire set of primary and secondary stakeholders involved in the process of private sector service provision. Central and local Governments, their policies, and the incentives (or obstacles) they create for small businesses; local Government and NGOs, and their capacities to manage private sector contractors; and communities themselves, and their adaptability to yet another set of development policies; all took on increasing prominence.

Finally the issue of regulation – encompassing construction quality control, water quality, price regulation, and consumer protection – emerged as key issues which are crucial to the success of the privatisation of any monopoly.

Project Aims and Objectives

The three-year Project had two overall aims:

- to develop, and transfer to the private sector, technology suitable for affordable shallow well construction
- to research the process of technology transfer and the conditions necessary for its success, in the context of rural water source construction

Put another way, the project was crucially concerned with implementation and uptake, but at the same time we wished to learn as much as possible from the process, in order to apply lessons in the future either in or beyond the rural water sector.

Technology Transfer and Uptake

The first aim of the project was addressed through three main objectives or outputs:

- the design, field testing, and evaluation of a new human-powered drilling rig (the “Pounder rig”)
- the uptake of the technology by a small number of contractors, and their use of the rig in commercial contracts
- the establishment of a sustainable means by which the rig and subsequent spare parts will be made available in country

The technology development and uptake aim was to be achieved through a flexible and evolving process of participation with project partners and stakeholders. This was explicitly a learning project, not driven according to a blueprint, but initiating discussion and research of key issues and responding to the resulting findings.

Research

The research aspect of the project used the technology transfer and uptake process as a gateway to action research. The process of developing the technology and introducing it into the private sector, and the concurrent investigation and learning process, were intertwined in such a way that the project informed the research, and the research informed the project. Both benefited.

The overall research question was:

> *"what enabling conditions and external actions are necessary to stimulate and strengthen effective rural water supply service delivery by the private sector?"*

In addressing this question, the research analysed a set of key sub-sectoral aspects (most of which are addressed in section 4 of this report), as well as an equally important set of cross-cutting issues. These will all be drawn together in an integrated framework which can provide future guidance to projects or programmes in this or other development sectors.

Project team

The project team grew from two (Richard Carter – Project Manager - and Peter Ball – Drilling Consultant) prior to commencement, initially by the addition of Kerstin Danert, and later by Ronnie Rwamwanja and Jamil Ssebalu. Danert conducted her PhD research using the project as a case study[1], and from mid-1999 onwards led the Ugandan team. Rwamwanja and Ssebalu began by acting as consultants to the project, subsequently in this role became full team members, and in mid 2000 commenced establishment of their own NGO, TEMBA (see section 4.9).

Through the duration of the project, only Danert was employed full-time. Ball's contract was for 3 months per year, and Carter's budgeted inputs were 45 days per year. Rwamwanja and Ssebalu carried out a series of tasks which at times employed them approaching full-time, but at other times far less than this. It is important to record for future learning that no member of the project team restricted their inputs to what was funded. Such were the demands of our stakeholders, and such was the ownership of the process by all involved, that far greater inputs were made than those evident from budgeted expenditure.

In addition to the inputs made by the project team, 13 other individuals were employed as consultants or assistants at various times. Without these, the breadth and volume of work actually carried out would simply have been impossible (Table 1.1).

Table 1.1 Project consultants and assistants

Project Consultants/Assistants	Role
Eng John Ogwang, Ministry of Agriculture	Consultant for irrigation baseline study
Dr Andrew Muwanga, Makerere University	Consultant for hydrogeology baseline study
Mr Callist Tindimugaya, Aquatech Ltd	Consultant on siting methodology
Mr Anthony Luutu, Aquatech Ltd	Consultant on siting/hydrogeology
Mr Kakooza	Consultant on financial issues
Mr John Okwi	Technical Assistant
Mr Juma	Field Assistant, drilling
Ms Joy Morgan, Morgan Associates	Managing consultant, business training evaluator
Mr Dan Kakumba	Field Assistant, source monitoring
Mrs Elizabeth Nakkazi	Secretary to Uganda Team Leader
Mr A Pataga, Kajara Kabitto & Co, Advocates	Legal advisers
Ms Lucy Acheng	Secretary, TEMBA
Ms Enid Katusasbe	Office Assistant, TEMBA

Four Masters students of Cranfield University (Martin Worth, Chris Wardle, Matt Snell, and Kim Littlefair) undertook their thesis projects directly or indirectly on the project.

[1] To be written up and completed in the first half of 2002.

The thesis titles are given in section 4.10. The findings of their work are reflected in this report.

In Uganda, the project has become known as the Low Cost Drilling Project, or simply "the low cost project". The drilling rig developed by the project is known as the "Pounder rig".

The project has not finished its work. Although this is a final report, it is the final report of the first stage only. Both the demand from Uganda and the future commitment from the project team mean that ways need to be found to continue the work to a satisfactory conclusion. This is the subject of sections 5 and 6.

1.2 Objectives

The project goal at the outset was DFID's Knowledge and Research Programme theme W4: *to raise the well-being of the rural and urban poor through cost-effective improved water supply and sanitation*. The purpose of the project was to design a new low-cost water well drilling rig, and bring about its manufacture in Africa and its uptake by small local contractors. The original outputs of the project were (a) a designed, tested and documented low-cost drilling rig, (b) the manufacture of the rig in at least one country in sub-Saharan Africa, (c) the uptake of the rig by local contractors, and their training in its use.

A significant change to project output (b) lies in the understanding of "local manufacture". This issue was discussed in several progress reports, and although those discussions extended the team's definition of "local manufacture", no change to the wording of project goal, purpose or outputs was made during the project. The discussion of this key topic is included in section 4.4.

Through correspondence which took place between December 1999 and June 2000, additional DFID funding was approved, in order to achieve the following revised purpose and outputs (additions in ***bold italics***):

Purpose:
New very low cost water well drilling rig manufactured, adopted by contractors, ***and being promoted beyond end of project.***

Outputs:
1. New rig designed and tested, and design and operation fully documented.
2. Manufacture and marketing initiated.
3. Contractors trained in use of new machine.
4. ***Sustainable uptake mechanisms in place.***

The revised project logframe is included as Annex 1.

All the project outcomes depend on the performance of the drilling technology, but the real proof of project success will be the stimulation of local, private, profit-making businesses, and through them the long term, sustainable provision of water at an affordable price to communities and consumers. Considerable progress has been made toward these ends, but as the remainder of this report shows, much more remains to be done before all the outputs can be completely fulfilled.

As a research project (more specifically an *action research* project), new knowledge and observations have emerged about (a) the capabilities, potential, and feasibility of low-cost shallow drilling in Uganda[2], (b) the existence, experience, and capacities of small contractors, (c) the experience and capacity of local Government to manage and supervise private sector contracts, (d) the challenges of community mobilisation, handpump maintenance, and community management of water supplies, and (e) the entire process of technology transfer in the context of a rapidly changing policy environment[3]. These issues will be written up over the coming months in a series of project publications and in Kerstin Danert's PhD thesis (for details of documentation see section 4.10).

1.3 Project funding

As the project proceeded, it became clear that additional funding would be needed, for four purposes:

- to achieve, as far as possible, the original objectives (the project proposal made in 1997 had been required to substantially reduce the originally anticipated budget, and inevitably some important aspects had been under-budgeted or omitted)
- to extend the project scope into the wider institutional and policy context (without which the project would rightly have been accused of tunnel-vision)
- to respond to the concerns of partners and stakeholders
- to attempt to ensure long term sustainability of the outputs

Consequently considerable management time was spent in UK and Uganda negotiating agreements with central and local Government, and seeking additional donor funding.

Specifically, the following new funding partnerships were brought into the project:

- a tripartite memorandum of understanding in 1999 with the Directorate of Water Development and Mpigi district, under which DWD provided a vehicle, Mpigi district a drill crew, and the DWD/WES programme (SIDA/UNICEF funded) materials and funds for transport and drill crew for the trial boreholes in Mpigi district. This agreement involved the following budgetary commitments: DWD – USh24,150,000 (plus vehicle); Mpigi district – USh990,000; Mpigi communities – USh2,840,000 (a total of about £11,200 excluding contributions in kind).
- a second agreement with Mpigi and Wakiso districts in 2000/01 to allow for contractor-drilling of 15 boreholes under DWD/WES funding. This involved the following financial commitments: DWD – USh54,999,650; Mpigi District – USh2,860,000; Mpigi Communities – USh6,310,150 (a total of about £25,700).
- a contract with GoU, through DWD, supported by the DANIDA-PMS budget section 1.5 intended for innovative approaches, for the sum of US$33,500 (approximately £22,300). This was to allow for monitoring of completed wells, development of well siting methodology, and further business training. This contract was agreed in December 1999.
- an agreement with Mukono district, whereby PAF funds budgeted for hand-dug wells would be re-directed to contractor-drilled Pounder[4] wells. This committed

[2] In the Ugandan context "shallow drilling" refers to slim boreholes (ie not hand-dug wells) up to about 30m depth.
[3] Specifically decentralisation, privatisation, and debt-relief/poverty alleviation.
[4] The drilling machine developed during this project was named the Pounder Rig. Different stages in the rig technology are referred to in chronological/numerical sequence as Pounder I, Pounder II, etc.

Mukono district to USh35,553,100 and Mukono communities to USh1,802,900 (a total of about £14,900)

- PAF funding for contractor-drilled wells in Jinja District (approximately USh6,400,000 or £2,600)
- a small contract with Water Aid (USh3m or about £1200 for drilling investigative holes in Katakwi District
- an anonymous donation from an individual in the USA who heard about the project through a BBC World Service interview with the project manager (about £6400).

In addition to these new financial partnerships, DFID funding was increased by £14,900 in 1999-00, to cover unforeseen costs, and another £40,000 in 2000-01 for the establishment of NGO TEMBA by the project's main Ugandan partners Rwamwanja and Ssebalu.

Overall therefore, the project budget increased from £223,394 funded by DFID at the outset, to approximately £362,600 through DFID, DANIDA, DWD, SIDA, UNICEF, PAF, Mpigi, Mukono and Jinja Districts, Water Aid, and an anonymous donor by the close.

An important funding issue relates to funds for well drilling, both in the trial period (1999) and subsequently (2000-01) as private sector contractors have adopted the technology. Funds for drilling were not included in the original DFID budget. This absence of a crucial funding component forced a closer partnership between the external team and central and district Government stakeholders than might have been the case had the project been entirely self-sufficient. The project could not have progressed without the financial partnership which developed with DWD and the districts. Although the project may be criticised for the limited number of holes drilled as the Pounder rig was developed and taken up, we believe the benefits in terms of mutually dependent partnerships have far outweighed that weakness.

At the time of writing, a small contract with Lutheran World Federation is under negotiation, to allow further technology development through a drilling programme in Karamoja (Moroto District). It is intended that this should provide a partial bridge between the present period of donor funding (ending 30th June 2001) and the next stage of funding.

2 Final report

2.1 Report purpose and target readership

The purpose of this document is to report the scope, experiences, findings and implications of the "Low Cost Drilling Project" to all project funding partners. In order to fulfill the project's contractual obligation to DFID at the end of the 3-year funding period, it broadly follows the guidelines supplied by DFID for report structure. It is also presented in a form suitable for others less closely involved in the project who require a summary of work to date.

In addition this report responds to the recommendations of the Stakeholder Consultative Workshop held at Kyambogo, 12th June 2001[5]. At this meeting approximately 25 representatives of the project's stakeholder constituency gave a firm mandate for continuation of the work which has begun in this project. They specifically requested that this final report should set out the project findings and the way forward, in a form which could provide a justification to potential funding partners for the next stage of work.

2.2 Report structure

The core of this document is the report of work done, and the corresponding findings, in section 4. Here the numerous component topics of the project are described individually. However, because of the importance of the <u>integration</u> of these separate topics, section 3 first presents a synthesis of the project as a whole. Section 5 draws out the implications of the previous sections as justification for the future work which is described in section 6. Section 7 presents summaries of project expenditure in relation to each of the international funding partners.

[5] A summary report of this workshop is in preparation at the time of writing.

3 Scope, structure and values of the project

3.1 Project scope

As has been explained (section 1.2), the initial project scope included:

i. research and development of drilling technology
ii. local manufacture of drilling technology
iii. uptake of drilling technology by private sector contractors.

The necessity of broadening this remit has also been referred to, and here this is justified in more detail. The reasons for broadening the scope of the project fall into three general categories.

First, the project has learned as it proceeded. The process which the project has gone through is best described as "*action research*". This is a process by which actions are taken, reflections and learning are made, and subsequent actions are modified accordingly. In the case of the low cost drilling project this flexible, interactive, and iterative process has taken place in the context of technology R&D and attempts to embed that developing technology in the private and public sector institutions of Uganda. The specific areas of broadening of scope under this first heading have included:

Table 3.1 Project learning, reflection and action

Broadening of scope	**Comments**
The ultimate "product" under consideration is not just a rig, but a functioning water source. Technology was extended to embrace well design and handpump selection/modification.	Human-powered drilling, with limited energy inputs, demands that hole diameters are as small as possible. This in turn requires consideration of direct install procedures[6], and this requires careful selection and/or modification of national standard or other handpumps, especially as the handpump cost is a significant part of the total cost.
Successful private sector uptake of rig requires a competent private sector. Even if the rig can perform, the uptake may fail if contractors are not competent in non-technical areas. Scope was broadened to understand and improve the private sector.	It rapidly became clear that competent small private contractors in the water sector are few in number. Contractors tend to lack equipment, business skills and capital. Our review showed that access to credit is limited. DANIDA co-funding enabled the project to undertake business training and follow-up with a large group of contractors.
Succesful private sector uptake of the rig requires contractors of a particular financial size. Scope was broadened to investigate the financial viability of Pounder drilling.	Although the Pounder rig is considered a low-cost technology, a contractor still needs working capital to operate with a hired or bought rig. Analyses of the tax situation, profitability and cash-flow were undertaken.
Under privatisation, district (LC5) and lower levels of local Government will contract out work to the private sector. The project was dependent on district government to enable	Districts are generally over-stretched, and in many cases inexperienced in working with the private sector. They lack supervisory capacity, and they have been uncertain, and in many cases unable, to disburse their

[6] Direct installation refers to the situation in which the borehole wellscreen is directly attached to the bottom of the pump cylinder, and the rising main doubles as well casing. This is in contrast to the "conventional" procedure in which a pump hangs in a cased/screened borehole.

drilling to take place. Scope was broadened to facilitate drilling in the districts, including lobbying for funds, site selection, and work on contractual arrangements between district and contractor.	massively increased budgets (conditional grants) supplied under the Poverty Alleviation Fund[7] effectively.
Communities are the end users of the water sources. Lack of mobilisation and inadequate understanding of the method can have detrimental effects on attitudes to the new technology. Scope was broadened to understand community perspectives and undertake mobilisation.	All trial wells and contractor-drilled wells were constructed under WES and PAF funding intended for completion of community water sources. The project therefore had a responsibility to ensure, as far as possible, that mobilisation was effective, and subsequent maintenance of completed Pounder wells was undertaken. The nature of community mobilisation was researched through well histories.
Lack of an adequate siting method and resulting unsuccessful Pounder wells threatened uptake of the technology. Scope was extended to identify a suitable siting methodology.	Despite Ugandan policy indicating a preference for low cost source options, there is still a bias toward deep drilling. One of the contributing factors is well success rate. As the rig was to drill in the little understood regolith, it was necessary to investigate siting options.

Second, the project has put very high value and emphasis on the building of relationships with stakeholders, and on listening to their concerns. In a number of formal and informal stakeholder workshops, as well as in individual meetings, concerns have been expressed, and the project has had a moral obligation to follow up on these. The main issues have included:

Table 3.2 Responding to concerns of stakeholders

Broadening of scope	**Comments**
Water quality was raised on more than one occasion as an area of concern with shallow wells. Scope was extended to include water quality monitoring of Pounder and other shallow well sources.	The additional funding provided by DANIDA allowed a limited water quality monitoring programme to be undertaken (see section 4.3).
The project was continually under pressure to extend geographically to more districts of Uganda, and so broaden the experience of the drilling technology into a wider range of geologies. This pressure was resisted.	The project was limited by money, human resources, transport, and equipment, and we knew that to stretch too far would weaken the effectiveness of the work. For these reasons the project made an early decision to operate close to Kampala, only in Mpigi, Luwero and Mukono Districts. However additional opportunities arose in Jinja and Katakwi, so this policy was slightly modified.

Third, sustainability and nurturing of introduced concepts, development of ideas, and future promotion took on increasing prominence as the brevity of the project was evident to all. Three years is a very short time to progress from the idea of a potential technology, through R&D, through the work with end-users, contractors, and those letting and supervising contracts, to the inclusion of the technology in Uganda's package of water source options. This is particularly so when every single aspect of the technology environment – geology, contractor and district capacity, and policy

[7] The PAF results from the HIPC (debt relief) process. This has resulted in hugely increased budgets in GoU FYs 2000-01 and 2001-02.

context – presents significant challenges. Consequently, measures were put in train quite early in the project to address this.

Table 3.3 Long term promotion

Broadening of scope	Comments
The project's two Ugandan team members proposed the idea of establishing an NGO with the capability and purpose of promoting the goals of the project both during and beyond its period of donor funding. (See section 4.9).	Rwamwanja and Ssebalu had been closely involved with the project from the outset, and with skills in community water supply and business development, as well as a strong sense of project ownership, they represented a strong potential for achieving long term nurturing of the seed sown in the 3-year funding period. Correspondence with DFID between December 1999 and June 2000 resulted in additional funding to establish such an organisation and provide year one running costs. TEMBA was physically established in mid 2000, and formal registration finally came through in June 2001.
There was still demand for the Pounder rig from contractors beyond the end of the funding period. The rig hire facility has been extended beyond the end of June 2001.	Continued commercial Pounder rig hire and maintenance has been placed facilitated.

Too often multi-disciplinary projects remain just that – a multiple set of disjointed disciplines, which are never seen as a synthesised whole. This project has attempted to avoid this trap, and this section on project scope is one part of the picture. The project started out seeing its remit in inter-disciplinary terms, but with the system boundary drawn around three issues only (drilling technology, local manufacture, and uptake by contractors). It finished with the system boundary drawn further out, to include other issues under the original headings, and some new issues too.

Many of the new issues addressed in the project can be seen as wider water sector issues which are not limited in relevance only to this project. This is indeed the case, and it was important in the project not only to avoid "re-inventing the wheel", but also to resist the temptation to try to solve all of Uganda's water sector problems. Nevertheless, all of these issues impinged on the successful test, commercial use, and long term uptake of the technology. If they had been ignored, there was a significant risk that the drilling technology would have been rejected. The project would have been of limited practical relevance to development, and it would have lost an opportunity to provide useful information to the wider water sector in Uganda.

Under the next heading, an attempt is made to interlink the wider system in which action, reflection, and more traditional research has been carried out during this project.

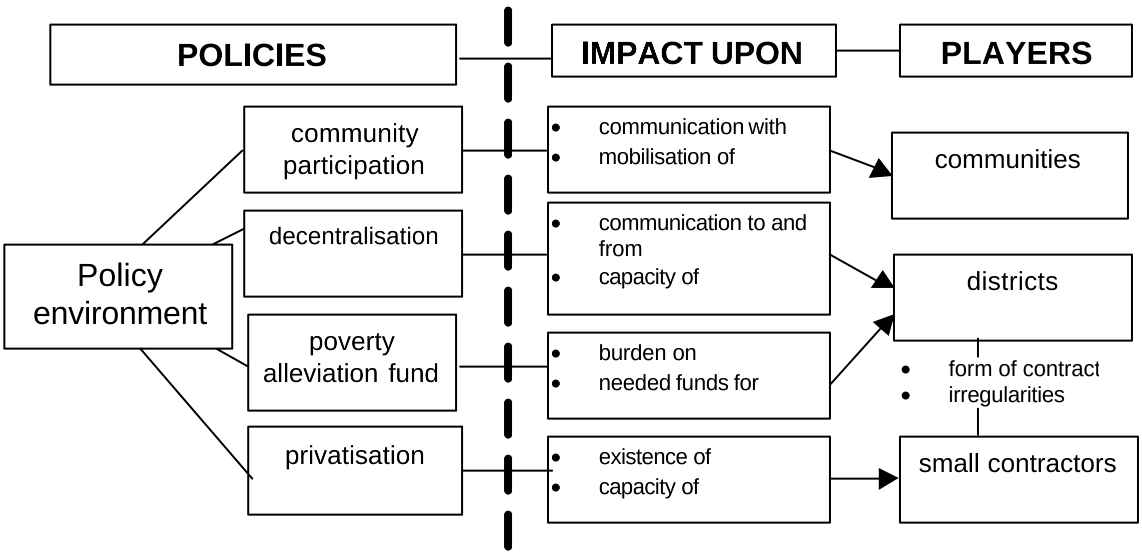
3.2 Inter-relationship of project issues and contexts

In this section, three annotated diagrams are presented, in order to represent the policy environment, the natural environment, and the institutional environment within which the project has been working. In reality these should all be combined into one picture, but this would result in a confusing complexity. The intention here is to present something mid way between the reductionism of section 4 (where the project issues are examined one by one), and a reality which is extremely complex.

Figure 3.1 relates the water sector policy environment of Uganda to the key players which are further referred to in Figure 3.3. The policy environment consists of 4 key principles: community participation, decentralisation, privatisation, and poverty alleviation. Community participation in rural water supply demands that communities fund part of the capital costs of their water supplies, organise water committees, carry out source maintenance, and finance the full costs of operation and maintenance. Decentralisation has turned over responsibility for planning, design, community mobilisation, construction, and capital funding to districts and lower levels of local Government. Privatisation means that all future source construction is supposed to be undertaken by private sector contractors under contract to districts. The Poverty Alleviation Fund (PAF) has delivered very large sums of money to the districts[8], and promises of even greater sums in the coming financial year. This has imposed an enormous burden on districts, especially when combined with the relatively recent policies of decentralisation and privatisation.

The three key players affected by these policies and policy changes are the communities, the contractors, and the districts. Communities receive varied levels of communication from local Government, and these are frequently contradicted by politicians, especially around election times. The experience of mobilisation varies from community to community, some receiving very limited quality and quantity of mobilisation inputs from sub-county and district. Small contractors, if they exist, have limited capacity, and experience the drawbacks of fixed price contracts (which only pay for successful wells; so who pays for dry wells?). Wells are paid for on completion, so small contractors are sometimes unable to complete works. Also they either master the system of “irregularities” in contract awarding and payment, or are marginalised from competition because of their lack of funds, contacts, or favours. Districts experience varied amounts and quality of communication or guidance from the centre, resulting in varied interpretation of the guidelines which do exist. They are often over-stretched, and in some cases inexperienced in dealing with private sector contracts. Some have limited capacity to supervise site work adequately, even to the extent required by the fixed price/successful source contracts prescribed by the conditional grant guidelines.

Figure 3.1 Policy environment and key water sector players



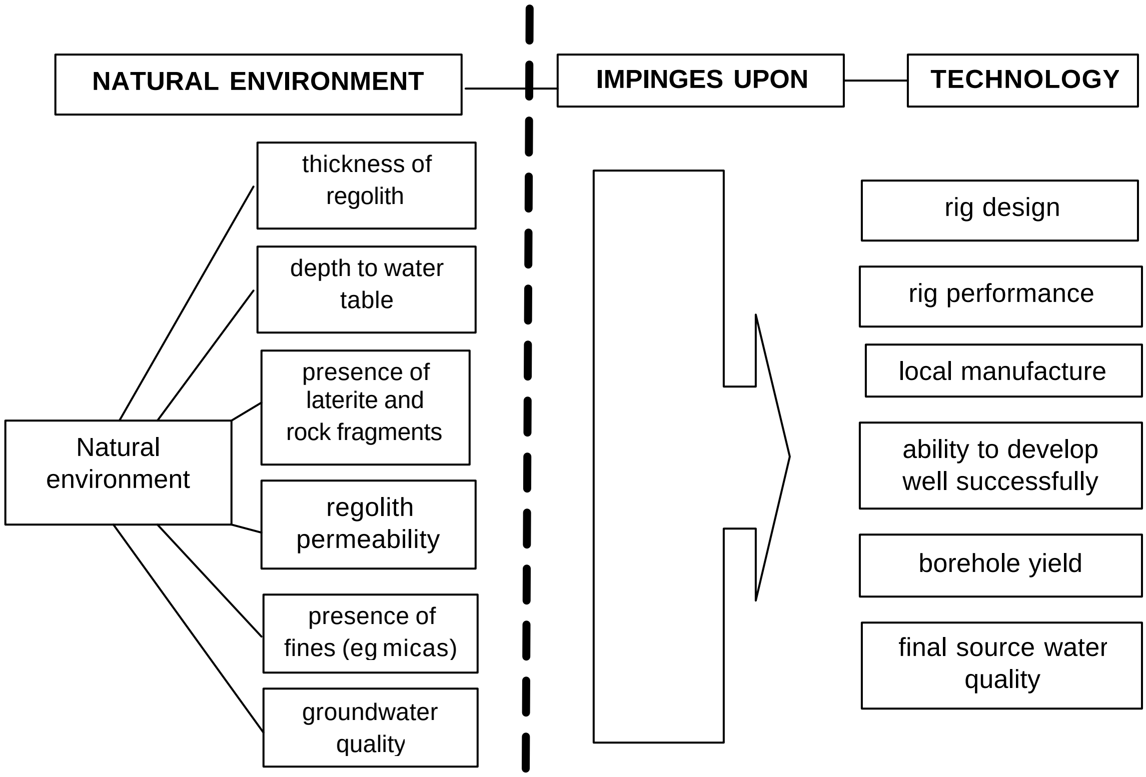
[8] A fourfold increase in conditional grant in FY 2000-01, with promises of a further doubling in FY01-02.

The natural environment – specifically the geology and hydrogeology - impinge on various aspects of the drilling technology and the water source as completed. These relationships are summarised in Figure 3.2.

Regolith[9] transmissivity (the product of saturated thickness and permeability) determines well yield. Hence total thickness, depth to water table, and permeability are key factors in determining yield.

The success of drilling with the new technology depends on water table depth (insufficient depth to water in particular causes difficulties with well collapse in certain formations), on presence of hard materials such as laterite and incompletely weathered "boulders", and on permeability. Although the rig has been designed to drill limited amounts of hard material, this inevitably slows drilling progress considerably. In practical terms, more than a few metres of laterite or rock make any human-powered drilling technique uneconomic. High permeability of formation, especially permeability caused by fractures or other openings, causes losses of the water which has been introduced in order to drill the hole.

Figure 3.2 The natural environment's interactions with technology



The ability to convert the drilled, screened[10] borehole into an acceptable water well (the process referred to as *development*) depends for its success on depth to water (and hence the ability to oscillate and pump large volumes of water), and on the chemical weathering products within the regolith. In particular, very fine particles of micas, originating from schists and gneisses, create difficulties.

[9] Recent hydrogeological studies by Taylor and others in the 1990s revealed that the regolith contains high potential for groundwater development, and that it may often be unnecessary to drill into the basement itself for water supplies. However, the variability of this material poses significant difficulties for siting, drilling and well completion.

[10] The well screen is a perforated (usually slotted) pipe, supporting the saturated formation and allowing water to flow into the well, while preventing ingress of particles.

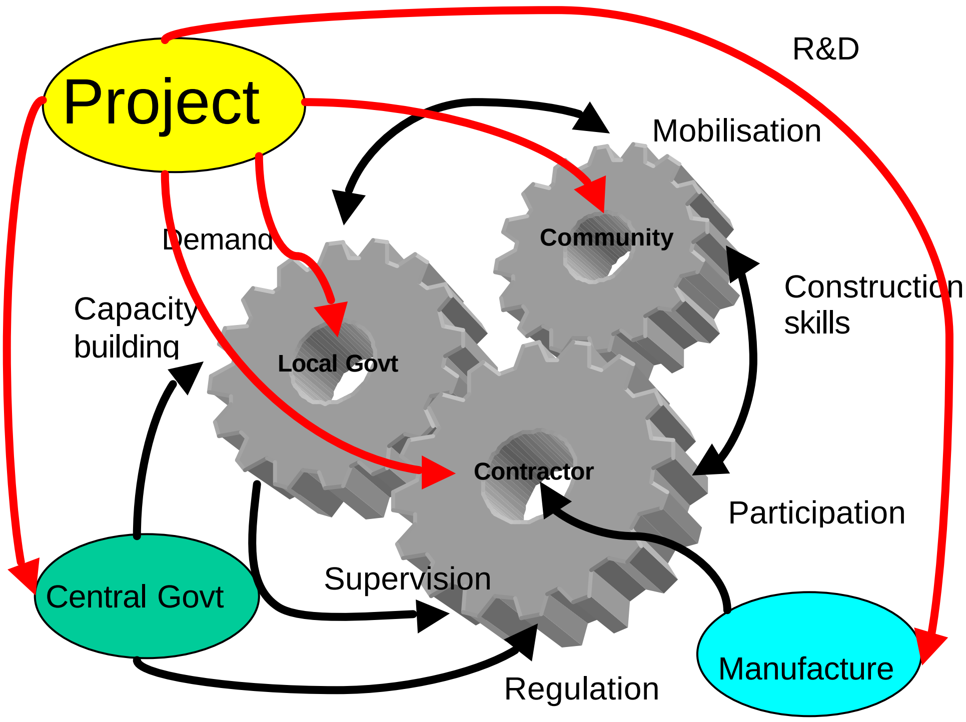
The final water quality of the source depends on the presence, after development, of fines – suspended particles resulting in turbidity. It also depends on the inherent groundwater quality. Particular concerns are *faecal coliform bacteria*, which are indicators of pollution by human excreta (and hence the existence of disease pathogens); *iron* (the presence of which, like turbidity, can cause rejection of a safe source in favour of an unsafe supply); and *pH* (the common measure of acidity). Low pH (ie acid groundwater) has been a major contributor to handpump corrosion in Uganda.

The design of the drilling rig has to be such that it can deal with a specified (and limited) range of ground conditions. The Pounder rig has been designed to extend the range of existing shallow hand auger drilling in order to cope not only with unconsolidated materials ranging from clays to gravels, but also with laterite and unweathered rock fragments. Hand auger rigs (which are fairly common in Uganda) cannot penetrate hard material or gravel. But the Pounder rig has not been designed to compete with conventional down-the-hole hammer drilling which is the most suitable technique for significant thicknesses of hard rock. Pounder drilling lies between the existing shallow drilling capacity and conventional deep drilling. The same factors which affect drilling success are those which have to be taken into account in rig design, with the addition of regolith thickness.

Finally, the viability and the details of local manufacture follow from the rig design, which itself has been determined by geology. In particular, the widespread existence of laterite and "boulders" has dictated the use of very strong drill pipe and special drill bits. The drill pipe is industry standard material, but unavailable in Uganda at present; while the drill bits have had to be specially designed and purpose-built in UK.

The third element of the environment in which concept development and transfer have been started in this project is the institutional context. Figure 3.3 shows the linkages between the key actors, namely the community, the contractor, and the district.

Figure 3.3 Key linkages between institutional players



At centre-stage, the contract between district and contractor to construct a community water supply is supposed to work like a well-oiled machine. In principle, the community expresses demand (through the LC system[11], up to the district, and involving a cash contribution up-front). The district has responsibility for mobilisation of selected communities, at the same time as establishing and supervising a contract whereby the contractor can bring its construction skills to the participating community. The contractor needs sources of materials and equipment. Central Government (DWD) has responsibilities, among others, for building capacity of districts, and for regulating the activities of the private sector.

In reality, challenges exist at all levels of the system. In particular:

- community demand is hard to measure, and the presence or absence of cash contributions may be an unreliable measure
- the demands on districts and lower levels of local Government in relation to community mobilisation are great
- communities may have very varied levels of understanding of the policies and institutional context into which they are to fit
- communities vary in their willingness to participate in construction and subsequent operation and maintenance
- contractors have widely varying levels of technical and business skills
- districts have varied experience of working with contractors
- the demands upon districts in relation to contract supervision are significant
- districts still interpret their funding (conditional grant) conditions with varying strictness

While the project has not set out to solve all these problems (which, as has been pointed out, are general, sector-wide problems), it has had to work with each of the three central players (communities, contractors and districts), as well as with DWD as a key stakeholder, and local manufacturing and supply industries. Figure 3.3 illustrates some of the linkages between these stakeholders.

3.3 Operational values of the project

The project has attempted to operate by a set of values, which are summarised below. *How* the project has functioned has been as important as *what* it has done.

In stating these values there are two dangers. First is the risk that examples will be cited of when the project failed to observe these principles. There are no doubt many such examples. Second, these are values which are supposedly shared by *all* development projects, and so repeating them here could be seen as simply giving lip-service.

The project has found that the attempt to take these values seriously has radical implications for a number of aspects of project management. The challenges inherent in full adherence to them probably explain why all projects have to compromise to some extent in observing them.

[11] The Local Council system of local government stretches from village (LC1) through parish (LC2), sub-county (LC3), county (LC4), to district (LC5). Beyond this the hierarchy continues to cabinet level (LC10).

The first issue is that of partnership. For the project, this has meant spending a lot of time building relationships, both within the team, but most particularly beyond it, with our many stakeholders. It has meant taking seriously the cultural difference between European attitudes, in which performance, outputs, and achievements take precedence, and African approaches, in which relationships, networking, and participation have a high significance.

The second value is that of capacity-building. Again there can be a conflict between, on the one hand, prioritising quality of output, and on the other, giving responsibility to less experienced individuals. In our view, it is only by such delegation and time spent in coaching that capacity can be built, both within and beyond the project team.

Third, the team has put great value on learning. In many ways this is easier to do in the context of research funding than in a development project, but not every applied research project can be said to seek and create significant learning. In this project, the main vehicle for recording this learning process will be Kerstin Danert's doctoral thesis, due for completion in mid 2002. Other learning outputs are listed in section 4.10. Danert's PhD attempts to analyse the process (both the *what?* and the *how?*) of transfer of a new technology concept into Uganda's policy context, and draw wider lessons for other places, for other technologies, and for other projects of this type.

The key practical issue in taking these values seriously is the factor of *time*. Meaningful partnership, effective capacity-building, and in-depth learning all take time, time which is spent at the expense of more tangible outputs. A second issue is that of *quality* of outputs, over which inevitably some compromises must be made.

Finally, the project will be criticised on two grounds: first for failing to operate according to these values, and second for putting too great a priority on them. As far as the first is true, that criticism is accepted. However, the second is not.

4 Project findings and outcomes

This section unpacks and reports the individual topics which have been implicit or explicit in previous sections. The key topics fall into four broad groupings:

- the technology, science and engineering involved in the project. Included here are (4.1) the technology of Pounder well completion, (4.2) the work on shallow well siting and hydrogeological potential, (4.3) the water quality monitoring results, and (4.4) the issue of local manufacture;
- our analysis of the three key stakeholders highlighted in the "machinery" of Figure 3.3, namely (4.5) the small businesses or contractors, (4.6) the communities which are intended to both participate in and benefit from the new technology, and (4.7) the districts as the employers of the contractors;
- the partnerships developed during the project, in particular with (4.8) DWD, the districts, and the contractors, and (4.9) with TEMBA, the new NGO established during the work;
- the listing, schedule, and availability of (4.10) the dissemination activities and documentary outputs of the project.

4.1 Technology

Introduction

Rural water supply in Uganda relies on a range of technologies from rainwater harvesting, through protected springs and gravity schemes, to shallow (hand-dug and hand-augered) and deep (drilled) groundwater sources. As the stock of springs and gravity schemes become more completely developed, the emphasis will inevitably fall increasingly on groundwater. The Pounder technology was conceived as filling a gap between existing hand-dug/hand augered shallow wells and conventional (high cost) deep wells. As the Pounder technology evolved, its possible role in exploration for shallow groundwater also emerged.

The Pounder technology has been specifically designed to complete small diameter wells in the regolith. While the potential of this hydrogeological environment is recognised, this potential has not been widely developed, in Uganda or elsewhere. Conventional drilling usually cases off the regolith to drill on and complete the well in fresh, fractured, basement. Hence both the environment and the technology itself are experimental.

Technology is central to the project for two key reasons. First, without the Pounder or other technologies, the other aspects of the project would have been of limited relevance. It is essential to integrate technology with the policy, institutional, social, economic and management issues - the "software". In the context of infrastructure development, neither is meaningful without the other. The current tendency to leave technology out of the definition of the "system" is unhelpful.

Second, by introducing a new technology concept, the project caught the imagination of its partners and stakeholders, in a way in which software development alone would have failed to do. New technology re-focuses the mind on the policy, insitutional, social, economic, and management issues which are equally important. While it has importance in itself, perhaps the equal relevance of new technology in the current context is to help stakeholders to analyse the wider system which includes both the hardware and the software.

There is however an uneasy relationship between technology and software, when the hardware is either undeveloped or untested in a new environment. In this project, the new technology began life in the project as a concept, and only developed into tangible hardware during the course of the project. The unease of the relationship is this: on the one hand the technology has to be promoted boldly, in order to create interest and commitment by partners, but on the other hand, one cannot have absolute confidence that the technology will function as hoped and intended. Expectations have to be raised, in order to create momentum, but there is a risk that those expectations may be disappointed. There are risks involved, both in research, and in technology transfer.

In the event, at the end of project funding, there is a great deal of interest and expectation among a wide range of stakeholders, and in parallel there has been a great deal of progress with the development of the technology. Nevertheless, we are at a stage when some further technology development is needed before the Pounder rig and its associated concepts and designs can be fully promoted.

The following sections outline the main activities of the project in relation to new technology, followed by the findings to date. Finally the outstanding technology issues are set out.

Technology development – from concept to contractor-drilling

Our initial ideas for regolith drilling centred around percussion as the preferred mechanism for breaking compact or consolidated ground with human energy. However, the attractiveness of simultaneous removal of drill cuttings soon led us to consider the traditional Asian “sludging” technology. Sludging is a very low-cost drilling method practised for generations in the extensive alluvial plains of north India and Bangladesh. It relies on the palm of the human hand being used as a valve at the top of a vertically reciprocating drill pipe. If the borehole is kept full of water, the reciprocating/percussion action, combined with the alternate sealing and releasing of the hand on top of the pipe, causes the drill pipe to act as a pump, delivering water and loosened ‘soil’ to the surface. Holes can be drilled to many tens of metres, very quickly, very cheaply, by a team of two.

In December 1998 the project sent drilling consultant Peter Ball to north India to observe, measure, and record a range of physical and economic characteristics of the traditional sludging technology. His findings are reported in [Reference 1].

During the first half of 1999 technology development concentrated on the modifications to sludging which would be needed to transfer it from Asian alluvium to African regolith. The key changes which we made initially were:

- replacement of the human hand at the top of the drill pipe with a simple valve
- replacement of ordinary galvanised water pipe with a material strong enough to withstand the shock loadings imposed by percussion on rock or laterite
- introduction of drill bits, also capable of withstanding the huge stresses involved in percussion on hard formations
- replacement of the traditional bamboo scaffold with steel scaffolding
- inclusion of a counterbalance to the drill string, to make lifting easier

Figure 4.1 Traditional sludging in north west Bengal

Much experimentation with valves, some sophisticated modelling and analysis of shock loadings, the selection of drilling industry-standard low-alloy (carbon) steel drill pipes, and the design of special tungsten carbide button bits supported this development.

By August 1999 Pounder I was ready for field trials. Following duty- and tax-exempt importation of equipment, trials began in Mpigi district the same month. A total of 14 test holes, and about 80m of drilling was undertaken in the period to mid November 1999. All drilling was carried out under funding from WES (the SIDA/UNICEF-funded Water and Environmental Sanitation programme). Because of this, compromises were having to be made constantly between the desire to gain knowledge of rig performance in a range of formations, and the need to complete water wells for use by communities. As well as training and trial holes, five water wells were completed, and these are still in use at the end of the project funding period. The field trials are published [Ref 2], and the results of water quality monitoring of these wells in section 4.3 of this report.

In December 1999, following the trials, a full design review was carried out, through analysis of both trial results and stakeholder comments. This is reported in [Ref 3]. The main proposed modifications to Pounder I were:

- the replacement of the scaffolding framework with a rigid welded frame
- an increase in drill pipe diameter to reduce fluid friction and so allow greater depth of penetration
- improvements to the drill bits
- the introduction of temporary casing for use when insufficient hydrostatic head exists to support the formation
- the inclusion of in-line flap valves to permit drilling using the natural water rest level (ie a non-flooded hole)
- a special footvalve and piston for in-situ test pumping to evaluate water strikes
- a means of consolidated transport of the machine to, from, and between sites.

These modifications were then incorporated into Pounder II over the first half of 2000.

In July 2000 the project published some basic instructions for operation of the Pounder rig, together with the specification, in the form of a complete set of drawings [Ref 4]. This was the first step toward putting the technology into the public domain (see section 4.4).

After a public demonstration of the rig at Silsoe, UK, in September 2000, two machines were air-freighted to Uganda:

- one to be placed with Mpigi district. This was imported duty- and tax-free through UNICEF, reaching Mpigi in December.
- The other imported by the project, for hire to contractors.

From December 2000 to (and beyond) the end of the project the Pounder II went into service with contractors, initially in Mukono district, followed by Jinja, Katakwi, and as the external donor funding was finishing, in Luwero. Fourteen holes had been drilled by contractors by June 2001.

Figure 4.2 Mpigi drill crew during 1999 trials

From early in the project, the technology concept was viewed as including more than simply the means to drill a hole in regolith. The end-product of the technology is a functioning low-cost water source. This consists of (a) a drilled hole, (b) lined with casing and screen, gravel packed as appropriate, and developed to remove fines, (c) equipped with a suitable, maintain-able handpump, (d) sanitary-sealed and suitably finished with surface drainage facilities. The first three of these aspects are closely inter-linked, and are the subject of the following sections. The fourth does not need to be considered here, as this aspect is well known in Uganda. Cost aspects are also summarised below.

Technology – the Pounder rig

This section briefly summarises the present state-of-the-art of Pounder II. The full details are in [Refs 4 & 17].

The rig (Figs 4.3 and 4.4) consists of a rectangular welded steel chassis, set up horizontally, with a vertical mast known as the pivot tube. The pivot tube carries the lever, which is allowed to pivot about a horizontal axis. On each side of the lever is an arc from which the drill pipe/sludging valve assembly hangs on one side, and a counterbalance hangs on the other. Both hang by chains. Ropes are attached to each end of the lever, and by passing these under rollers on the chassis, alternate pulling achieves a see-saw action of the lever, and the required reciprocating action of the drill pipe.

Figure 4.3 Pounder II set up and ready to drill

On the up-stroke of the drill pipe the sludging valve (a leather-surfaced flap) is closed, so maintaining the pipe full of water and slurry. On the down-stroke the valve opens releasing water bearing drill cuttings. These fall onto the slightly inclined steel <u>base plate</u> on the chassis, from which water drains back to the hole being drilled. Consequently water is circulated (down the annulus between the wall of the hole and the drill pipe, and up the drill pipe) as drilling progresses.

The drill bit used in the contractor drilling consists of a high strength, 'tool' grade steel body, further hardened by heat treatment, into which tungsten carbide buttons have been inserted.

In the contractor-drilling period from December 2000 to the end of June 2001, a number of minor and more significant issues have come to light which affect rig performance. These are set out fully in [Ref 17].

Of most significance is the wear experienced by the drill bits over this period. Heavy wear to the body and buttons (the latter caused at least in part by one or more buttons working loose) is evident in Fig 4.6

The hypothesis guiding current work (post project funding) in this area is that the drill bit should not embed itself forcefully into the formation being drilled. Rather, the tungsten carbide teeth should penetrate material only a small distance, leaving the bit body untouched. Consequently, not only is a modified bit needed, but also a mechanism to control stroke (and consequently impact). Based on this, the project is continuing design work on both of these aspects.

Figure 4.4 General assembly drawing of Pounder rig (note scale lost in re-sizing)

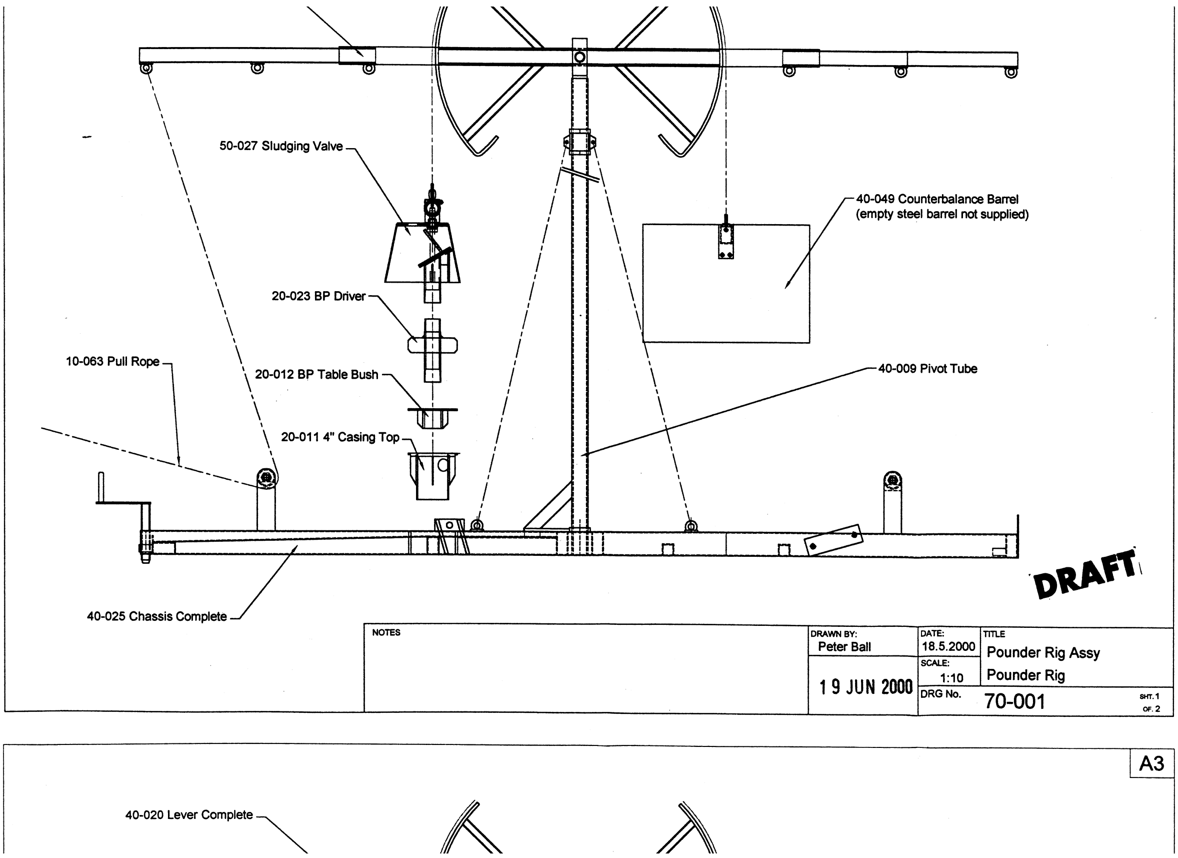


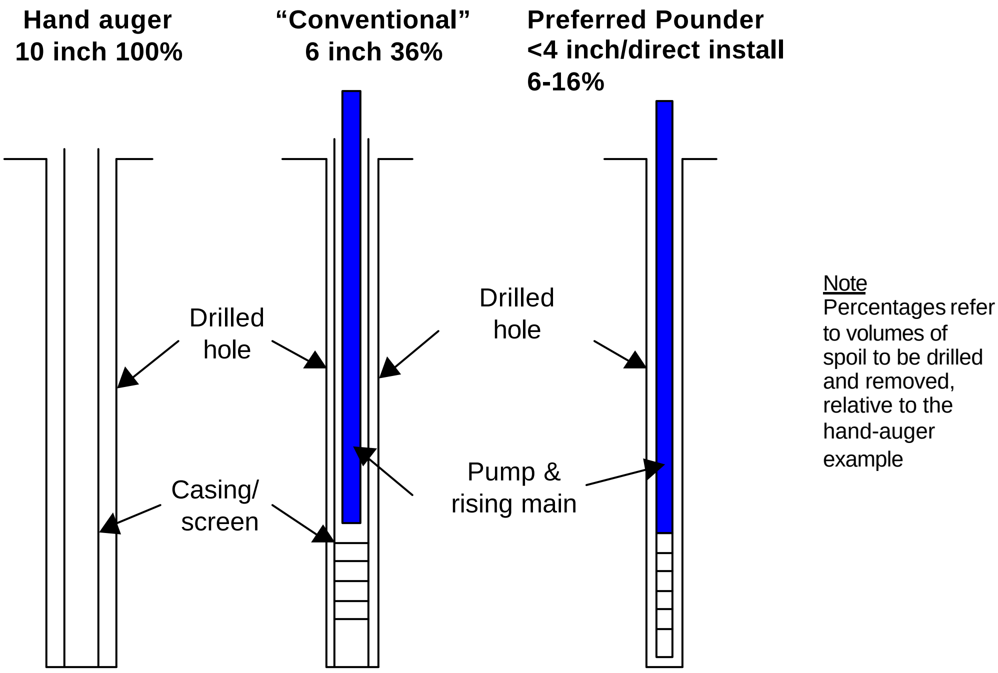
Figure 4.5 The sludging valve in action (right) and the counterbalance (left)

Figure 4.6 Wear to drill bit

Technology - the Pounder well

In human powered drilling the imperative is to drill at as small a diameter as possible. Figure 4.7 illustrates the case, by reference to a typical Ugandan hand-augered well, a conventional 6 inch (150mm) well, and the preferred Pounder well.

Figure 4.7 Drilled diameter and well construction



In the 10 inch diameter well, taken as reference, a large amount of spoil (100%) has to be removed. Common Ugandan practice is then to use a large diameter (5 or 6 inch) screen and casing, in order to limit the amount of gravel pack required.

A "conventional" drilled well (6 inch drilled, 4 inch casing and screen) requires only 36% the amount of spoil to be drilled and removed compared to the 10 inch hand augered well. In this option the handpump hangs freely inside the 4 inch casing, and in principle it is therefore all removable for maintenance and repair[12].

The preferred Pounder well is drilled at 3 or 4 inch nominal diameter and "direct-installs" a handpump, in which the rising main doubles as well casing, and a well screen is attached below the pump cylinder. In this way, the pump cylinder and rising main are non-removable, although the footvalve and plunger remain extractable in the case of VLOM pumps[13].

The direct-install option just outlined is not original. The Tara pump designed in Bangladesh in the 1980s was designed for this form of installation.

The other implication of small diameter, direct-install wells, is that the annular space remaining after installation of the pump is very small. Consequently, although back-

[12] Although in practice most of the time only the extractable footvalve and plunger need to be removed for maintenance
[13] Village level operation and management of maintenance – implying extractable footvalve and plunger, while remainder of pump stays in place.

filling of this space with gravel is desirable, it should be noted that this gravel envelope is not a true gravel pack, but rather a formation stabiliser (a space filler). Because of the difficulty of placing a very thin gravel envelope uniformly around the well screen, such a gravel pack is unlikely to be effective in preventing the ingress of fines into the well. This means that screen slot size must be carefully controlled, and in certain circumstances (very fine, uniform-textured aquifer material) a geotextile fabric wrap may be desirable.

Whatever well design is adopted, the development period and processes are key. This set of activities removes fines from the well and adjacent aquifer, leaving behind a permeable zone around the well screen. Development must be carried out in such ways, and for a sufficient period of time, to ensure that the water subsequently pumped from the well is clear and clean.

Technology – the Pounder well handpump

The logic of small diameter drilling has knock-on effects regarding handpump selection. Although the first Pounder wells in Mpigi district were completed with Ugandan standard U3 pumps (based on India Mark III), this would not be the preferred option, for reasons given below. Annex 2 shows the U3 direct-install well specification. It is important to note that the modification for direct-install capability means that slightly non-standard U3s have been installed.

There are two main reasons why the U3 is not the preferred option for Pounder wells. First, the cylinder outer diameter of the U3 is 85mm. This means that a hole of larger diameter needs to be drilled to accommodate it. In fact the over-diameter inherent in Pounder drilling[14] means that drilling at 100mm nominal diameter is sufficient. A pump such as the U3M (modified U3) is more suitable, with an outer diameter of only 63mm. There are also other 63mm diameter pumps such as the Malda and Tara which offer greater compatability than the U3 with the requirement for small diameter direct installation. Moreover the latter two are direct action pumps which are more suited ergonomically and from a maintenance point of view to shallow wells.

Second, the U3 has been widely criticised, and with justification, for being highly prone to corrosion. Even within the duration of this project, Pounder wells only one year old had high levels of galvanised pump rod corrosion, leading to high iron concentrations in pumped water. If this extent of corrosion reached the cast iron cylinders of the U3 pumps, causing deformation or blistering behind the brass cylinder liners, then they could fail prematurely. Replacement of all cast iron and mild steel (whether galvanised or not – galvanising is remarkably ineffective in corrosive groundwater) components with plastics, as in the case of the pumps just mentioned can solve the corrosion problem immediately.

Because of the inability to remove pump cylinder and rising main in the case of direct install pumps, it is necessary to have methodologies and tools for the fishing and replacement of all replaceable components such as broken pump rods and valves. Should fixed components such as brass cylinder liners wear, then the direct install procedure will not permit their removal or replacement.

Annex 3 shows a well specification based on the U3M handpump.

[14] As the drill bit “wanders” around the hole, it creates a larger hole than the nominal size of the drill bit.

Financial aspects of Pounder technology

Two recurrent financial questions arise in relation to Pounder drilling technology:

1. how much does the Pounder rig cost?
2. how much does a Pounder well cost?

Both are simplistic questions, for reasons set out in the following paragraphs.

First, in relation to the drilling machine, the direct answer depends on the following factors:

- the degree of in-country manufacture
- the source of all components
- the freight (sea, land, air) arrangements for delivery
- the number of machines purchased
- the VAT status of the purchaser

However, even this only paints a small part of the picture. If a potential contractor considers purchase, (s)he also needs to consider the capital required to cover:

- transport of the rig
- purchase of start-up stock of well consumables (well screen, casing/rising main, handpumps, 'gravel pack')

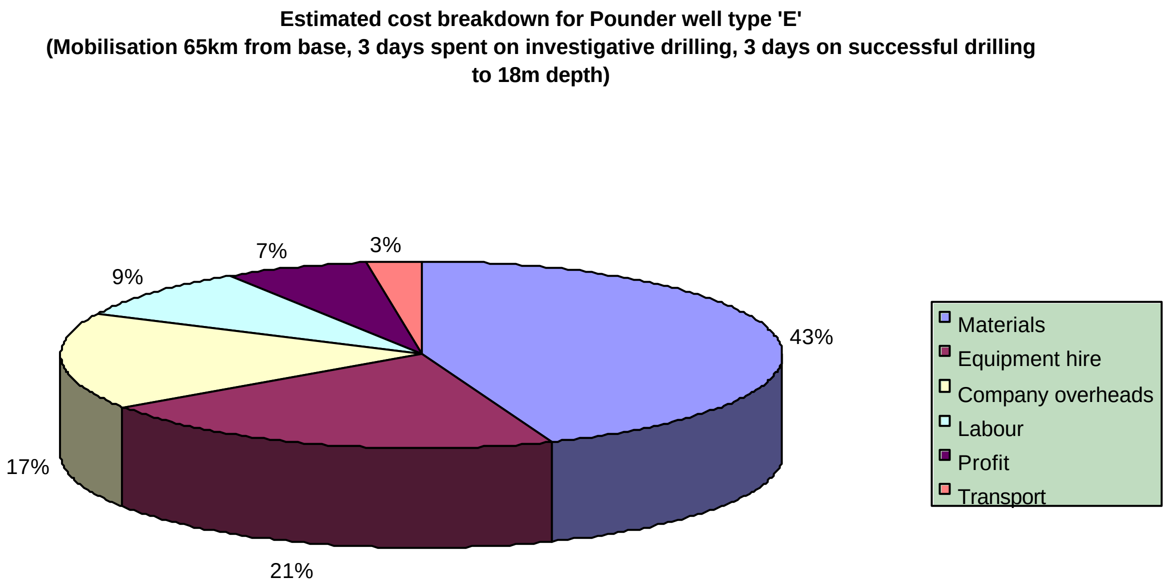
The project has carried out detailed studies of these aspects, and the full results will be published in [Refs 8 & 9]. To summarise though, depending on the anticipated workload in the first year of operation, the startup capital (to cover transport and stock) required by a contractor is in the region of USh10-30m (£4-12,000, $5,500-16,700).

Second, in relation to the well cost, this too depends on a multiplicity of factors. That there is no such thing as an "average" well (except for general budgeting purposes), is stressed in section 4.7. Nevertheless, our detailed costings show that under fixed price (successful well) contracts, prices very similar to hand-dug and hand-augered wells are attractive to contractors. These are in the range USh2.5-3.5m (£1000-1400, $1400-1950).

Of more interest perhaps than an indicative total cost is the breakdown of the main components of a Pounder well. This is shown as figure 4.8. Here it can be seen that about 33% of the total is the direct costs of drilling (equipment hire, labour, and transport), 43% is materials (of which the handpump is by far the single largest item), while another 24% (company overheads and profit) is the cost associated with private sector involvement rather than direct labour or NGO construction[15]. In addition to these costs, the district would incur VAT charges, and the costs of community mobilisation, site selection, and supervision. Any or all of the latter three could be contracted out.

[15] A full costing of either local Government direct labour or NGO construction should, of course, include overheads. These are often not fully costed however. In the private sector, these become more explicit.

Figure 4.8 Indicative cost breakdown of Pounder well



4.2 Shallow well siting

Introduction

The heterogeneity of regolith geology means that drillability and the success of a shallow hole as a water source are very variable. Every failed hole represents a financial cost, which *may* be worth minimising by investing in scientific siting (geophysical) procedures. The assessment of whether it is economically worthwhile to do so however is complex.

The major factors involved in this assessment are:

- the "blind" success rate of drilling (ie the success rate achieved in random drilling)
- the costs of (a) failed holes (in which setting up and drilling time is spent, but no well linings or pumps are installed, and the next attempted site is nearby) and (b) successful holes (in which well linings and handpumps are installed following drilling)
- the costs of scientific siting procedures
- the certainty of the predictions made by scientific siting procedures

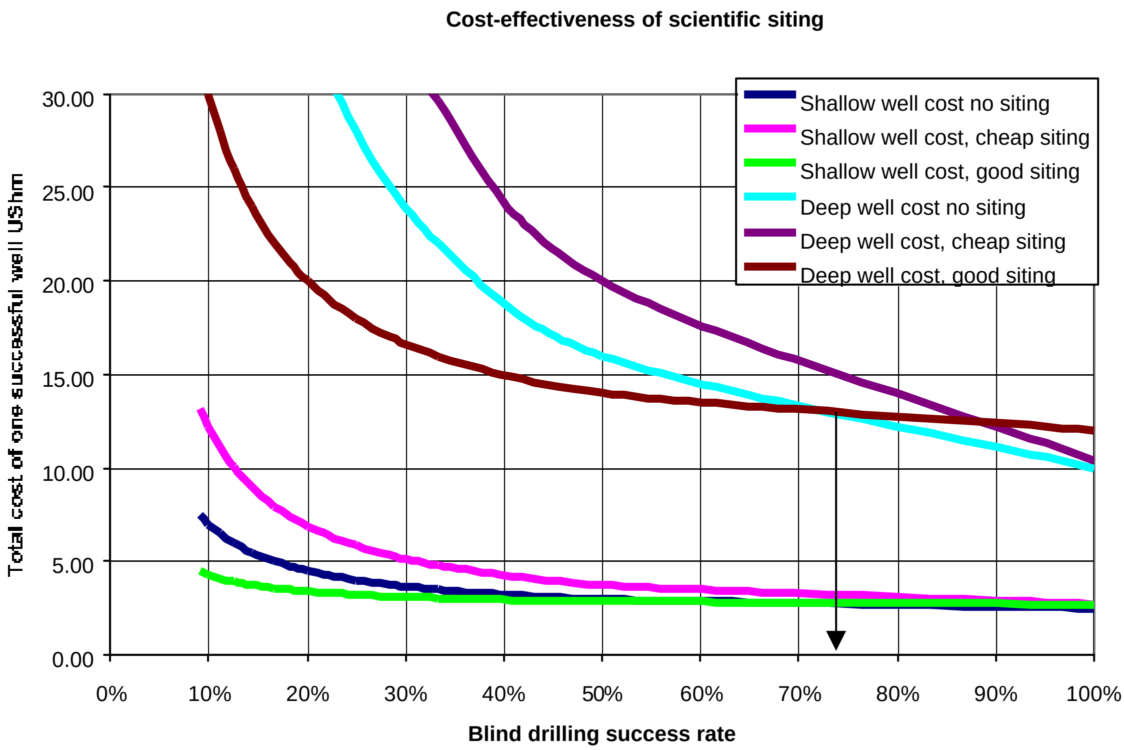
Unfortunately it is not easy to tie down any of these figures with precision. Taking them in turn in relation to Pounder drilling:

- there has been insufficient drilling experience to date with the new technology (about 25-30 holes in total), to make generalisations about success rates. Moreover, the science of hydrogeology in Uganda being as young as it is, the hydrogeological variability is not known well enough to make very useful generalisations which help at the local scale.

- well costs include many variables, so the possible ranges are broad.
- budget costs of scientific siting range widely in cost (year 2001 data gathered by the project suggests as little as USh200,000 (£80) per site to USh1.35m (£540), from cheapest to most expensive (comparing similar numbers of sites and distance from base)[16].
- undoubtedly an experienced hydrogeologist or geophysicist with good equipment can give a greater (although not absolute) *reliability of prediction* than a less competent specialist[17].

Nevertheless, it is possible to make realistic estimates of these values, and draw some general conclusions. Figure 4.9 shows the results of a simple model (Annex 4 contains the assumptions used) which takes all these factors into account.

Figure 4.9 Well siting economic model



The conclusions to be drawn from the figure are that:

- *in the cases of both shallow and deep wells, the reliability of siting procedures is crucial. "Cheap", low reliability siting is worse than no siting at all.*
- *For deep wells, if "blind" success rate falls below about 70-80%, then investment in scientific siting is financially worthwhile. This would be true most of the time in Ugandan deep drilling*[18]*.*

[16] The lower cost here almost certainly represents "moonlighting" using "borrowed" equipment, while the higher figure involves professional consultants fully costing their inputs.
[17] In addition, siting in basement (fracture identification) is easier than in heterogeneous regolith

- *for shallow (Pounder) wells, only if "blind" success rate falls below about 30-40% is investment in scientific siting is financially worthwhile[19]. However, at higher success rates than this, the situation is less clear cut, with the costs and benefits of scientific siting running very close together.*

Why should these critical success rate values be so different? Two reasons are evident from the model:

1. in the case of shallow wells the cost of a failed well is small in absolute terms, and a smaller proportion of the cost of a completed well than in the case of a deep well (in the model a failed shallow well represents about 20% of the cost of a successful well; for deep wells this proportion is 60%)
2. in the case of shallow wells the cost of scientific siting is a much higher percentage of the cost of drilling than in the case of deep wells (for shallow wells "good" siting costs more than 50% the cost of a successful well; for deep wells, only 20%).

Consequently, a greater failure rate can be accommodated *from an economic point of view* in the case of shallow wells than deep[20]. Moreover, with shallow wells, the economics drives one to consider trial drilling as the siting method of choice. This is further developed below.

To complicate matters further though, the assessment of the worthwhileness of using scientific siting procedures is not simply an economic decision. From an economic viewpoint one may accept a certain amount of drilling failure as an alternative to more expensive scientific siting. However there are social implications of mobilising communities (including raising cash contributions and organising committees) and then having to disappoint them when two or three trial holes fail to find water.

In our view full mobilisation should only be carried out *after* two or three trial holes have either proved or disproved the presence of water, and a decision has been taken whether to construct a Pounder well, a hand-dug well, or to investigate deep well potential. In other words, two drilling contracts should be let, one for siting with the Pounder rig, then if sufficient groundwater is proved, a period of mobilisation, followed by a second contract to complete a Pounder well.

The following sections describe, first, the project activities which have helped to lead to this conclusion, and second, some of the more detailed findings of those studies.

Work done

Table 4.10 summarises the main project activities on hydrogeology and siting and their findings.

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[18] Tindimugaya reports that typically "blind" deep drilling achieves a 20% success rate, and that scientific siting can increase this to 60%. Siting is clearly economically attractive.
[19] The relatively high cost of siting, together with its own unreliability in regolith, makes it unattractive.
[20] Note all the figures used in the model are open to debate. This is an area that justifies further in-depth development.

Table 4.10 Summary of activities related to hydrogeology and siting

Activity and consultant	Funding	Comments
Baseline study in hydrogeology, November 1998 to March 1999, by Dr Andrew Muwanga, Makerere University	DFID	General review seeking guidance on likely drilling conditions and site selection. Focus on Mpigi, Mukono, and Luwero districts (immediately surrounding Kampala). Potential of regolith highlighted, but heterogeneity noted too. Study limited by paucity of data and difficulties of making useful generalisations. At this point project did not know rig capabilities.
Development of a siting methodology for Pounder rig well drilling in Uganda, December 1999 to January 2000, by Mr Callist Tindimugaya, Hydrogeologist	DFID	First, brief, consultancy specifically addressing siting methodology. Budget guideline given to consultant was that siting cost should not exceed USh100,000 per site. Consultant recommended siting methodology consisting of (a) desk study, (b) field reconnaissance and mapping, (c) test drilling with the Pounder rig.
Development of the ideas in the draft Pounder rig well siting methodology, May-June 2000, by Mr Callist Tindimugaya.	DANIDA	Second consultancy, reviewing draft siting methodology, and carrying out field work, in the light of data from the new Pounder wells/well logs in Katabi subcounty, Mpigi district – ie an ex-post drilling test of the siting methodology. Test drilling was carried out with a hand auger, and the limitations of this tool for Pounder well siting became apparent. Overall the appropriateness of the three-step methodology was confirmed.
Shallow well siting in Mukono district using the draft Pounder well siting methodology, November 2000, by Mr Callist Tindimugaya.	DFID	Third consultancy, to apply the siting methodology (still using hand auger for test drilling) ex-ante drilling. The consultant investigated 7 sites, of which 4 were considered suitable for Pounder drilling, and the remaining 3 were considered only to have potential for hand-dug wells. In the event, because of decisions taken on the spot in the field, only 2 of the positive sites were drilled. One of these was developed as a successful source.
Observation of Safewater Technical Services siting procedure, 13-14 January 2001	DFID	Based on hand auger (75 & 100mm augers) investigation following site reconnaissance, with possibility of in-situ test pumping.
Project review of Scan Water Contractors and Groundwater Consultants report on hydrogeological investigations for four shallow well sites in Butagaya, Budondo, Buwenge and Mafubira subcounties, Jinja district, 3-4 January 2001, under contract to Blessed Contractors Ltd.	DFID	Based on electrical resistivity investigations informed by information on existing hand auger wells from RUWASA database.
Final consultancy, revisiting siting procedures and hydrogeological potential of Pounder well drilling in Uganda, June 2001, by Mr Anthony Luutu, Aquatech Ltd.	DANIDA	Confirms general siting methodology developed in the project, and supplements existing knowledge with information on shallow well potential in all districts of Uganda.

All the individual project reports on well siting are to be gathered under a single cover (for reference see section 4.10).

Conclusion

The view at the end of this project stage, drawing together economic, hydrogeological, and social issues surrounding siting, is as follows:

Regolith heterogeneity limits the value of regional desk studies. Initial site selection should be based primarily on field reconnaissance and local (indigenous) knowledge. Use of a hand auger for test drilling is of limited value, because a failed hand auger hole does not necessarily mean a failed Pounder hole. Contracts should be let in two stages: (i) using the Pounder well for investigative drilling, (ii) Pounder drilling a water well. Between the two should come (a) the assessment of the investigative well results, with a corresponding decision as to the way forward (Pounder well, hand-dug well, or investigate deep drilling options) and (b) full community mobilisation. It is assumed that prior to ALL of this there is an assessment of spring (including gravity) and rainwater options.

4.3 Water quality

On a number of occasions project partners in central or local Government expressed concerns about the quality of water which would emerge from Pounder wells. Although this was not considered by the project to represent a significant risk[21], it was important to take these anxieties seriously, and produce evidence one way or the other to settle the issue. Consequently, once DANIDA co-funding was approved in December 1999, equipment was purchased and a period of water quality monitoring was undertaken, comparing five Pounder wells completed in 1999 in Katabi sub-county of Mpigi district, with five hand augered wells drilled in 1998, nearby. Monitoring of the Pounder wells commenced in March 2000, and continued to the end of the project. Monitoring of the non-Pounder wells commenced in June 2000. Both sets were monitored approximately monthly. The Pounder wells were monitored on 14 dates, and the non-Pounder wells on 10 dates. Table 4.11 lists source locations and dates of monitoring.

Table 4.11 Locations and dates of Pounder and non-Pounder wells monitored

Pounder Wells			
Reference	**Name**	**GPS location**[22]	**Monitoring dates**
PW2/6	Kajubi (Fence)	N 00 08.104 E 032.31.956	2000: 14th March, 6th April, 29th April, 27th May, 1st July, 29th July, 2nd Sept, 30th Sept, 30th Oct, 20th Dec 2001: 1st Apr, 22nd Apr, 20th May, 25th June
PW2/7	Valley (Captain)	N 00 08.495 E 032.32.140	
PW2/8	Ndula (Pond)	N 00 07.950 E 032.31.871	
PW2/9	Zzika (Steep Slope)	N 00 07.166 E 032.31.632	
PW2/11	Bukandekade	N 00 07.166 E 032 31.410	
Non-Pounder Wells			
TW2/109	Big Tree	N 00 06.052 E 032 29.730	2000: 2nd July, 30th July, 3rd Sept, 1st Oct, 31st Oct, 21st Dec 2001: 31st Mar, 21st Apr, 19th May, 24th June
Tw2/108	Sand Pit	N 00 05.823 E 032 29.748	
TW2/110	Two Pumps	N 00 05.737 E 032 29.804	
TW2/116	Mugezi	N 00 07.614 E 032 31.642	
TW2/16	Night	N 00 08.248 E 032 31.948	

The parameters measured, with reasons, were:

- thermo-tolerant coliforms (**faecal coliforms**): as an indicator of faecal contamination and hence risk of presence of faecal pathogens
- **iron**: because high levels of iron may cause consumers to reject disease-free source water in favour of faecally contaminated waters. High iron levels may be natural, or resulting from pump or well casing/screen corrosion

[21] Because percolation of water through a very few metres only of unsaturated ground is effective in removing pathogens. As long as the well has a good sanitary seal, water quality of shallow wells is generally not problematic.
[22] All GPS references are in latitude and longitude, expressed as degrees, minutes, decimal fractions of minutes.

- **turbidity**: because (a) high levels may indicate poor well development (although not in the case of naturally occurring fines which refuse to be developed out), and (b) high levels may cause consumer rejection in favour of inferior water
- **pH**: as a crude indicator of groundwater corrosivity.

Faecal coliforms were measured with a Del Agua kit (portable membrane filtration equipment with incubator set at 44.5C). Three replicate samples were taken at each source on each date, and results arithmetically averaged. On each date a control sample of distilled water was included for quality control purposes. Resources did not allow for any household testing of faecal coliforms.

Iron was measured colorimetrically with a Hanna Instruments kit, type HI93721.

Turbidity was measured using the turbidity tubes supplied with the Del Agua kit.

pH was initially measured using indicator tablets, but in June 2000 this was changed to a digital display stick-type pH meter.

The results of the faecal coliform testing are shown in Figure 4.10 below. In the case of the Pounder wells, all measured values are below 50FC/100ml (the Ugandan standard for untreated supplies). All but one of the values are below 20FC/100ml, and only 5 values (out of 64) exceed 10FC/100ml. These are very encouraging.

The faecal coliform counts of the non-Pounder wells are not as good as those for the Pounder wells. Nine values (out of 43) exceed the 50 FC/100ml standard. However, 30 values lie below 20 FC/100ml, and 22 values lie below 10 FC/100ml. Two of the 5 non-Pounder wells (TW2/109 and TW2/110) show high counts, especially the former.

The dissolved iron content of the Pounder wells (Figure 4.11) shows a very interesting pattern. Values are generally low (less than 0.5 mg/l) up to about December 2000, but from January through April 2001 iron levels rise to 1-2mg/l. After April, levels drop again. This pattern is consistent with the fact that heavy corrosion was observed in below ground pump components (galvanised pump rods) in April 2001, when the GI rods were replaced with stainless steel. The April water samples were taken immediately after replacement of the rods, when the borehole still probably contained a lot of iron which had originated from corrosion of the old rods.

The iron contents of the non-Pounder wells are generally higher than those of the Pounder wells. Twenty two out of 43 values exceed 1 mg/l, rising to nearly 3 mg/l. This is probably accounted for by the somewhat greater age of the installations there, which almost certainly have galvanised rods.

Turbidity values of Pounder wells are all 5NTU or less, except for one well (PW2/9) which had values of 10NTU or more on four dates. Since September 2000 though, all values for this well have been 5NTU.

Turbidity values for non-Pounder wells are all 5NTU, except well TW2/108 which has consistent values of 10NTU.

pH values for the Pounder well waters mostly lie between 5.0 and 5.9, but there are 8 occasions when pH dropped below 5.0, and to as low as 3.9. These values are very low, and instrument (calibration) error cannot be ruled out.

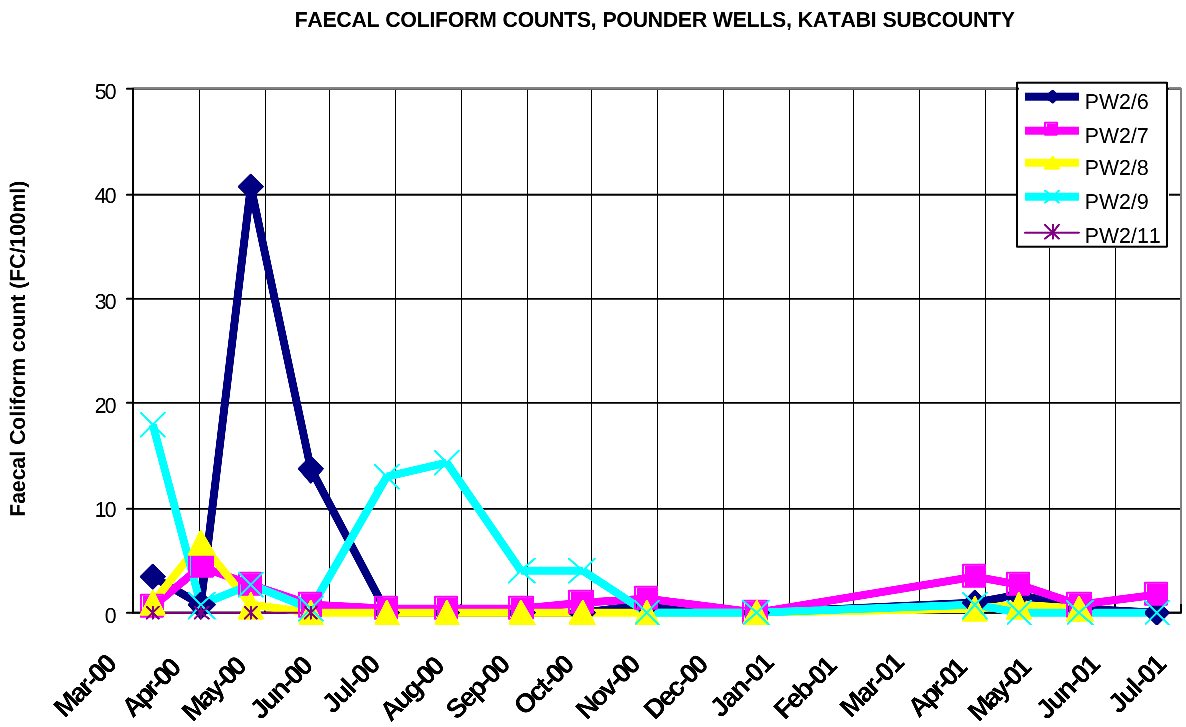
pH values for non-Pounder wells all lie between 5.5 and 6.5, except for one value which dropped to 5.0. Again instrument calibration error cannot be ruled out.

To summarise, the water quality data over 12-15 months from the small sample of Pounder and non-Pounder wells included in this study give rise to the following conclusions:

- All Pounder well data gives faecal coliform counts well within the GoU standard.
- Faecal contamination of Pounder wells is no worse than that experienced by other shallow wells. The data in fact show Pounder wells to be better in this regard than their comparison group of hand-augered wells.
- Groundwaters can have quite low pH values, which can cause severe corrosion of galvanised below-ground pump components. This corrosion can lead to rapidly increasing dissolved iron contents. Replacement of GI rods with SS causes iron levels to drop.
- Turbidity values in both groups of wells are generally low, and in this sample give no cause for concern.

The full water quality data, together with observations of handpump yield and source condition/care, are included in a separate report (see section 4.10).

Figure 4.10 Faecal coliform counts of Pounder (upper) and hand augered (lower) wells [Note same time scales, but different y-scales]



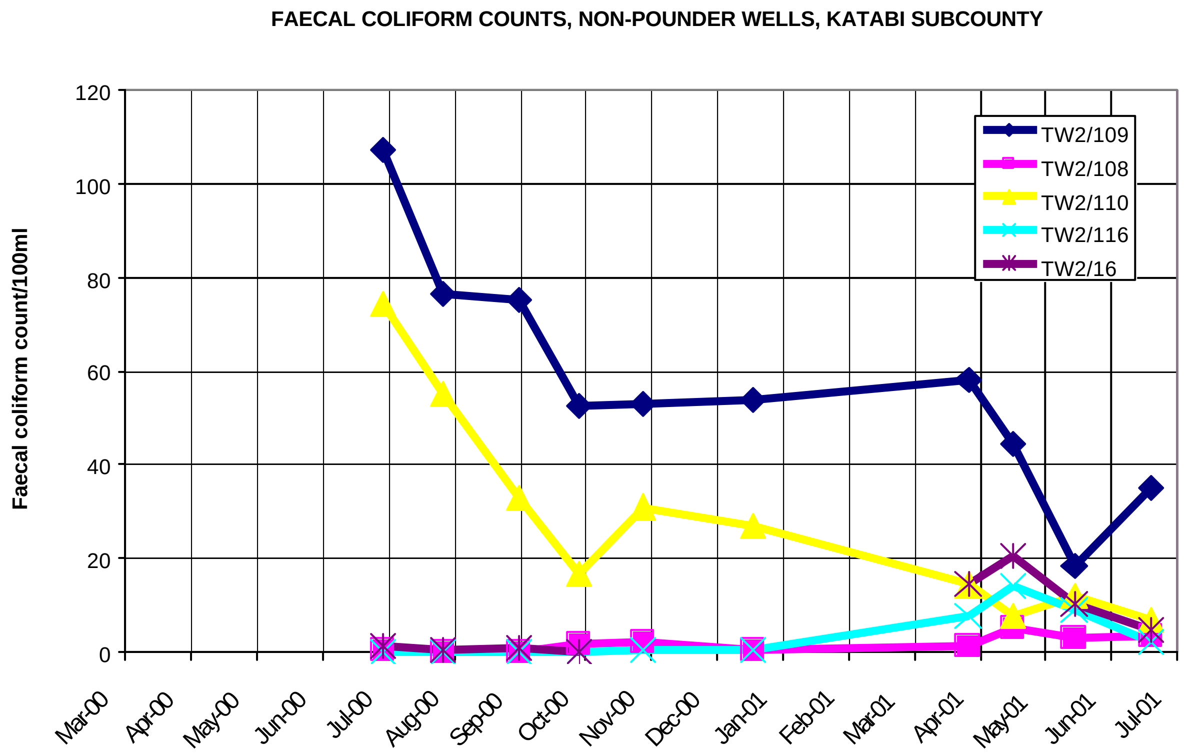
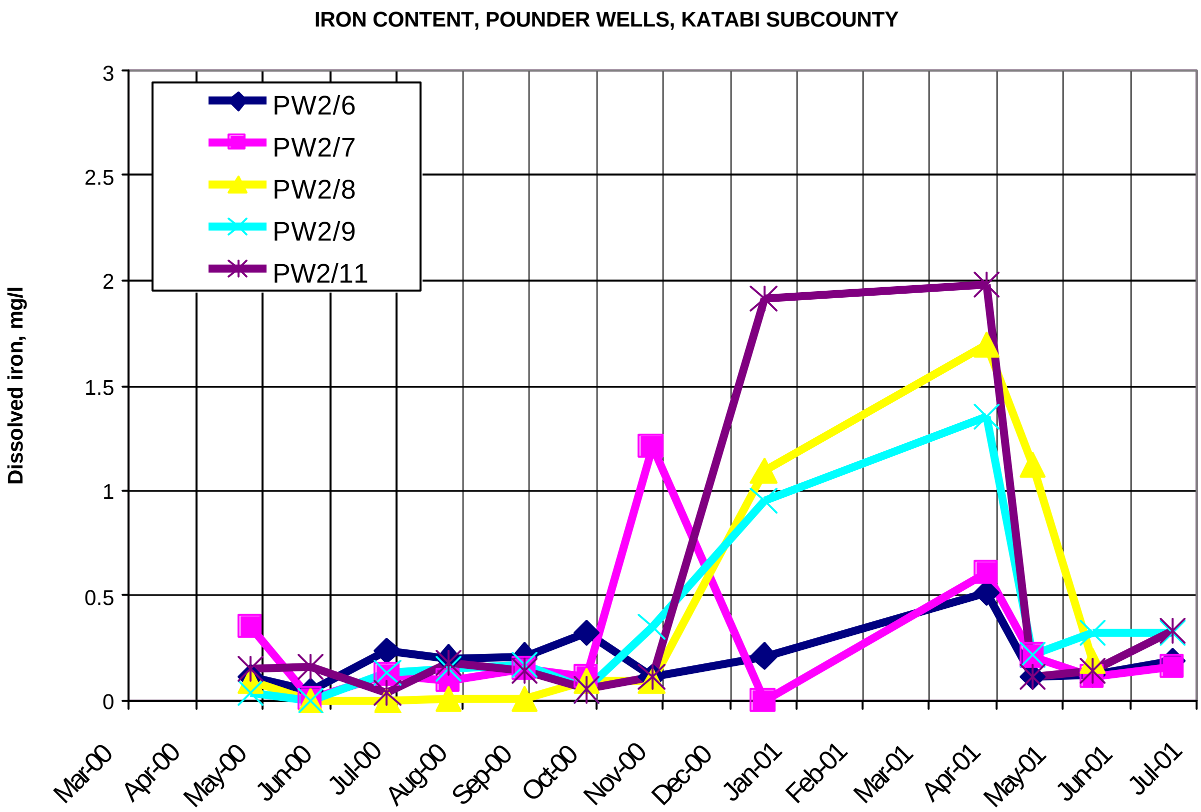
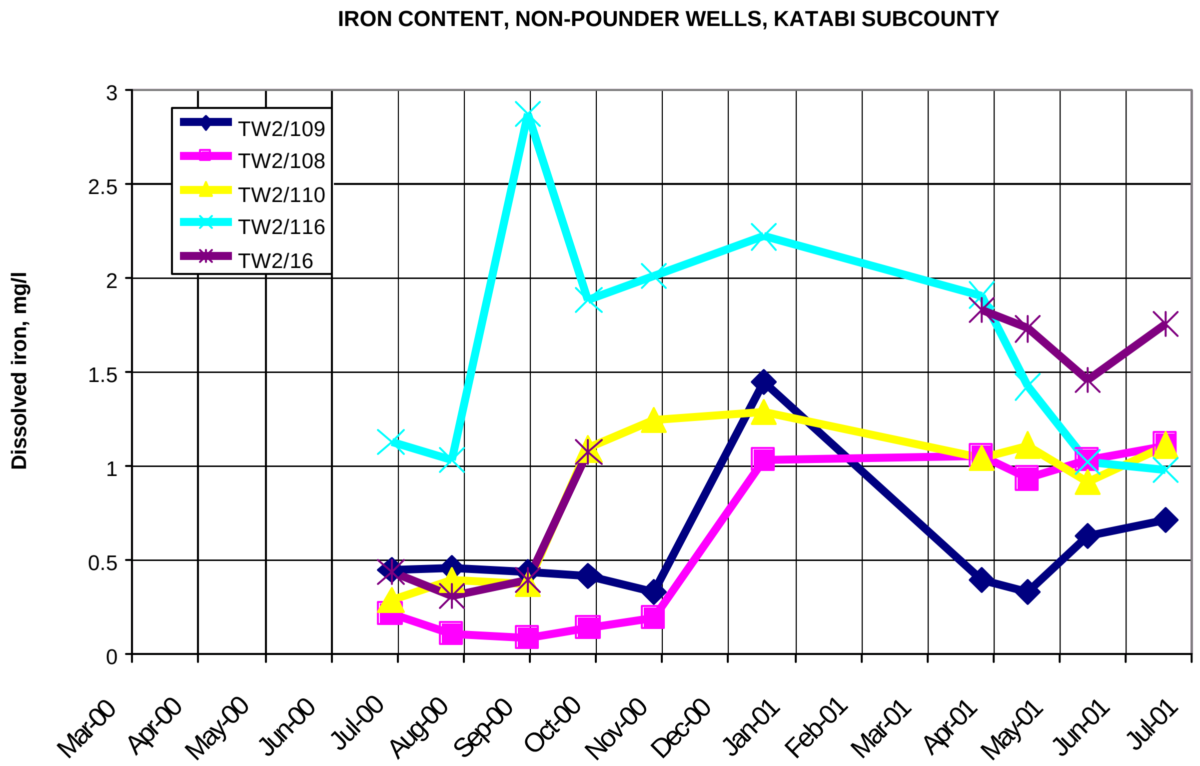


Figure 4.11 Iron contents of Pounder wells (upper) and hand-augered wells (lower)





4.4 Local manufacture

Work done

Specific study of the local manufacturing options has taken place in three main periods of activity.

The first took place at various stages in the first full year of the project, 1999. Initial meetings with possible manufacturers of rig and well components took place around Easter of that year, with an in-depth internal study following the field trials at the end of 1999.

The second phase of work took place from October 2000, consisting of more detailed analysis of Ugandan manufacturing capacity, together with analysis of the published Pounder rig design drawings.

The final input was made in June 2001, drawing together the technical aspects of rig, well, and handpump, and considering these alongside the local manufacturing options.

Issues

While remaining committed to the concept of local manufacture[23], the project has had to carefully consider precisely what this means in the context of human-powered drilling of Ugandan regolith.

A purist definition of local manufacture might require the use only of existing local materials and local skills. Since Uganda does not produce steel, and it has no petrochemical industry producing plastics, this would limit the options in the extreme.

Further along the spectrum one could consider the use of materials which are generally readily available in the Ugandan market, although imported. A range of steel and plastics components then comes into view – although not including every material needed for drilling basement regolith[24].

At the other end of the spectrum of “local manufacture” appears the model used by Uganda’s handpump industry. The manufacturer in Uganda of the U2 and U3 pumps imports the below ground components from India, and has the capacity to manufacture the galvanised pump head in Kampala. Nevertheless, Indian-made pump heads can compete economically with the locally manufactured equivalent, to the detriment of the latter.

A second issue is the range of technology to be included in local manufacture. Section 4.1 has already stressed the importance of integrating the full range of well technology – ie drilling rig, handpump, well screen, casings, formation stabiliser - in the package. Numerically and financially, the components/consumables which remain behind in the well will represent bigger business than the drilling rigs alone.

So what does local manufacture mean, particularly in the context of Uganda’s drilling conditions, and the implications these have for rig and well design? And how far does

[23] We are very aware too of our partners’ and funders’ commitment to this issue.
[24] For example the carbon steel used for drill pipe and some other rig components, and tungsten carbide components for drill bits.

GoU commitment to local manufacture extend? Would it be prepared to favour local manufacture over importation, even if the imported product were cheaper?

Together with our partners, we are equally committed to the principle of public domain ownership. To this end the project published the full set of drawings of “Pounder II” in July 2000, and has disseminated these widely. But this is another concept with a spectrum of possible meanings.

In one sense the publication of drawings (free of copyright, and with no component patented) puts the design firmly into the public domain. But the local manufacturing context is an industry which is more comfortable copying a physical product than interpreting a drawing. Moreover, the skills required to take the steps from engineering drawing, through design and fabrication of jigs and fixtures, to production (to an adequate quality standard) are scarce. In this case, public domain ownership means the development of the local capacity to do these things. It also means an intimate local understanding of the design, so that it is clear where minor variations can be safely made, and where such changes would compromise product performance.

In the latter sense, the project has some way to go before the Pounder rig and associated technology are fully in the public domain. But the process of achieving full public domain ownership is dependent on further progress with the technology itself (see section 4.1).

This discussion raises the wider issue of intellectual property. There is an almost inevitable conflict between the concept of public domain ownership, and ownership of intellectual property, when a so-called public domain design goes into commercial manufacture. While the design documentation, drawings, and specifications remain publicly available, these documents cannot spell out every single issue involved in manufacture. A certain amount of know-how and expertise is developed by the commercial manufacturer, and this remains the intellectual property of that private sector player. This intellectual property (whether or not patented or copyrighted – such issues have little relevance in the present context) is the means by which the manufacturer achieves comparative advantage and business success. The only way to keep all intellectual property in the public domain is for public sector or non-profit organisation(s), to be the sole manufacturers, and for them to have no interest in income generation. It is hard to imagine such a situation.

Conclusion

The twin drivers behind all the discussion on local manufacture are (a) the desire to ensure local availability of Pounder technology over the long term, and (b) the desire to create employment in the manufacturing/supply sector. Uganda needs to decide whether these ends are best achieved through market forces, by public sector control, or by a regulated private sector. The dangers of the public sector stifling, rather than facilitating, the private sector are well known; but an unregulated private sector has its own drawbacks too.

The key stakeholders in the Pounder technology need to jointly determine the particular model of local manufacture and ownership of intellectual property which they wish to see put in place. The options span the following ranges:

Local manufacture	1. using only locally produced materials and existing techniques of manufacture 2. using readily available (imported) raw materials and existing techniques of manufacture 3. following (2) as far as possible, but permitting importation of necessary components, and using existing techniques of manufacture 4. following (2) as far as possible, but permitting importation of necessary components, and introduction of manufacturing techniques new to Uganda 5. (2), but only so long as imported equivalent is more expensive; when import is cheaper, abandon local manufacture.
Intellectual property	1. all design, manufacturing know-how, and expertise transferred to, and remaining in, Ugandan public domain 2. drawings and specification published, but IP of imported components vested in foreign manufacturer(s), and of locally made components in Ugandan commercial manufacturer(s) 3. drawings and specification published, but entire technology imported commercially, with manufacturing IP in hands of foreign manufacturer.

The present status is that, subject to further R&D on the drilling technology to bring it to readiness, local manufacture is close to point (3), and IP at point (2).

4.5 Small water sector businesses

Introduction

A range of interactions with the small businesses active in the water and construction sectors took place over the duration of the project. These are summarised below in Figure 4.12, and referred to further in the text. As the project progressed, two companies (Aquatech and Washcco) seemed likely to be the partners for the contractor drilling phase in Mpigi. In the event the first two contractors to use the Pounder rig were Blessed and Jurusa in Mukono.

Identification of contractors

The first activity during the baseline business survey (November 1998 to March 1999) was to locate as many water sector contractors (in particular those involved in groundwater development) as possible, in the environs of Kampala and Mpigi. Three categories of such contractors were initially located, through key informants in Government and elsewhere. These are referred to here as “large” (those using conventional drilling machinery for deep wells in basement), “medium” (those Kampala-based companies involved in both conventional drilling and borehole siting, and small-scale source works), and “small” (Mpigi-based companies and NGOs[25] involved in small-scale water and sanitation construction activities). Two large companies, 10 medium, and 6 small organisations were initially located. A sample of the second and third categories was the focus of the first analyses of company strengths and weaknesses. No work was subsequently done with the first category.

Later in 1999 (25th October), after the first memorandum of understanding had been established with Mpigi District and the field trials (August to December 1999) were under way, at the request of DWD an advertisement was placed in the local press to identify further relevant businesses in Mpigi District. Other media exposure (local TV,

[25] The distinction (in terms of activity) between for-profit companies and not-for profit NGOs is sometimes rather blurred in Uganda. Both act under contract to local Government, and both can do similar work.

newspaper, and radio) was also used to raise the profile of the project, and to establish contacts with potential private sector partners. Fourteen organisations responded to the newspaper advertisement. Many of these were non-water sector businesses.

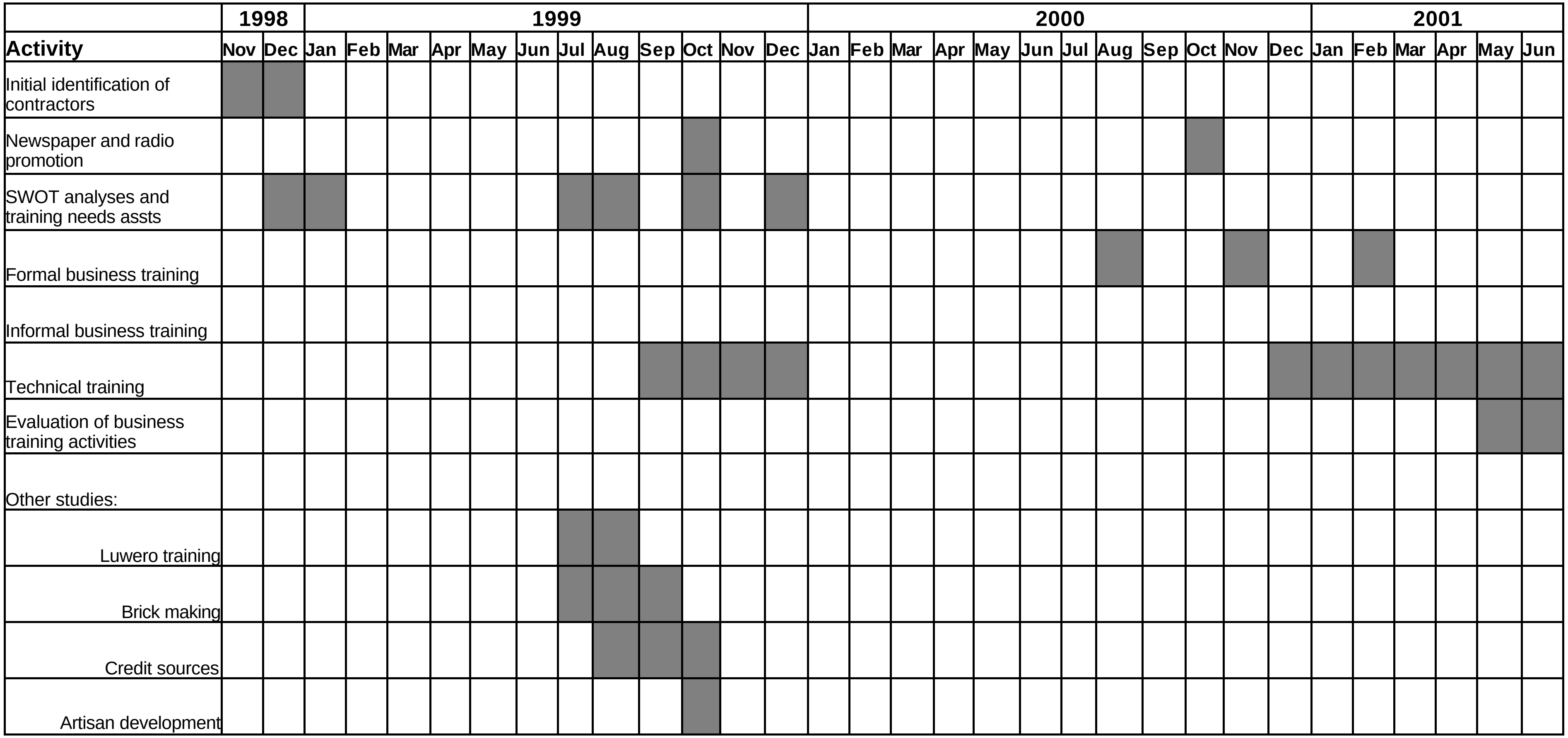
Subsequently, and throughout the project, other small businesses came to the notice of the project, either through informants among our other stakeholders, or through the project's own observations.

Table 4.11 lists the contractors which were identified through the baseline survey and the Mpigi newspaper advertisement.

Table 4.11 Private sector contractors identified in baseline and media exercises

	Company, location	Identified by
1	Drillcon Ltd, Kampala	Baseline survey Nov 98-Mar 99
2	Uganda Drilling and Wells Services Ltd, Kampala	
3	Safe Water Drilling and Pumps Ltd, Kampala	
4	UGANDRILL Ltd, Kampala	
5	Drill Consult Ltd, Iganga	
6	Kalebu Ltd, Entebbe	
7	Uganda Hand Pumps Ltd, Kampala	
8	Nile Drilling Company Ltd, Kampala	
9	Aquatech Enterprises Ltd, Kampala	
10	Diako Hardline, Kampala	
11	Geo Consultants, Kampala	
12	Hippo Technical Services Ltd, Kampala	
13	Victoria Line 2000	
14	SUN CITY Enterprises Co Ltd, Kampala	
15	WashCCO, Mpigi	
16	SANWAT 2000, Mpigi	
17	KDF, Mpigi	
18	Buso Foundation, Mpigi, Kampala & Luwero	
1	Lenomat Technical Services Lt, Mpigi	Mpigi Newspaper Advert Oct 99
2	Katabi Environmental Sanitation Initiatives, Mpigi	
3	Kenz Engineering Services Ltd, Mpigi	
4	Kheny Technical Service Ltd, Mpigi	
5	Sekanyola Timber Works, Mpigi	
6	KDF, Mpigi (note repetition)	
7	Aniyali Amanyi Development Group, Mpigi	
8	MMK Engineering Services, Mpigi	
9	KK Enterprises, Mpigi	
10	Mpigi Teachers' Development Trust	
11	Kituni Constructors Company Ltd, Mpigi	
12	Companionship of Works Association, Mpigi	
13	Home Repair Master Company, Mpigi	
14	Kikondo Multi-Purpose Youth Service Group, Mpigi	

Figure 4.12 Summary bar chart showing main interactions with private sector contractors



Over the duration of the project, gradually the for-profit contractors fell into a number of categories. In relation to capital assets, water sector experience, and competence, three groups emerged as of interest. These were:

- well resourced, experienced and able contractors, few in number, mostly Kampala based, and with good contacts for winning contracts
- a middle group of contractors with an interest in the sector, some experience, but limited access to capital, and significant technical and financial weaknesses – a larger group, many of whom are based outside Kampala
- very small, artisan, businesses, often with technical skills, but with extremely limited capital base.

The nature of the emerging technology[26] soon excluded the third of these groups from consideration (although not without much study and thought as to how they might feature in the future of the Pounder rig). The first two groups represented the main potential, the second however presenting the greater challenges.

A further categorisation of the small businesses emerged later, driven by the constraints of project funding as well as the nature of the businesses themselves.

- Before the DANIDA funding was agreed, financial resources limited the amount of business training which could be offered. Consequently the project worked with two contractors, Aquatech (Kampala based, experienced in the sector) and Washcco (Mpigi based, limited experience in the sector, limited capital, and female-run). Formal training of this pair took place in August 2000.
- Later, a group of 9 businesses (from the baseline group, but with some additions) was chosen for SWOT analyses, training needs assessments, and subsequent training. When the training was offered in November 2000, additional businesses from Mukono's prequalification list were invited too.
- Finally, the 14 contractors which had responded to the October 1999 newspaper advertisement, together with others which were prequalified in Mpigi District were offered training which took place in February 2001.

SWOT analysis of contractors

A "snapshot" SWOT analysis of the 6 "small" companies identified in the baseline study (Hippo Technical Services, Geo Consultants, Diako Hardline, Aquatech Enterprises Ltd, Nile Drilling Company Ltd, Uganda Handpumps Ltd, Kalebu Ltd, Drill Consult Ltd, UGANDRILL Ltd, Safe Water Drilling and Pumps Ltd) was included in the report of that work (March 1999, included in DFID Progress Report No 2 of the same date).

Subsequently (July-August 1999) an overlapping group of 8 companies was the subject of a more detailed analysis. The report of this work forms part of Matthew Snell's MSc thesis. The list of companies is: Vicline 2000, Washcco, M & M Multipurpose Technicians, Aqualab, Safe Water Drilling and Handpumps, Aquatech, KDF, and Suncity Enterprises Co Ltd.

[26] In particular the capital needed for initial investment and cashflow (estimated as USh10-30m or £4000-12000)

The general weaknesses identified by both these studies are summarised as follows:

- most companies lack capital and easy access to credit
- private hire of equipment can reduce profit margins significantly
- companies lack formulated business strategies and vision for their future
- companies lack marketing strategies, and “expect business to come along”
- companies’ administrative and financial management procedures are poor
- companies vary in their access to knowledge of up-coming contracts
- many companies do not understand costing, pricing and tendering procedures

Nevertheless, the fact that (a) companies are identifiable, (b) companies have personnel and business premises, (c) many companies have some, albeit limited, experience in the sector, and (d) SWOT analyses can be carried out at all, is an indication of a latent private sector. It may be that few of the identified companies will have the capital to invest in Pounder technology in the short term, but many of them may have potential either if equipment hire is available or if they concentrate on lower capital technologies such as rainwater harvesting, spring protection, hand-dug well construction, and latrine slab casting. Poor business and marketing skills, restricted access to contracts, and lack of entrepreneurship, are their main constraints to development.

Training needs analysis

The most thorough TNA was that carried out for two companies (not named for reasons of confidentiality). This was undertaken through in-depth discussion with the companies individually, and analysis of the companies’ responses during a training workshop held in August 2000. This combination of personal and empirical methods, building on an earlier SWOT analysis, yielded the project an increasing depth of insight into the areas of internal weakness of (hence training needs), and external threats facing these two companies.

The detail of the findings is included in an internal project report dated August 2000, but for reasons of confidentiality, they are not elaborated here.

General areas of weakness, which were addressed in the subsequent training, include:

- unfamiliarity with use of business documentation such as letters, delivery notes, invoices, application letters, and responses
- lack of business planning
- poor awareness of need for detailed costing and pricing of work
- weak entrepreneurial skills
- poor financial management, especially the tendency to muddle private and company funds, poor book-keeping
- poor office management, especially in relation to filing, telephone manner and abuse
- poor internal communication and general company management
- lack of awareness of competitors, of opportunities, and of importance of marketing strategies
- need for concern about quality of work
- ignorance of tendering procedures
- poor time management
- poor networking and ineffective human resource development

Externalities which pose threats to effective operation:

- non-payment by clients
- political interference, and financial/tendering irregularities (corruption)
- lack of contacts and information

A less detailed TNA was carried out in a half day workshop promoted to the 14 advertisement respondents in Mpigi district, together with other prequalified contractors in Mpigi. This was held on 19th December 2000, and 9 companies attended. It formed the basis of the training subsequently conducted in February 2001.

Business training conducted

Three formal business trainings were carried out during the project:

Table 4.12 Formal business training activities conducted

Companies trained	Date and place	Comments
Aquatech Ltd Washcco Ltd	August 2000, company offices	Individual training for each of the two companies which at the time were expected to be the project's main private sector partners. Trainers Ssebalu, Kakooza.
Jurusa Enterprises Ltd Peak Engineering Works Ggoli Ltd Hadoto Water and Sanitation Vicline 2000 M & M Technical Services Buso Foundation KDF	November 2000, Kyambogo (Technical School)	5-day joint course conducted by Ssebalu, Kakooza, Danert and Rwamwanja. AWASCO (Association of Water Sector Contractors) formed as a result of the course.
Lenomat Technical Services Ltd Katabi Environmental Sanitation Initiatives Mpigi Teachers Development Trust Kikondo Multi-purpose Youth Service Group Kituni Constructors Mbalabye Ltd Twassy Africa Ltd Victor construction Mel Engineering Works K.K. Enterprise	February 2001, Mpigi District Council Hall	9 companies attended out of 29 invited (14 advertisement respondents plus Mpigi prequalified contractors). Training conducted by Ssebalu, Kakooza and Danert.

The contents of formal trainings varied slightly, but by the end came to include the following subjects:

- Introductions to workshop and project
- Marketing
- Business administration and management
- Project implementation
- Entrepreneurship development
- Taxation
- Costing and pricing
- Record keeping
- Tendering and business contract laws
- Accounting and financial management
- Pounder rig demonstration

Technical training

Technical training in drilling and well construction using the Pounder rig began during the field trials in Mpigi district in the second half of 1999. A crew of 5, supplied by the district, gained full familiarity with “Pounder I”, the trial version of the rig. Subsequently two members of this crew have set up their own company.

The next major period of technical training focused on contractors Jurusa and Blessed, from November 2000 until the end of the project. These two were selected by Mukono district at the commencement of the contractor-drilling phase which began when “Pounder II” was imported. Blessed took on most of the available work, and gained much experience with the equipment. The training began with a two-day familiarisation, including technology, costing and pricing, meeting suppliers, and discussing well specification. This was then followed by intensive site training.

At the same time as the contractor training, the opportunity was taken to expose two of the project’s consultants/assistants to the new technology. For a short time Juma from Mukono acted as a field assistant, and gained some knowledge of Pounder drilling. Throughout the contractor phase, John Okwi acted as technical assistant, and he now has excellent familiarity with the equipment. He has also carried out local manufacturing studies for the project, and has expressed personal interest in future involvement in this aspect.

Internal evaluation of business training

In May 2001, an external consultant (Joy Morgan) worked with Jamil Ssebalu on a short evaluation of the business training undertaken to date. Three companies were visited in person for in-depth interviews, while most of the rest of a sample of 20 were surveyed by questionnaire and shorter visits subsequent to Morgan’s input.

The evaluation revealed that many of the topics addressed in the training (in particular organisational management, costing and pricing, marketing, and tendering) were found to be very relevant to the needs of the companies. However, the attempt to cover all of these, and more, topics in a short training was concluded to be less effective than a more focused set of training activities, spread over a longer period, would have been.

The evaluation findings emphasised the importance of trust in the relationship between trainer and small business. As such a relationship grows and is strengthened, the companies reveal more and more of the real problems which they face, so allowing these to be addressed. This takes time, and a special focus on this aspect.

Also emerging from the evaluation is a clearer picture of the profile of typical small water sector businesses. There are several fundamental aspects of the small businesses with whom the project has worked, which limit their effectiveness. The key issues are:

- the difficulty companies have in organising and prioritising their time, observing deadlines, keeping appointments, and organising paperwork;
- the overlap and confusion between business and family priorities;
- weaknesses in forward planning;
- lack of a proactive mentality – for instance in relation to marketing themselves;
- poor record keeping;
- the perception that the main problem is shortage of funds;

- a dependency on others to give them work, rather than going out and winning business.

Many of these attitudes and issues simply describe the current small business culture, but to a greater or lesser extent they reflect externalities such as the relative immaturity of the private water sector and the challenges of corruption.

Related studies

Several other studies of relevance to the small business aspects of the project were undertaken.

Snell, with support from Danert, Ssebalu and Rwamwanja studied the costings of hand-augered wells[27] in NGO programmes, the characteristics of the brick making industry of rural Uganda[28], and options for artisanal businesses[29] to be included in the future of the new technology. These are all written up in Snell's thesis.

Littlefair, also with support from Danert, Ssebalu and Rwamwanja, examined the place of Pounder drilling, as then understood, within the policy context of Uganda's water sector. Her findings are also written up as an MSc thesis.

Ssebalu and others prepared a comprehensive annotated listing of credit sources, concluding, as others have observed, that Uganda's credit institutions present a "missing middle" between micro-credit (loans up to about USh2m, approximately $1000) and large loans (typically exceeding USh450m or $250,000). Ssebalu also carried out an evaluation of artisanal business training undertaken prior to this project in Luwero district. This work raised a number of questions which the project has subsequently had to address.

Ball, Kakooza and Danert carried out studies of (a) small business taxation and related issues, and (b) Pounder drilling cashflow, profitability, and business planning.

All the above reports are listed in section 4.10.

Over the course of the project, the issue of corruption has become increasingly prominent. Whether referred to euphemistically as "irregularities", or "brown envelopes", or more directly as corruption, every player in the sector is aware of its importance. This importance is particularly great in the case of emerging private businesses, which have great difficulty getting established if they lack the right contacts, or sufficient resources. In addition some contractors lack the motivation to try to extend their business to other districts. This subject is not documented by the project, and while this is not the place to detail its practices, it is the place to highlight its significance as a constraint to good business practice and the growth of an effective, competitive and quality-driven private sector.

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[27] Hand augering being the nearest comparative technology to Pounder drilling in Uganda
[28] As an unrelated business, having potential similarities as well as contrasts with Pounder drilling
[29] Before the capital requirements of Pounder drilling became apparent, this was an attractive prospect.

4.6 Communities

Introduction

As with the districts, communities are primary stakeholders[30] in the public-private-civil society partnership which is supposed to deliver sustainable safe water infrastructure. Consequently the project has had to research and address community-level issues which affect the likely viability of Pounder technology. Table 4.13 sets out the main community-focused activities undertaken during the project, and the remaining sub-sections describe the major findings and contributions.

Table 4.13 Main community-focused activities

Activity	Comment
Baseline study, March 1999	Includes summary of community role in watsan provision, sector weaknesses in relation to community experiences, community financing issues, willingness to pay, and attitudes to shallow groundwater sources. Report included as part of Annex 9 of DFID Progress Report No 2, March 1999.
Histories of first 5 Pounder wells in Uganda, May 2000	Describes community experience of the process of constructing Pounder wells under the WES programme in Mpigi district. Included as Annex 4 in DANIDA Progress Report 1, May 2000.
Selection and histories of 5 hand-augered wells in Katabi subcounty, Mpigi district, August 2000.	Provides comparative description of the process of mobilisation, from community viewpoint, and outcomes 3 years later in terms of maintenance and recurrent funding. [Ref 20]
Mobilisation of communities using Pounder wells in Katabi subcounty, Mpigi district, Feb-Mar 2001	Correction of poor or non-existent mobilisation at the time of drilling. Establishment of water committees.
Rehabilitation and repair of handpumps at Pounder wells. Feb-Apr 2001.	Working with communities/committees to repair broken handpumps at Pounder well sites, and to encourage communities to raise funds and carry out future maintenance.
Observation of state of repair of handpumps and condition of well apron/surroundings at all Pounder well sites, April 2000 to date.	This was included as part of the monthly monitoring activity. Included in consolidated report of all Pounder well monitoring data. [Ref 12]
Community discussions during contractor drilling of well in Kibundayire, Jinja district, 23 March 2001	Report included with “well histories” report – see section 4.10 [Ref 20]
Histories of contractor drilled Pounder wells in Mukono, and comparison with local hand-augered wells. June 2001	Report included with “well histories” report – see section 4.10 [Ref 20].

Shallow groundwater development and communities

At the outset of this section it is important to point out some linkages between community understanding of shallow well construction, the natural environment, and the new technology.

Basement regolith is an extremely variable and inherently unpredictable material. While hydrogeological texts show idealised regolith profiles, it is rare to encounter these “typical” sequences in practice. Regolith contains uncemented material ranging in grain size from clay particle size (less than 2 thousandths of a millimetre) to boulders (in

[30] Arguably *the* primary stakeholders, if the project is viewed from a livelihoods or poverty point of view.

the order of 0.1-1.0m). The boulders or unweathered rock fragments themselves are relict basement, and composed of hard crystalline igneous and metamorphic rocks, including some of the hardest encountered anywhere in the world. The thickness of the regolith varies enormously over short distances, and moreover it often contains laterite. Laterite is itself a very variable material, consisting of cemented iron, aluminium, and silicate minerals. It may appear as pea gravel, soft clay rich layers (murram), or very hard highly cemented (duricrust), layers. Its only common property is its colour – red – indicative of oxidised iron-bearing minerals. Enough has been said here to show that the ability to (a) predict water bearing sites in regolith, (b) drill it successfully, and (c) produce water in adequate quantity and quality is inherently challenging.[31]

Low-cost drilling of the type pursued in this project has one major difference when compared to conventional drilling. In conventional drilling (typically down-the-hole hammer[32] in Uganda), energy is in surplus. A large conventional drill rig can use several hundred litres of diesel fuel per day – enough to drive a full mutatu from Kampala to Kinshasa and back. A small human-powered machine has only human energy – enough to light a few small electric light bulbs. A conventional deep drilling machine relishes hard rock – the harder the better. A human-powered machine is operating on the limits of possibility when it tackles rock or laterite. Not only does the driller lack certainty as to what to expect below the surface, but he needs to use all his skill (as well as that of the rig designer) and his limited energy resource merely to make a hole in regolith. This is a second challenge.

It is almost certain that neither of the foregoing issues are fully understood by the community. They see a new machine enter their village in the hands of a contractor, and their expectations are of a successfully completed water source within a few days. This of course poses enormous problems for community mobilisation and organisation, up-front cash contributions, and what to do if community expectations fail to be fulfilled.

Despite all these caveats, there seems to be little evidence of adverse community perceptions or attitudes toward shallow drilling and hand-dug well construction. Anecdotal evidence (Luutu, pers. comm.) from Ruwasa (eastern Uganda) suggests that community motivation may have been a contributing factor in that programme's rejection of hand-auger drilling some years ago. However, there is also concern in Ruwasa now (Jacinta B. pers. comm.) that that may have been a precipitate decision. A study may follow before Ruwasa winds up.

Information, communication, and political interference

There seems little doubt that both the quantity and the quality of the information reaching communities about the opportunities open to them, the roles expected of them, and their responsibilities, are very mixed. Decentralisation, despite not being a new policy (the Local Government Act of 1997 supported a process which was already under way at that time) is still working itself out. Communication up and down the hierarchy from LC1 to LC5, is far from perfect.

Communities' experiences of poor communication are exemplified by:

- expressing demand for improved services, and hearing nothing

[31] On the other hand, studies by Taylor and others in Uganda point to regolith's untapped potential as a water source.
[32] Using a compressor-powered pneumatic hammer to smash a drill bit composed of hard steel and tungsten carbide (the second hardest material after diamond) many times per second on to the bottom of the hole.

- paying community cash contributions, and seeing no change
- community demand being expressed through LC representation, without true community involvement
- communities making financial contributions, but never being told how much had been collected
- seeing the arrival of a drilling crew, without prior knowledge that their community had been selected for a new water source
- communities being told that there is plenty of money at the district for improving water supply coverage, and yet being asked to pay community contributions
- being asked to buy spare parts for handpumps, but not knowing where to find them

All these examples have arisen in the course of meetings and discussions carried out by the project with community members.

Worse than imperfect communication is the issue of political interference in watsan infrastructure development. Repeatedly the project was informed of examples of politicians making unfulfillable promises to communities, or contradicting GoU policies on demand responsiveness and community participation. This practice is evidently sufficiently common (especially around election time) to create cynicism in the community.

Community mobilisation

Section 4.7 draws attention to some districts' limited capacity to carry out community mobilisation and training activities. To avoid repetition, here we consider the *consequences* of poor mobilisation – weaknesses in source maintenance.

Source maintenance

The project has widely observed Uganda's experiences in handpump maintenance. Rather than generalise, the following text box exemplifies the problems, from the community point of view. It is drawn from the "history of non-Pounder wells" elicited by the project from communities around 5 hand-augered wells in Katabi subcounty, Mpigi district.

"There does not seem to be any established water source committee at the water-users level. Though there are Caretakers, the structure of a typical water source committee is missing on all the wells. Caretakers are not facilitated to carry out preventive maintenance of the pumps. Any breakdown on the pump is reported to the Production and Environment Secretary on LC I who relays the message to the subcounty. The subcounty informs the district about the reported breakdown. The district then sends a member of the drilling crew to effect repairs. Over the years the area Health Assistant (Dan) has acquired some skill in maintenance/repair work and often fills the gap. The trained Pump Mechanics for Katabi subcounty (two in number) have not been put on the subcounty payroll and as such are not active.

None of the wells had an O&M account. Beneficiaries contribute for repairs only after the pump has broken down.

The communities expressed concern with the quality of handles on the pumps. Two of the wells ('Night' and 'Bananas') were found with broken handles. The rest had had the broken handles repaired. The communities attributed the breaking of the handles to two factors. The first being the manufacturer's omission to make good quality handles, while the second is over-use of the pumps. It was estimated that Night handpump (TW 2/16) at Kauku served over 100 households. Because of high demand on the wells, the ponds (traditional sources) were used as alternative water sources during peak hours. To avoid the use of the unsafe ponds, the community in Tadeo village, Kabale A parish, requested for another water source which was drilled close to the existing one. It is estimated that over 150 households collect their water from the two pumps that stand a couple of metres apart."

[Having gone on to describe the *theory* of the handpump maintenance system, the report then describes "the reality in Katabi subcounty" as follows:

"The subcounty selected and sponsored two pump mechanics for a three-week training programme. The subcounty however did not pay them any wages or allowances. Efforts by the pump mechanics to work and be paid by communities have not been successful as communities could not understand why someone had to open up their pump when the pump seemed to work well. It was even more difficult to replace a worn out part. The end result was two fold:

- *The pump mechanics could not survive on voluntary work. They opted out of the system to earn a living elsewhere. None of the two mechanics is now active.*
- *There is total lack of preventive maintenance. The caretakers have not been equipped with the basic tools to at least grease the chain or tighten nuts.*

The toolbox is currently being kept with the Health Assistant who, with limited experience, does his best to keep the pumps working.

Although all water sources have caretakers, most do not have water source committees. It is estimated that 60-70% of the committees (where they exist) have been trained. The last training was done more than two years ago. The Health Assistant is of the view the that the LC3 Council does not consider training of committees a priority.

Pump breakdowns are reported to LC1, (usually to the Secretary for Environment and Social Services) who relays the message to the subcounty. At the subcounty, the Health Assistant takes up the matter by visiting the handpump and assessing the technicality of the breakdown. The Health Assistant carries out the repairs if the problem is within his abilities to rectify or will inform the district of the breakdown and request that the district sends a mechanic to effect repairs. The district sends a member of the drilling crew to carry out the repairs.

Communities finance repair works. There are no accounts for maintaining water sources operated by user communities. Communities contribute only when there is a breakdown. There may be a contribution from LC1 when substantial amounts are involved. The district technician informs the community how much money is needed to buy spares. The community is then given time to raise the required amounts. This may take a few days or weeks depending on the demand on the community, the ability and willingness to pay."

What the text box illustrates, is that handpump maintenance *can* happen after a fashion, but *despite*, rather than *because of*, the theoretical maintenance system. That theoretical system includes provision for:

- subcounty level (paid) pump mechanics with tools, transport and training
- community level caretakers and committees in place
- community bank accounts for maintenance funds

In the Katabi example, which may typify the situation elsewhere, none of these are in place. The absence of the third may not be a key issue, since it is frequently impracticable to collect monthly contributions from households whose cash income is very small and intermittent. The key financing issue centres on community motivation to solve problems as they arise – and to find the resources to do so.

Community participation in the context of private sector participation

Community participation in the context of public sector or NGO provision of technical assistance is relatively well established and straightforward. Participation, when private contractors construct infrastructure under local Government funding, in our experience, is not.

A contractor enters the community knowing he[33] will only be paid for a successful well. He has his own views about the likely success of different sites. He may even pay for his own hydrogeological survey (this has happened in the case of one of the project contractors in early 2001).

On the other hand, the community has its own view about the site(s). Conflicts may arise.

The contractor will wish to minimise the amount of labour committed to the site, and will take full advantage of free labour offered by the community.

The community may (with some justification) take the attitude that the contractor is being paid out of public funds, and so refuse to participate in construction.

If the community loses out in the siting decision, and refuses to participate in construction, this is likely to severely weaken its sense of ownership of the source, and its commitment to long term operation, maintenance, recurrent funding, and taking on board any related hygiene and sanitation promotion.

These issues need to be carefully thought through as public-private-civil society partnerships develop further in Uganda.

Demand

GoU policy on rural water supply is clear on the point that it should be demand-driven. That this is good policy is without question. The practical outworking of the policy is not so straightforward.

In practice, the receipt of a written request, followed by a cash contribution, are taken as evidence of demand. They may reflect demand from within the LC system, or from influential people (especially when the cash contribution originates from the subcounty). However, they do not necessarily reflect community demand – especially from those primarily responsible for water management - which will lead to sustainable maintenance over the long term.

Project outputs cannot add much more to this debate, but it is highlighted here as a centrally important issue for the whole of Uganda's water sector.

4.7 Districts

Introduction

Although considerable time was spent in discussions with local Government personnel, the project did not set out specifically to conduct research on local Government capacity. In fact, few of the project activities in this area can be described as formal research. Nevertheless, local Government has a central role in this project and its future, for a number of reasons:

[33] Most (but not all) contractors in Uganda are male. "He" is used in what follows simply as a shorthand for "(s)he"

- local Government has responsibility for the mobilisation of communities prior to construction, and for ensuring communities understand their roles in system operation, maintenance and recurrent funding,
- it is primarily local Government which lets contracts for private sector construction of rural community water supply and sanitation infrastructure,
- local Government has primary responsibility for contract supervision.

The project's experience of local Government is that it suffers from both internal weaknesses relating to these areas, as well as external threats to its ability to manage effectively.

Consequently the purpose of this brief section is simply to outline these issues with reference to the project's direct experience with a few districts. If these points are well known already, then we will have added nothing; however, their centrality to the context within which the project operates means that they cannot pass unmentioned.

This section should be read alongside section 4.8. Nothing said here is intended to detract from the fact that our experience of partnership with local Government has generally been very positive. Despite facing major challenges in fulfilling their mandate, the districts (Mpigi in particular) have willingly and enthusiastically partnered the project, sharing its vision and its own challenges.

Capacity to mobilise communities

At the beginning of the project we specifically excluded our direct involvement in community mobilisation. All project drilling (ie the intial 14 trial holes in 1999, and the 12 contractor drilled holes in 2000-01) has been carried out under WES or PAF funding, and it is clear therefore that responsibility for community mobilisation falls directly on district and sub-county. However our first evaluation of this aspect (reported as Annex 4 in the project progress report to DANIDA for the period 1 Dec 1999-31 May 2000) clearly showed the inadequacy of community mobilisation for the first Pounder wells. Subsequent follow-up by the project has attempted to correct this poor start.

The project's elicitation of the histories and present status of the non-Pounder wells, further confirms our experience that community mobilisation can be weak. Among a random sample of 5 shallow wells hand-augered in 1998, in the same sub-county as 5 successful Pounder wells drilled during the field trials,

- the community contribution was paid by the sub-county,
- there are no water user committees,
- caretakers do not carry out maintenance, but report faults through the LC system,
- none of the wells had a system of revenue collection in advance of pump breakdown, and
- communities have little appreciation of the need for preventive maintenance.

In Mukono, by contrast, histories of both Pounder and non-Pounder wells elicited in June 2001 indicate a greater sense of ownership, through more effective community mobilisation.

Form of contract

A tendering contractor in Uganda's rural water sector will usually put in a price very close to the DWD budget guideline for a successful "typical" source. The contract between the district and the contractor is then a fixed price arrangement for a successful source. Despite having some advantages[34], this arrangement has two major weaknesses in the case of well construction work.

First, there is no such thing as a "typical" well, except in the context of budgeting for a multiple well programme. The cost of an individual successful well depends on a multitude of factors including distance from the contractor's base, site accessibility, access to water for drilling, number of trial holes needed per successful well, depth to water, completed well depth, time taken to drill (mainly as a function of problems such as hard ground, collapsing ground, lost circulation, and degree of community participation), cost of locally procured materials, and ease or difficulty of well development. Consequently the contractor relies on the tendered price being sufficient to cover his losses – dry holes, deep holes, hard rock, and so on – over the long term.

Second, there is no effective price-based competition. For each contractor, the need to remain solvent in an inherently uncertain area of business (groundwater development) means that rather than compete with others on price, he must find other ways of competing. This puts more emphasis on "contacts" and "favours", with a greater incentive to take part in "irregularities", than on free and fair competition.

The alternative to fixed price/successful well contracts would be standard itemised contracts based on bills of quantities, with invoicing and payment based on work actually done. Hence a dry well would be paid for directly, rather than being hidden in the cost of a successful well.

The project spent some time examining the existing form of contract for hand auger wells (as a possible model for Pounder wells), and consulting in Uganda and UK on alternatives. The Engineering and Construction Short Contract (published for the UK Institution of Civil Engineers by Thomas Telford, London, in 1999[35]) has some advantages, particularly in its simplicity of language and structure. Nevertheless it would need some modification in the Ugandan context. Further work in this area will have to take full account of the fact that although written contracts are signed, commonly word-of-mouth agreements take precedence.

Furthermore, the quality and quantity of supervision necessary with itemised contracts could prevent any short-term move away from fixed price agreements.

Supervisory capacity

In order for districts to move to the point of paying a contractor for work actually done (rather than only for end product), they will need to be able to monitor or supervise the work in question more fully than at present. The supervisory capacity needed is as follows:

- adequate staffing at field level[36]
- knowledge of what and when to monitor and how to record information
- objective supervision which resists compromising pressures

These qualities are also needed in judging the end product quality in fixed price contracts, but the demands are less great.

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[34] In particular, reducing the need for close supervision, and making it easier to avoid irregularities involving payments for work not actually carried out

[35] There is also a set of guidance notes and flow charts published at the same time, under separate cover.

[36] Judging appropriate staffing levels is not simply a question of numbers: the key question is whether there are sufficient staff with knowledge, experience, resources, and above all motivation to do the job in question.

The limited experience of the project suggests that for the time being fixed price contracts are the better of the two options.

One possible approach, with some merit, is to facilitate the supervision of contract work by the community rather than by local Government. If Uganda is to take seriously the community ownership of infrastructure, then the community needs to be given a much greater stake in the whole process.

At present many forces are reducing community participation:

- so-called community contributions are either not being sought, not being collected, or are being made by lower levels of local Government or wealthy individuals,
- efforts to create informed community-level demand for sources are weak or lacking,
- sometimes media and political messages are discouraging communities from participating in capital contributions and recurrent funding, expressing demand, and participating in community-based operation and maintenance

If the community had a realistic understanding of the source options open to them, of the uncertainties inherent in the development of groundwater sources, and of the dynamics of the public-private sector partnership in which they are the key participant, then they could take their centre-stage role in the management of the entire process.

It has been beyond the scope of the project to initiate community supervision of private sector construction, but we would strongly recommend that it be debated and possibly introduced in a pilot scale trial.

Threats to management capacity

The complex interaction of three external pressures on districts has already been referred to. Two policies – decentralisation and privatisation – combined with the hugely increased budgets available to the districts through HIPC/PAF, are putting districts under immense pressures. Some re-organisation of districts (eg Mpigi splitting into Mpigi and Wakiso, and Mukono splitting into Mukono and Kayunga) are compounding the pressures. It is easy for outsiders, including professionals at the centre, to under-estimate the time and support needed for adjustment to such external pressures.

A further contributing factor to the inertia already referred to is the way in which districts interpret the conditions for disbursement of the conditional grant. While some adopt flexible approaches, others are much more rigid in their interpretations. Mukono district for example diverted PAF funds earmarked for hand-dug wells to Pounder well construction, while Mpigi saw this as going beyond the guidance. At the centre, there is frustration with over-rigid interpretation in some of the districts. However that frustration needs to outwork itself in patient capacity-building, and it will take time to see the desired widespread change.

A particular concern of the project, and of many if not all of its informants, is the scale of the budgetary increases. On the one hand budgets have quadrupled, and are set to double again. Such increases would challenge the ability of any organisation, let alone ones experiencing so many other pressures. On the other hand the budgetary increase in FY2000-01 from USh4bn to USh22bn (sic New Vision 16:143 Friday 15th June 2001, report of Parliamentary speech on budget proposals by Finance Minister Gerald Ssendaula) represents an increase of expenditure per member of the public unserved with safe water and sanitation from about £0.16 to £0.88 (US$0.23 to US$1.30). In other words the scale of the increases are both unmanageably large, and yet the actual amounts are still small compared to the scale of Uganda's water sector problems.

Drawing on these concerns, Cranfield University presented a proposal to DFID London and subsequently to DFID Kampala, with the purpose *"To evaluate the ability of Public Private Partnership (PPP) approaches to benefit the poor, and identify strategies to enhance their performance".* In the context of Uganda's water and sanitation sector policies, and PAF/HIPC funding, the research would aim to answer the following questions:

- How are local governments coping?
- How is the private sector responding?
- How well are private contracts actually working? And in particular,
- What is the impact on poor people?

This research is still urgently needed.

4.8 Partnerships

Directorate of Water Development

The project has had excellent relationships with DWD from the outset. A key reason for selecting Uganda for this project was a comment made in a very early meeting (1998) with the Cranfield team. An Assistant Commissioner who was chairing the meeting concluded the discussions by saying "we have to be prepared to take a risk". This constructive and forward-looking attitude was subsequently backed up by financial commitment, and in-kind contributions. Throughout the project DWD staff have taken a keen interest in progress, and have constantly facilitated the work. Such has been the commitment and interest of DWD, that the project has been criticised for its failure to keep this key stakeholder sufficiently informed and involved in activities.

Districts

The first partnership which the project experienced was with Mpigi district. The interest, cooperation, and commitment of many individuals in the district headquarters has been exemplary. The only reservation which we have to express in this regard has been the fact that private sector Pounder drilling did not begin in Mpigi district during the project funding period. This has been largely due to the pressures on too few staff in the district, who are overstretched for the reasons outlined in earlier sections.

In Mukono and Jinja, partnerships have been based on a much shorter acquaintance, and so they have not yet generally led to the same depth of trust and shared ownership as in the case of Mpigi.

Contractors

The project's main linkage has been with contractor Blessed who has drilled all but one of the holes in the contractor-drilling phase of the work. The partnership here has been excellent, characterised by a high level of trust and professionalism. This is perhaps best illustrated by the lack of conflict in the equipment rental arrangement between the project and the contractor.

Donors

Both donors (DFID and DANIDA) have shown a responsive attitude to the project's flexible approach, especially in relation to additional financial support.

4.9 TEMBA – "Technology Mobilisation and Business Access"

From the beginning of the project, uptake (of concepts, of technology, of good practice) has been the key driving force behind all activities. However, diffusion of innovation to the point of widespread adoption takes time, and a three year funding period is only time to plant seeds which then need subsequent nurturing to the point of maturity.

A second, related, key issue has been that of ownership. Much has been done to create local ownership of the Pounder concept, but again significant time is needed to fully establish the new ideas in the institutions which will use and benefit from them.

Consequently, the project has had to carefully consider how the project concepts and technology could be sustained beyond the first period of project funding.

Following much discussion, the two Ugandan members of the project's core team, Rwamwanja and Ssebalu proposed the establishment of an NGO to further the aims of uptake and national ownership. A briefing meeting in which this proposal was discussed took place at DFID's office in London in December 1999 between Mr Ian Curtis (Senior Water Resources Adviser), Kerstin Danert and Richard Carter. The project followed this up with a letter the same month, supplemented by more detailed correspondence in April 2000, and in June 2000 additional funding was agreed to permit the establishment of TEMBA. The funding covered start-up costs and the first nine months overheads, as well as much of the consultancy input provided by Rwamwanja and Ssebalu until the end of the project funding period.

TEMBA is a non-government organisation, registered in June 2001, that combines elements of technology, mobilisation and capacity building of private sector businesses and their clients in the water and sanitation sector, to achieve improved livelihoods for rural communities.

TEMBA has been born out of needs identified by the Low Cost Drilling Project, in particular the realisation that there is a great requirement for improving the capacity of the private sector, local authorities and communities to improve their water sources by working together. With the focus on developing water sources through the private sector and in view of the decentralisation policy in Uganda, it is crucial that support is provided to both the private sector and local Government: to the private sector in improving their businesses and managing contracts, and to the local authorities in improving the planning process and managing contracts undertaken by the private sector. TEMBA hopes to make a contribution in providing such support.

TEMBA is well placed to capitalise on the skills of its directors and associates, and become an influential and effective contributor to Uganda's debates and delivery in the rural water and sanitation sector.

4.10 Dissemination activities and documentary outputs

Introduction

In the project's view, uptake, which is broader than dissemination, is the more important issue of the two. Bringing about uptake has been a specific and central aim of the project, and not an add-on. Nevertheless, certain promotional or publicity activities have been carried out either as part of, or going beyond the immediate aims of the project in Uganda. We have used all available media – print, radio, TV, web, workshops, and an international conference – to tell others about the project. This section summarises the main dissemination activities within and beyond Uganda, and some of their consequences, and lists existing and planned documentation.

Much informal dissemination of information has taken place, although limited human and financial resources sometimes prevented this important aspect being given the priority demanded by our stakeholders.

Dissemination

Table 4.14 sets out in summary form the main dissemination activities and their consequences.

Table 4.14 Main dissemination activities

	Activity/output	**Date**	**Comments/consequences**
1	Project newsletters	July 1998, November 1998, February 1999, April 1999, February 2000.	Mailed and opportunistically distributed in UK and Uganda.
2	Project website	Established June 1999	
3	News included in Africa Water web page	1999	
4	Advertisement in local Mpigi district press	25th October 1999	Fourteen Mpigi contractors express interest in the project.
5	Interviews for Ugandan TV and radio	24th November 2000 and 9th February 2001	These resulted in many contacts with the TEMBA office.
6	Mid-project consultative workshop, Kyambogo.	18th November 1999	Attended by about 80 representatives from central and local Government, manufacturers, contractors, NGOs, and research, scientific and technical institutions.
7	Presentation to HTN Workshop, Hyderabad, India.	February 2000	Drilling consultant invited to present the project's progress and achievements.
8	Open day at Cranfield University to demonstrate Pounder II, and present project.	21st September 2000	Attended by approximately 30 representatives of water sector NGOs, research organisations, academic institutions, and consultancies
9	Exposure of Pounder II to 30 RedR trainees on course at Cranfield University	22nd September 2000	
10	Filming in UK for British Satellite News	25th September 2000	Following UK Open Day and press release
11	BBC World Service interview recorded at Cranfield for "Science in Action"	4th October 2000	Following UK Open Day and press release. Several contacts and one financial donation from the USA.

12	Demonstration of Pounder rig to HRH Duke of Kent, visiting Cranfield University	31st October 2000	
13	Paper presented by Ssemugera (Mpigi District Deputy District Health Inspector) and Danert, WEDC conference, Dhaka, Bangladesh.	November 2000	UNICEF-sponsored visit.
14	Article about the Pounder rig in Waterlines	January 2001	A few direct contacts.
15	End-of-project consultative workshop at Kyambogo	12th June 2001	Attended by about 25 participants from central and local Government, contractors, regional programmes, NGOs and networking organisations.
16	Demonstration of Pounder rig to Institution of Plant Engineers visiting Cranfield University	20th June 2001	Visiting group of approximately 15 senior members.

Existing and planned documentation

The following listing is of project documentation which is either **complete now (June 2001) or will be available very shortly.**

1. Ball, P and Danert, K (1999) Hand Sludging: a Report from North West Bengal. Report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University. ISBN 1861940 548

2. Ball, P and Danert, K (1999) Field Trials of the Prototype Pounder Rig, Uganda, 20th August – 13th November, 1999. Report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University. ISBN 1861940 556

3. Ball, P (1999) Design review of the Pounder Rig, Following Field Trials of the Prototype. Report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University. ISBN 1861940 564.

4. Ball, P and Carter, R C (2000) Specification and Drawings for the Pounder Rig. Report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University. First Edition, July 2000. ISBN 1861940 53X

5. Carter, R C, (1998, 1999a, 1999b, 2000a, 2000b, 2001) Project Progress Reports to DFID, dated (1) September 1998, (2) March 1999, (3) September 1999, (4) March 2000, (5) September 2000, (6) March 2001.

6. Carter, R C, (2000) Project Progress Report to DANIDA for period 1st December 1999 to 31st May 2000.

7. Carter, R C (2001) Private Sector Participation in Low Cost Water Well Drilling. DFID Infrastructure and Urban Development Division KAR PROJECT R7126 Final Report.

8. Kakooza, S M, Ball, P, and Danert, K (2000) Study of Taxation, Registration, Legal and Regulatory Issues Affecting Small Businesses in Uganda. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

9. Kakooza and Danert, K (2001) Pounder rig contractor business: projected cashflow. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

10. Littlefair, K (2000) The role of the private sector in the provision of rural water supplies: an insight into Uganda. Unpublished MSc thesis, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

11. Rwamwanja, R (1999) Artisan business training programme, Luwero diocese water project. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

12. Rwamwanja, R, Danert K, and Carter, R C (2001) Water quality data for 5 Pounder wells and 5 hand-augered wells in Katabi subcounty, Mpigi district, Uganda. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

13. Snell, M (2000) The potential for introducing a new shallow well drilling technology (the Pounder rig) into local industry in Uganda. Unpublished MSc thesis, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

14. Ssebalu, J, Rwamwanja, R, Snell, M, and Danert, K (1999) Information on potential sources of credit. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

15. Wardle, C (1999) Investigation into the effective use of a low cost water well drilling rig. Unpublished MSc thesis, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

16. Worth, M (1998) A mechanism for percussion drilling of low cost water wells in developing countries. Unpublished MSc thesis, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

The second listing is of documentation which will be compiled over the period July to November 2001.

17. Ball, P, Danert, K, Okwi, J, and Carter, R C (2001) Technology of Pounder II and Pounder wells. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

18. Ball, P, Danert, K, Okwi, J, and Carter, R C (2001) Potential for local Ugandan manufacture of the Pounder II. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

19. Danert, K and Carter, R C (2001) Contractor drilling with Pounder II, Uganda, December 2000 – June 2001. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

20. Rwamwanja, R and Carter, R C (2001) Histories of Pounder wells and hand-augered wells in Mpigi and Jinja districts. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

21. Ssebalu, J and Carter, R C (2001) Compilation of work on small business identification, analysis, training and evaluation. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

22. Tindimugaya, C, Luutu, A, Danert, K and Carter, R C (2001). Compilation of work on siting methodology and hydrogeological potential of the Pounder rig. Unpublished project report of DFID KAR Project R7126 “Private Sector Participation in Low Cost Water Well Drilling”, Cranfield University at Silsoe, Silsoe, Bedford, MK45 4DT, UK.

5 Implications of the findings – summary of conclusions

The following key conclusions are drawn from the findings to date:

In relation to technology, science and engineering,

- Human powered well construction demands drilling at as small a diameter as possible, because of energy constraints. Small diameter wells require handpumps to be direct installed (ie the rising main doubles as well casing, the well-screen extends below the cylinder, and the entire string of screen-cylinder-rising main are permanently installed). Groundwater corrosivity demands use of plastics/stainless steel pump components, and this requires models such as the U3M, Tara or Malda, rather than U2/U3.
- The low-cost drilling rig – the Pounder Rig – developed during this project has drilled 14 holes in initial trials, and another 14 in trials with private contractors. The technology shows much promise, but further technology R&D is needed before the rig can be fully promoted and disseminated.
- Siting of boreholes in regolith is technically problematic because of the high degree of lateral and vertical geological variability. Also it cannot be economically worthwhile to spend large sums of money on siting, in the context of low-cost drilling. It is shown that a low drilling success rate in Pounder drilling is acceptable economically, effectively using the rig itself as the exploratory or siting tool, but questions remain as to whether this approach will be socially acceptable at the level of the end users of the water point.
- The quality of water from completed Pounder wells has been shown to be good, from the point of view of faecal pollution (as indicated by thermotolerant ‘faecal’ coliforms). The iron content of Pounder well water may be high or low depending on background levels in the aquifer; in addition our monitoring results clearly show the impact of corrosion of galvanised pump components on iron content. High iron contents of well waters cause people to reject safe sources in favour of unsafe waters. The turbidity of well water is determined by geology and by the effectiveness of the process of well development. Good development is crucial, but it cannot always and entirely compensate for naturally high levels of fines (such as micas) in the regolith aquifer.
- While the Pounder rig is not yet ready for full-scale local manufacture, substantial work has been done on this aspect of the project. The complex issues of intellectual property, public domain ownership, and local manufacture, combined with inherent technical constraints, lead to the following conclusions: (a) a rig which can drill regolith will not be manufactured in its entirety in Uganda, for the forseeable future; (b) nevertheless the control of availability could be in Uganda’s hands; (c) to bring this about, substantial future capacity building work is needed; (d) at the same time, all future technical developments should be placed in the public domain, through publication of drawings, specifications, and design and operating principles.

In relation to three key stakeholders (small businesses, communities, and districts),

- Small water sector businesses suffer from major conceptual, financial, organisational, and technical weaknesses. Nevertheless, they welcome and respond to training and capacity building in all these areas, when carried out with understanding and in a spirit of mutual trust between trainer and trainee.
- Small businesses suffer from a range of external constraints, ranging from access to credit, technology and training, to the need for ‘contacts’ and ‘brown envelopes’ in order to win contracts.

- Communities vary in their understanding, abilities, and willingness to respond to the demands of participation, and now public-private-civil society partnership. Moreover, they experience very varying levels of external support, through the LC system and in terms of mobilisation by sub-county and district. Unsurprisingly, therefore, the quality of post-construction operation, maintenance, and recurrent financing, not only varies, but sometimes can be poor.
- The recent policies of decentralisation and privatisation, combined with the greatly increased funding made possible by HIPC/PAF, are generally recognised to be constructive steps which promise great opportunities for serving the unserved, and reaching the poor. Nevertheless, these large changes, all coinciding with one another, present great challenges to the capacity of districts and lower levels of local Government. Little is yet known about how districts are coping, nor about the effectiveness of the public-private- civil society partnership model which is now in operation. Systematic research is needed, of the type proposed by this project.

In relation to partnerships developed during the project:

- The project partnerships, with DWD, districts, small businesses, communities, NGOs, donors, and other stakeholders have been, without exception, constructive, enthusiastic, and backed up by real contributions in cash or in kind.
- Project ownership is very firmly planted in Ugandan soil. Well beyond the confines of the core project team, reference to the project is in first person terms ("we", "our") rather than second person ("you", "your").
- The final stakeholder workshop in June 2001 endorsed the work of the project, giving it a clear mandate to continue and extend. The primary stakeholders indicated in addition their desire for a more structured, formal, involvement in steering and decision-making.

In relation to dissemination:

- Wide use has been made of written materials (newsletters, news reports in journals, informative pamphlets), electronic media (local and international radio and TV, web), open days and stakeholder workshops, and conference attendance. All opportunities have been taken, and many created, for public dissemination of project concepts, experiences and progress.
- Extensive documentary output (some internal/confidential, most publicly accessible) has been produced. All project documents are listed in this report.

The overall conclusion is that more remains to be done to fully develop Pounder well technology, build capacity of small businesses to effectively practice this and other low-cost water sector technologies, and to facilitate local Government and communities in their parts of the public-private-civil society partnership. The remaining question is *how* this should be done.

6 Priorities for follow-up – shape of next stage

The following paragraphs outline the shape of a three-year second stage, the aim of which is to bring Pounder well technology in Uganda to the point where it will continue to develop, evolve and grow with little or no external support. The intention is that this section can form the basis for a detailed project funding proposal. As far as possible the following words reflect discussions in Uganda with the key stakeholders.

Purpose, outputs and activities

The Purpose of the second stage is to “develop Pounder rig technology, manufacture, ownership, and capacity to the point at which it is self-sustaining”. In this statement “Pounder technology” refers to rig, well design, and handpump installation – ie all that is needed to ensure an acceptable and sustainable water source.

The Outputs of the second stage would be:

1. Fully developed and documented Pounder technology.
2. Pounder availability assured through partial local manufacture, public domain ownership of intellectual property, and standardisation.
3. Three to six small water sector businesses trained and using Pounder technology
4. Corresponding districts facilitated in private sector construction works.
5. TEMBA capacity built to the point of full control of Pounder promotion.

Key Activities corresponding to each of these outputs would be:

1.1 Further develop of Pounder technology through R&D, and field trials through to well completion.
1.2 Fully document of Pounder III technology.

2.1 Facilitate of partial local manufacture of rig and well components.
2.2 Build capacity of local manufacturer(s) and agent(s).
2.3 Conduct trainings and workshops to transfer understanding of Pounder technology design and manufacturing issues.
2.4 Bring documentation to point of standardisation, using appropriate agreed model such as Uganda National Bureau of Standards (UNBS) or Swiss Appropriate Technology Organisation (SKAT).

3.1 Identify and select short-list of one or two contractors each in 3 districts, preferably all in one DWD Technical Support Unit).
3.2 Carry out participative training needs assessments.
3.3 Conduct formal and informal trainings and capacity building in business concepts, organisation and management.

4.1 Assess district and sub-county experience in private sector rural water source construction.
4.2 Conduct workshops with districts and sub-counties to raise key issues of contract management, supervision, and community mobilisation.
4.3 Liaise between DWD/TSU and districts on issues of interpretation of policy.

5.1 Develop participative SWOT analysis of TEMBA.

5.2 Identify training and other capacity building needs of TEMBA
5.3 Conduct trainings, consultancies, and workshops with TEMBA Directors and Associates.

Organisation and management

As mandated by the June 2001 stakeholder workshop, it is proposed that Cranfield University would lead the second stage of the project. However, the university would phase itself out of the project by the end of year three, with TEMBA taking an increasing lead over that duration.

Cranfield's management would consist of a full-time Uganda-based project manager. TEMBA likewise would assign the equivalent of one Director full-time to Pounder project management. Technical and management support would be provided from UK. TEMBA would assign office space, secretarial and administrative support.

A steering committee consisting of representatives of Cranfield, DANIDA, DFID, DWD, Other donors, TEMBA, and UWASNET (Uganda Water and Sanitation Network) or an appointed NGO, would be established. Quarterly meetings are envisaged.

7 Summary of financial expenditure

Introduction

This page sets out the financial expenditure summaries of DFID and DANIDA funding in their respective copies of this report. Copies of this report for general dissemination do not include these financial summaries.

8 Name and signature of author of final report

Dr Richard C Carter

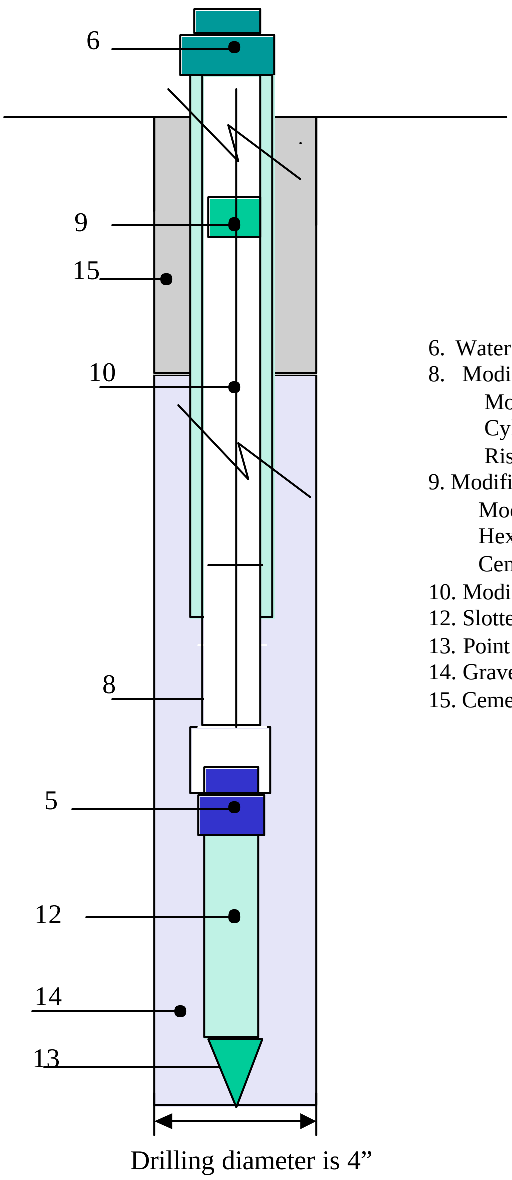
ANNEXES

ANNEX 1 Project logframe

Narrative Summary	Measurable indicators	Means of Verification	Important assumptions
Goal : Well-being of rural and urban poor raised through cost-effective improved water supply and sanitation (TDR Theme W4).	Ten low cost water wells in use by families as main source of small scale irrigation and drinking water by end 2001.	Feedback from manufacturers and contractors, documented in project reports.	That farmers and communities will manage their water use ***effectively***.
Purpose: New very low cost water well drilling rig manufactured, adopted by contractors, ***and being promoted beyond end of project.***	At least two contractors have successfully completed 5 wells each, at realistic economic cost, by end of project. ***Further contracts are in pipeline.***	Project reports including financial summaries from manufacturers and contractors.	Demand increases and credit continues to be available. ***Support to private sector and local Government continues. Regulation mechanisms in place.***
Outputs: 1. New rig designed and tested, and design and operation fully documented 2. Manufacture and marketing initiated 3. Contractors trained in use of new machine. ***4. Sustainable uptake mechanisms in place***	1. Five wells drilled to 20m in a range of ground conditions by end of first phase. One manual with drawings produced. 2. Production rig manufactured by developing country company, to satisfactory quality standards, by end of second phase. 3. One training workshop for contractors completed. ***4. TEMBA registered, active in project, and promoting its services***	1. Phase 1 report and rig design and operation manual. 2. Phase 2 report. 3. Phase 3 report ***4. Project Progress Report, TEMBA first year annual report***	Appropriate physical conditions for completion of wells at 10 sites. Stable economy to ensure design continues to be low cost. Manufacturers and contractors stay in business.
Activities: 1.1 Identify local research institution and manufacturing partner. 1.2 Review all previous work on very low cost drilling (international and in the region). 1.3 Design and construct prototype. 1.4 Field test and modify design. 1.5 Finalise design and complete drawings and documentation. 2.1 Supervise in-country manufacture of first rigs. 2.2 Market new rig locally. 2.3 Identify possible contractors. 3.1 Train contractors in use of rig. 3.3 Establish small number of contractors in business with new rig. ***4.1 Assist in establishment of TEMBA office and start-up costs*** ***4.2 Progressively transfer ownership of project concept, and responsibility for project activities to TEMBA***	***Original budget*** Staff costs: £58,026 Materials: £24,732 T&S: £61,694 Industrial Partner: £45,000 Local Consultant: £27,618 International tel/fax:£1400 Conference fee: £250 Dissemination: 1500 Overheads: £18074 Requested extra costs in Yr3. ***TEMBA start-up and year one overheads: 8500*** ***TEMBA professional services: 26250**** ***Staff costs: R C Carter £3029*** ***T&S: £6050*** ***Comms - £1150*** ***Overheads- £989*** ****TEMBA Professional Services includes £6,000 of Local Consultant original budget***	1. Design and operation manual for rig. 2. Existence of locally manufactured rig and publicity material. 3. Final report on contractors' operations; papers in international "water" literature. ***4. TEMBA progress reports***	Basic geological data exists to aid site selection. Suitable ground conditions exist for field tests. Suitable local manufacturer exists. Suitable local contractor exists. Demand for low cost wells exists or can be stimulated ***TEMBA can create business opportunities which extend beyond year one of operation.***

ANNEX 2 U3 handpump direct install specification

Based on the Uganda Standard Specification for Shallow Well Handpump – US405:1995



6. Water tank - Riser Pipe connector (80-021)
8. Modified Cylinder (80-024) including parts
   - Modified Cylinder Body (80-025)
   - Cylinder - Screen Connector (80-026)
   - Riser Pipe - Cylinder Connector (80-027)
9. Modified Pump Rod Assembly (80-028) including parts
   - Modified Connecting Rods (80-029)
   - Hex. Coupler (80-030)
   - Centralisers (80-031)
10. Modified uPVC riser pipe (80-032 or 80-033)
12. Slotted Pipe (80-014)
13. Point (80-010 or 80-011)
14. Gravel Pack (80-017)
15. Cement Grouting (at least 3m) (80-018)

Item no	Sub Assy	Part No	U3 Standard Drawing No.	Description	Qty Per pump
	80-001			***U3 Direct Install Hand Pump***	
2		**2**	***2***	***Head Assembly***	1
			2a, 2b & 2c	*Head*	1
			2d & 2e & (2f or 2g)	*Bracket/window*	1
			2h	*Front Bottom end Plate*	1
			2I	*Gusset*	2
			2j	*Axle Bush (Right)*	1
			2k	*Axle Bush (Left)*	1
			2l	*Flange*	1
				Washer	1
				Hex. Bolt M12 x 20	1
				Hex. Nut M12	9
				Hex. Bolt M12 x 40	4
3	**3**		***3***	***Front Cover Parts***	
			3 & 3a	*Front Cover*	1
4	**4**		***4***	***Third Plate***	
			4a	*Flange for third plate*	1
			4b	*Guide Bush*	1
5	**5**		***5***	***Handle Assembly***	
			5a	*Handle Bar and Pipe*	1
			5b	*Handle Axle*	1
			5c or 5d	*Chain Guide*	1
			5e	*Chain Coupling*	1
			5f	*Roller Chain*	1
			5g	*Bearing housing*	2
				Hex nut M12	2
				Ball Bearing 6204 ZZ	1
				Axle Washer (4mm thick to suit M12)	1
				Hex bolt M10 x 1.75 x 40	1
				Prevailing torque type steel hex locknut M10 x 1.5	1
				Spacer M20	1
6	**80-020**		***6***	***Modified Water Tank Assembly***	1
			6a	*Top Flange*	1
			6b	*Bottom Flange U3*	1
			6d	*Tank Pipe*	1
			6e	*Spout Pipe*	1
			6g	*Riser Pipe Holder U3*	2
		80-021		*Water Tank - Riser Pipe Connector*	1
			6h	*Gusset*	*2*
	80-021			***Water Tank – Riser Pipe Connector***	
		80-022		*Riser Pipe Reducing Bush*	1
		80-023		*O-ring*	1
7	**7**		***7***	***Stand Assembly (All Options)***	
			7q	*Stand Assembly Gusset*	2
			7m	*Stand Assembly Flange (Top)*	1
AND 7A, 7B OR 7C					
7A	**7A**			***Stand Assembly (Base Plate Option)***	
			7e	*Stand Pipe*	1
			7n	*Base Plate Flange*	1
			7r	*Bottom Flange Gusset*	4
OR					
7B			***7c or 7d***	***Stand Assembly (NB 150 Option)***	
			7i or 7j	*Stand Pipe*	1
			7p	*Legs*	3
7C	***7C***		***7a or 7b***	***Stand Assembly (NB 150&175 Option)***	
			7i or 7j	*150 NB Pipe*	1
			7h	*175 NB Pipe*	1
			7l	*Connection of 150 to 175*	
			7p	*Legs*	3

8	**80-024**			***Modified Cylinder Assembly***	
			80-025	*Cylinder Body*	1
			80-026	*Riser Pipe – Cylinder Connector*	1
			80-027	*Cylinder – Screen connector* 75mm uPVC x 5mm min wall thickness uPVC tube with one end having a male BS 879 buttress thread to form flush coupled threads. Other end with 75mm socket. 1m effective length	1
			80-028	*Cylinder – Screen connector* 75mm uPVC x 5mm min wall thickness uPVC tube with one end having male BS 879 Buttress thread to form flush coupled threads. Other end with 75 mm socket. 1m effective length.	1
			8c	*Brass Liner*	1
			8d	*Bottom Cap*	1
			8e	*Upper Valve*	1
			8f	*Check Valve*	1
			8g	*Spacer*	1
			8h	*Push Rod*	1
			8i	*Plunger Rod*	1
			8j	*Check Valve Seat*	1
			8k	*Cage*	1
			8l	*Follower*	1
			8m	*O Ring Nitride Rubber*	1
			8n	*Sealing Ring*	1
			8p	*Rubber Seating (upper valve)*	1
			8q	*Rubber Seating (lower valve)*	1
			8r or 8s	*Pump Bucket (leather or rubber)*	2
9	**80-029**			***Modified Pump Rod Assembly***	1/3m
		80-030		*Modified Connecting Rods*	1/3m
		80-031		*Lock Nut*	2/3m
		80-032		*Hex. Coupler*	1/3m
		80-033		*Centralisers*	1/3m
10A	**80-034**			***Modified Riser Pipe*** ***75mm uPVC x 5mm min wall thickness uPVC tube with with BS 879 Buttress threads form flush coupled threads. 3m effective length.***	1/3m
OR					
10B	**80-035**			***Modified Riser Pipe*** ***75mm uPVC x 5mm min wall thickness uPVC tube with BS 879 Buttress threads form flush coupled threads. 3m effective length.***	1/3m
11A	**80-012**			***63 mm uPVC x 4.8mm min wall thickness uPVC tube with DIN 4925 Part 11 Trapezoidal threads form flush coupled threads. 3m effective length***	1/3m
OR	**80-013**				
11B				***63 mm uPVC x 4.8mm min wall thickness uPVC tube with BS 879 Buttress threads form flush coupled threads. 3m effective length.***	1/3m
12	**80-014**			***Slotted Pipe – either 80-012 or 80-013***	
		A		***.2 mm slots***	
		B		***.5mm slots***	
		C		***0.75 mm slots***	
		D		***1 mm slots***	
		E		***2 mm slots***	
		F		***3mm slots***	
13A	**80-010**			***Formed Point***	
OR					
13B	**80-011**			***Machined Point***	1
14	**80-017**			***Gravel Pack – sieved Alluvial sand of particle size 1.18 to 2.5 mm washed and pre packed into 25b litre volume sacks***	Per m
15	**80-018**			***Cement Grout – mixed in ratio of 50 kg portland grade cement to 27 litres of water to yield 33 litres mixed grout***	Per m
16	**80-100**			***Sample Box*** (details not shown)	1

ANNEX 3 U3M handpump direct install specification

ANNEX 4 Summary of simple economic decision support model for well siting

SITING MODEL

All costs UShmillion

SHALLOW WELLS

Failed hole	0.50
Successful hole	2.50
"Cheap" siting	0.20
Siting reliability	0.40
Good siting	1.35
Siting reliability	0.80

Blind drilling no. of failed holes per successful well	Blind drilling success rate	Shallow well cost no siting	New success rate	No. of failed wells per successful well	Shallow well cost, cheap siting	New success rate	No. of failed wells per successful well	Shallow well cost, good siting
0	100%	2.50	1.00	0.00	2.70	1.00	0.00	2.70
1	50%	3.00	0.40	1.50	3.75	0.80	0.25	2.88
2	33%	3.50	0.25	3.00	4.80	0.67	0.50	3.05
3	25%	4.00	0.18	4.50	5.85	0.57	0.75	3.23
4	20%	4.50	0.14	6.00	6.90	0.50	1.00	3.40
5	17%	5.00	0.12	7.50	7.95	0.44	1.25	3.58
6	14%	5.50	0.10	9.00	9.00	0.40	1.50	3.75
7	13%	6.00	0.09	10.50	10.05	0.36	1.75	3.93
8	11%	6.50	0.08	12.00	11.10	0.33	2.00	4.10
9	10%	7.00	0.07	13.50	12.15	0.31	2.25	4.28
10	9%	7.50	0.06	15.00	13.20	0.29	2.50	4.45

DEEP WELLS

Failed hole	6
Successful hole	10
"Cheap" siting	0.4
Siting reliability	0.4
Good siting	2
Siting reliability	0.8

Blind drilling no. of failed holes per successful well	Blind drilling success rate	Deep well cost no siting	New success rate cheap siting	No. of failed wells per successful well	Deep well cost, cheap siting	New success rate good siting	No. of failed wells per successful well	Deep well cost, good siting
0	100%	10	1.00	0.00	10.40	1.00	0.00	12.00
1	50%	16	0.40	1.50	20.00	0.80	0.25	14.00
2	33%	22	0.25	3.00	29.60	0.67	0.50	16.00
3	25%	28	0.18	4.50	39.20	0.57	0.75	18.00
4	20%	34	0.14	6.00	48.80	0.50	1.00	20.00
5	17%	40	0.12	7.50	58.40	0.44	1.25	22.00
6	14%	46	0.10	9.00	68.00	0.40	1.50	24.00
7	13%	52	0.09	10.50	77.60	0.36	1.75	26.00
8	11%	58	0.08	12.00	87.20	0.33	2.00	28.00
9	10%	64	0.07	13.50	96.80	0.31	2.25	30.00
10	9%	70	0.06	15.00	106.40	0.29	2.50	32.00