Discussion Paper Series

The Tara Handpump

The Birth of a Star

by Bent Kjellerup, William K. Journey, and Khawaja M. Minnatullah

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The Birth of a Star

UNDP-World Bank Water and Sanitation Program

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THE TARA HANDPUMP

The Birth of a Star

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THE TARA HANDPUMP

The Birth of a Star

Introduction

This is the story of the Tara handpump. The Tara (Bengali for "star") is a low-lift, direct action handpump developed in Bangladesh using concepts that are now proving to be suitable for community water supply applications in a number of other developing countries.

The pump's main features are its simplicity, low cost, and ease of maintenance. It has been specifically designed to make maximum use of materials and skills available in Bangladesh, where, in 1987, it was adopted as the standard handpump for installation in areas of the country where the depth to the water table exceeds the normal suction limit for handpumps (about 7.5m) and is less than 12m.

The design of the pump has been developing since the first prototypes were produced in July 1982, and at each stage the Tara has been subjected to comprehensive testing both in the laboratory and in field trials. There is therefore a complete record of the pump's performance over several years of operation to support the claims made for the Tara. In brief, those claims are:

- **Good user acceptance**
  Children and adults are able to lift water comfortably and in sufficient quantities without complaints. Designed for a user group of 75, the Tara has been found to operate satisfactorily with more than 200 users per pump, though so large a user group is not recommended.

- **Lift**
  Fifteen meters has been specified as the maximum lift for the Tara pump. The Tara was designed to cope with a pattern of declining groundwater levels in most areas of Bangladesh during the pre-monsoon season, while still allowing most children to pump.

- **Easy serviceability, minimum downtime**
  The average amount of active repair time per pump is only one to two hours per year, based on a repair frequency of about two interventions per year. No hand tools are required for changing of valves and seals, and minimally trained women caretakers are able to carry out all routine maintenance.

- **National production**
  The Tara pump and tubewell are fabricated from locally available materials, using skills and tooling available within the country, with spare parts which can be made in rural workshops.

- **Compatibility with indigenous manual drilling technique**
  No change is needed in the traditional "sludger" drilling technique used for sinking tubewells in Bangladesh. A slightly larger diameter hole is drilled to a depth of about 20m, to accommodate the upper well casing/cylinder module.

- **Low costs**

Assuming a user group of 75 people, the average installation cost of a Tara pump and tubewell is roughly US$3.50 per user (a cost breakdown in given to the right); average spare parts costs come to approximately $0.05 per user per year; and average annual labor costs for maintenance come to $0.04 per user, if hired mechanics are used (which is unnecessary, since the pump is readily serviceable by a minimally trained caretaker). Assuming a pump life of 12 years, and a discount rate of 15%, the total annualized costs for the Tara come to only $0.88 per user.

Table 1. Tara installation costs

Item	*US$ Cost*	*Taka Cost*
Pump and associated manufacturing costs	65	2080
uPVC upper well casing and pump rod	45	1440
Lower well casing	35	1120
Roboscreen (2m length)	5	160
Platform materials	25	800
Installation labor	100	3200
Total	**275**	**8800**

(Exchange rate assumed: US$1.00 = Takas32.00)

The aim of this publication is to track the development of the Tara from its origins in Bangladesh's need for an alternative to the ubiquitous New No. 6 suction pump, to the present proven design, now finding application in Africa and Latin America as well as on the Indian sub-continent. Thus, it is hoped to provide pointers for others seeking to profit from the Bangladesh experience, either by adapting the Tara design to their own circumstances, or by initiating their own research and development program.

The Tara pump was designed to allow routine maintenance by minimally trained female caretakers using few specific tools.

1. Bangladesh's Water Dilemma

For the young and crowded country of Bangladesh, water is both friend and foe. While its two main rivers fluctuate annually between flood and drought, a vast underground reservoir holds the promise of plentiful supplies of safe water.

Making optimum use of this precious resource has been a high priority since the Bangladesh nation was created in 1971.

Background

Bangladesh's 100 million plus people occupy the world's largest deltaic plain. At about 700 people per square kilometer, the country's population density is one of the highest in the world. Environmental sanitation is poor, and for four months of the year when the delta is inundated with surface water, pathogens spread quickly and widely, creating further health risks. Diarrhoeal disease is a major killer, claiming more than 200,000 children annually according to a 1983 Ministry of Health report.

Providing safe drinking water and adequate food supplies for the rapidly growing population has always been a priority for the Bangladesh Government. That means managing the country's water resources efficiently and in the most cost-effective way. Regulation of surface water is impractical. The flat terrain makes surface storage impossible, and control of the major rivers lies outside Bangladesh. Irrigation supplies from surface sources are therefore restricted by the low minimum flows.

Groundwater on the other hand is plentiful and replenished during the annual floods. For this reason, plus the ideal geology, which permits the use of an inexpensive, rapid drilling technique, Bangladesh's water resource planning has been based on full exploitation of groundwater supplies.

Hydrogeology and appropriate technology

The geology of Bangladesh has been described very simply by a local engineer as "sand, over sand, over sand." With a water table only a few meters below the surface over much of the country, and a water chemistry so close to neutral as to make no significant difference, Bangladesh might easily be regarded as a hydrogeologist's dream. Certainly, the combination of plentiful shallow water and easy drilling provided the opportunity for some highly effective water resources development in the late 1970s and early 1980s

One crucially important factor in the early success of this program was the adoption of the cheap and simple well-sinking method, commonly referred to as the "sludger" method. First used in Calcutta in the 1940s, the manual well-drilling technique is ideally suited to the deep sand and silt which underlies most of Bangladesh. It enables a three-man team equipped only with a bamboo scaffold, a chain and enough 40mm-dia. galvanized iron pipe for the planned well depth, to sink a hole to 50m in only a few hours, from which clean water can be drawn in abundant quantities. Teams of local contractors rapidly took up the sludger method, so that in the late 1970s, installation of a village tubewell, including a locally made handpump and all the necessary uPVC tubing, could be accomplished in half a day at a cost of less than $100.

The rural water program

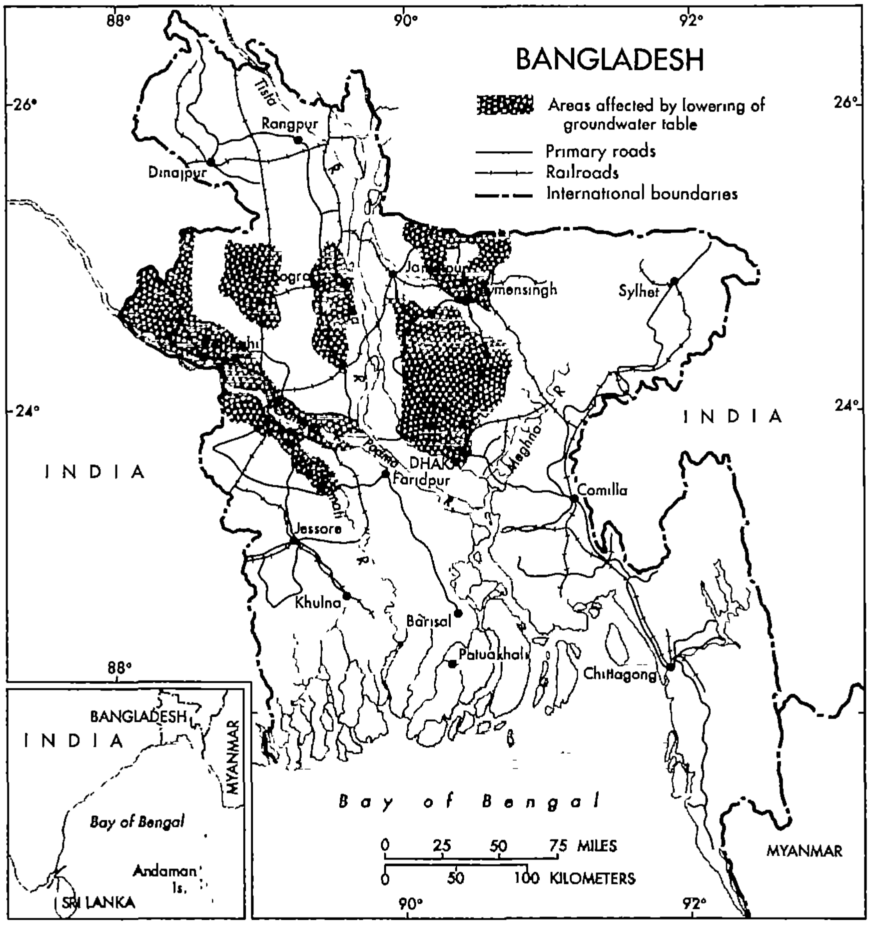
Alongside the cheap drilling made possible by the sludger method, Bangladesh's aim of providing safe water to the rural population was assisted by development of a standard handpump, which could be manufactured cheaply and in large numbers within the country. The New No. 6 handpump was developed in the late 1970s, with financial and technical assistance from UNICEF, as an improvement to the old Maya No. 6 pump (in Bangladesh, No. 6 indicates a 3-1/2 inch (90mm) cylinder diameter).

A simple and robust pump constructed almost entirely of cast iron, the New No. 6 is a suction pump. This has the advantage that all moving parts are above ground, which makes the pump easy to repair and maintain. With most of Bangladesh having a groundwater table that remains at within 5 or 6 meters of the surface throughout the year, a suction pump was the logical choice for the Department of Public Health Engineering (DPHE) rural water program, which sought to improve water and sanitation facilities for all the rural population as quickly as possible.

Because most Bangladesh families have ready access to water from contaminated surface sources, any alternative supply must be convenient, reliable, and cheap if it is to gain widespread acceptance. The New No. 6 pumps installed on hand-sunk tubewells met all these criteria, and more than half a million New No. 6 pumps have been installed in Bangladesh for domestic water supplies alone during the last ten years. Each pump serves a maximum of 150 people, though the longer term aim is to bring this figure down to 75 users per pump. As many wells and pumps again have been installed as MOSTIs (manually operated shallow tubewells for irrigation), enabling individual farmers to pump enough water to irrigate their small plots.

Lowering of the water table

Substantial as Bangladesh's groundwater resources are, they are not inexhaustible. At the same time as DPHE was successfully implementing its rural water program, demand was rising for both manual and motorized irrigation pumps to meet the nation's ambitious food production targets. The large scale of groundwater-based irrigation has resulted in declining groundwater levels, characterized by increased depths to the water table before the monsoon season. By the early 1980s, a growing number of suction pumps were found to be going out of action during the dry season, as the water table fell below the suction limit (approximately 7.5 meters). The problem is aggravated by the fact that many handpumps are located



The map shows the areas where suction handpumps were rendered inoperative in the dry season through lowering of the water table. By the year 2000, it is estimated that as much as 50% of the rural areas may be unsuitable for suction pumps.

on "baris," the higher habitation areas built to protect the people from the annual flood waters, increasing the pumping lift by about 2.5-3m above the field surface level.

There have always been some areas, mainly in the western districts of Bangladesh, where the groundwater levels were too deep for suction pumps. These were served by deep set handpumps consisting of a New No. 6 pump head and a cylinder and rising main set below the water table in a 4-inch diameter tubewell. As demand has increased through the 1980s, more and more areas have been affected by falling groundwater levels. Projections suggest that by the year 2000, half of Bangladesh's rural areas may be subjected to dry season water tables below the suction limit. It became obvious at the start of the 1980s that a technology change was necessary to guarantee dependable future water supplies. In 1981, DPHE, with encouragement from UNICEF and the UNDP-World Bank Interregional Handpumps Project, initiated research to develop an alternative to the New No. 6, for use in areas where suction pumps would not be able to provide supplies throughout the year. It was that research and development program, and the associated laboratory and field testing which, in 1987, resulted in the adoption of the Tara as the standard handpump for areas where the water table is expected to drop below 7.5m at some time during the year.

2. Design of the Tara Handpump

> **Development of the Tara design has been a collaborative effort, involving many agencies and individuals. The concepts of community water supply have been changing rapidly during the 1980s, and the Tara design has incorporated lessons from experiences in many different countries and involving many different handpumps.**
>
> **Hopefully, the experience gained during the Tara's own development will now prove valuable to other pump designers.**

The design team

Beginning in 1981, a handpump development team was assembled to help DPHE to develop a suitable pump for the deep set areas (in Bangladesh, the term "deep set" is used to distinguish pumps with an immersed pumping element from suction pumps, in which the pumping element is above the groundwater level). Members of the team were drawn from DPHE, The Mirpur Agricultural Workshop & Training School (MAWTS), The UNDP-World Bank Interregional Handpumps Project (UNDP-WB Handpumps Project), and UNICEF. At a later stage, the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) assisted with field testing. The Canadian International Development Agency (CIDA) was a major underwriter of handpump research. The panel on the following page provides more details of agency contributions.

The VLOM concept

In 1981, the UNDP-WB Handpumps Project coined the term VLOM, for village level operation and maintenance. The VLOM concept was heavily promoted as a way of avoiding the serious shortcomings of handpump projects in many countries caused by the high costs and unreliable service when central maintenance organizations were responsible for the upkeep of rural handpump schemes. The lesson had already been learned in Bangladesh, where the DPHE rural water program trained local caretakers and pump mechanics to look after the New No. 6 pumps. It was important that any alternative to the New No. 6 should also be suitable for village level maintenance, and the VLOM principles were adopted from the start by the Tara design team.

In terms of hardware, the VLOM concept recommends that pumps should be specifically designed to be:

- Easily maintained by village artisans or caretakers, requiring few specific skills or tools;
- Manufactured in the country of use, primarily to ensure the availability of spare parts;
- Robust and reliable under field conditions; and
- Cost effective.

Roles of Collaborating Organizations

The common objective of improving service levels for rural water supply in Bangladesh brought together several national and international organizations in the development of the Tara pump. The following list is an attempt to describe the main contributions of each organization to the Tara development process, though because of the close collaborative arrangements, it is difficult to isolate individual contributions.

Department of Public Health Engineering (DPHE)

(a) National policy decision to support development of a non-suction low lift pump;
(b) Field monitoring of initial installations of Tara pumps;
(c) Deputation of an engineer to the Mirzapur Project.

UNDP-World Bank Interregional Handpumps Project

(a) Original design concept for the Tara pump;
(b) Technical assistance and field test data analysis;
(c) Provision of specialized technical consultants;
(d) Linkage with handpump development activities in other countries;
(e) Provision of laboratory testing capability through the Consumer Research Laboratory in England;
(f) Sponsorship of performance monitoring of the initiation phase of installation of the current Tara specification;
(g) Sponsorship of adoption of national standards for handpumps.

United Nations Children's Fund (UNICEF)

(a) Financing of Tara prototype fabrication and sponsorship of first field installations;
(b) Sponsorship of groundwater table mapping;
(c) Technical assistance to manufacturers in quality control of Tara pump manufacture;
(d) Provision of experienced staff and technical assistance to the design team;
(e) Major source of external financing for Tara pump procurements;
(f) Sponsorship with DPHE of a design manual for Tara pump production.

Mirpur Agricultural Workshop and Training School (MAWTS)

(a) Fabrication and demonstration of prototypes;
(b) Facilities for design team meetings;
(c) Provision of experienced production specialists;
(d) Extensive experience in development and dissemination of similar equipment in Bangladesh.

International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B)

(a) Data collection on the performance of Tara pumps in the Mirzapur test area;
(b) Surveys of water use and specialized expertise on the behavioral aspects of pump user preferences.

Canadian International Development Agency (CIDA)

(a) Financial contributions to the South Asia Handpumps Project;
(b) Financial contributions to the Mirzapur Field Study.

The VLOM concept is not restricted to handpump technology. Equally important is the emphasis on community management of maintenance to reduce dependence on central government support of essential functions. To reinforce this message, the VLOM concept includes three further elements linked to the operation of handpump schemes:

- Community choice of when to service pumps;
- Community choice of who will service pumps; and
- Direct payment of repair personnel by the community.

Direct action handpumps

In seeking an alternative to the New No. 6, the design team needed to find a pump type capable of lifting from depths greater than the suction limit of about 7.5m. On the other hand, in Bangladesh only in rare cases is it necessary to pump from a greater depth than 12m. For that pumping range, consideration fell on direct action pumps.

The term *direct action* refers to the fact that in such pumps the pumping action is transmitted directly from the handle to the pump rod, without the mechanical advantage that more conventional handpumps achieve through a lever arm, a flywheel, or a gear box. The most straightforward form of direct action handpump is operated by the user raising and lowering a T-bar handle attached to the top of the pump rod. This in turn moves the piston in a submerged cylinder.

The inherent simplicity of the design means that direct action pumps tend to be easier to maintain and repair than other pump types. Compared with conventional lever action handpumps, they generally have a smaller cylinder diameter and longer stroke length. The smaller piston diameter and absence of a lever to give mechanical advantage mean lower forces on the pump rods, and the opportunity to consider a greater variety of pump rod materials. As there is no lever, there is no need for the heavyweight pump stand commonly needed to support the fulcrum and the eccentric application of handle forces. Another significant advantage of direct action pumps is the elimination of fulcrum and hanger bearings, which often create maintenance problems on conventional pumps.

Absence of the mechanical advantage provided by a lever restricts the application of direct action pumps to pumping lifts of less than 15m or so, as beyond that depth the physical effort of raising and lowering the handle becomes difficult to sustain (by using a very small cylinder, the range can be increased, but the resulting low discharge rate makes pumping exhausting work). In the case of Bangladesh, a pumping range of 0-12m is enough to cater to the vast majority of potential handpump applications, which makes direct action handpumps a viable option. On the other hand, the New No. 6 has proved to be an economic pump for low lift applications and has well-established production, spare parts distribution, and maintenance arrangements in place. It would be difficult to provide a more appropriate solution for those applications.

From the start, therefore, the design team saw direct action pumps as appropriate primarily for regions where suction pumps could not be used or were at risk of running dry through lowering of the groundwater table.

While the operating principle of a direct action handpump is simple, designing a pump to achieve optimum performance over a range of pumping heads requires a clear understanding of the hydraulic principles involved. The chief complicating factor has already been mentioned as one of the pump's advantages — the opportunity to consider alternatives to steel for the pump rod material. In particular, the low stresses involved make it possible to use lightweight or tubular materials, which give a buoyancy effect, reducing the effort needed to raise the handle and resulting in a compensating need for a downward effort on the downstroke. Such arrangements mean also that the pump discharges water both on the upstroke, as the piston lifts the water column, and on the downstroke, as the buoyant pump rod displaces water in the rising main.

Evaluation of the optimum combination of rising main and pump rod diameter to give both ease of operation and satisfactory discharge rates involves both theoretical calculation and field trial monitoring. The hydraulic principles of direct action pumps with buoyant rods are described in a paper by W.K. Journey and A.W. Karp in Report No.4 of the UNDP-WB Handpumps Project (World Bank Technical Paper No. 29, published in 1984).

Tara design criteria

The merits of direct action pumps for low and medium pumping lifts quickly led the design team to choose that pump type to fill the gap between suction pumps and the more costly deepwell piston pump and tubewell. So, the search began for the new "star" — the Tara. Design criteria were established to suit the Bangladesh conditions, as well as to recognize the VLOM principles emerging from the UNDP-WB Handpumps Project. The principle criteria were:

- **A high discharge capacity for pumping lifts up to 15m.** As high a discharge as possible had to be achieved, as potential users were accustomed to the rapid discharge they could achieve with the New No. 6. The 15m limit recognized the practical limitation of the direct action design and related well to the anticipated maximum requirement for widespread application in Bangladesh, where few areas are expected to suffer drawdown beyond 12-15m.
- **Good user acceptance, indicated by consistent utilization, positive feedback, insignificant level of complaints, and negligible vandalism.** The team recognized that research and development would not be complete until users were fully satisfied with the Tara. Both UNICEF and the UNDP-World Bank Water and Sanitation Program were finding numerous examples of handpump projects in different parts of the world where handpumps were in disrepair or disuse because they did not meet the expectations of the users.

- **Capital costs for the full system (pump and tubewell) in the region of US$3–4 per user, and recurrent costs in the range of $0.05-0.10 per user.** These targets were based on affordability and willingness to pay criteria already apparent from the DPHE rural water program, and on early calculations of the effect of implementing VLOM principles of community-managed maintenance. They recognized the immense cost benefit of Bangladesh's favorable geology.

- **Easy serviceability, good maintainability, maximum availability for use, minimum downtime; easy repair without tools by minimally trained members of the user group.** These different attributes have different technical meanings and all need to be present if the pump is to provide reliable water supplies. In essence these criteria are expressions of the technical requirements to make the pump suitable for village-level maintenance.

- **Provide reliable service to a maximum user group of 75 people.** DPHE's national service level target for Bangladesh is 65 people per pump.

- **Manufactured from locally available materials, using skills and tooling available in Bangladesh, with spare parts which can be made in rural workshops.** Another key aspect of the VLOM concept, already proving its worth on the DPHE rural water program in the case of the New No. 6 pumps.

- **Compatible with the indigenous manual well construction technique.** The "sludger" method offers enormous cost advantages and is the only foreseeable way of achieving the coverage rates needed at an affordable cost.

The design process

As with the New No. 6, the Tara design was seen as a total system, including not just the pump components, but also the tubewell. The pump module and tubewell module include the pump head and platform, handle, pump rod, piston, foot valve, cylinder, upper well casing, and lower well casing. In the standard Tara for use in Bangladesh, the upper well casing doubles as the rising main and cylinder. The emphasis on use of indigenous materials, technologies, and skills led to maximum use of locally extruded standard uPVC pipe, including a locally made continuously slotted uPVC screen — the Roboscreen — introduced to Bangladesh by the UNDP-WB Handpumps Project in 1982. The pump head and handle assemblies are fabricated from standard steel pipes and hot-dip galvanized after welding. Metal threaded fasteners are used for top and bottom connectors and small manually injection-molded plastic components are used for the piston and foot valve assemblies. Only basic fabrication processes are used, which makes the Tara suitable for manufacture in most developing countries.

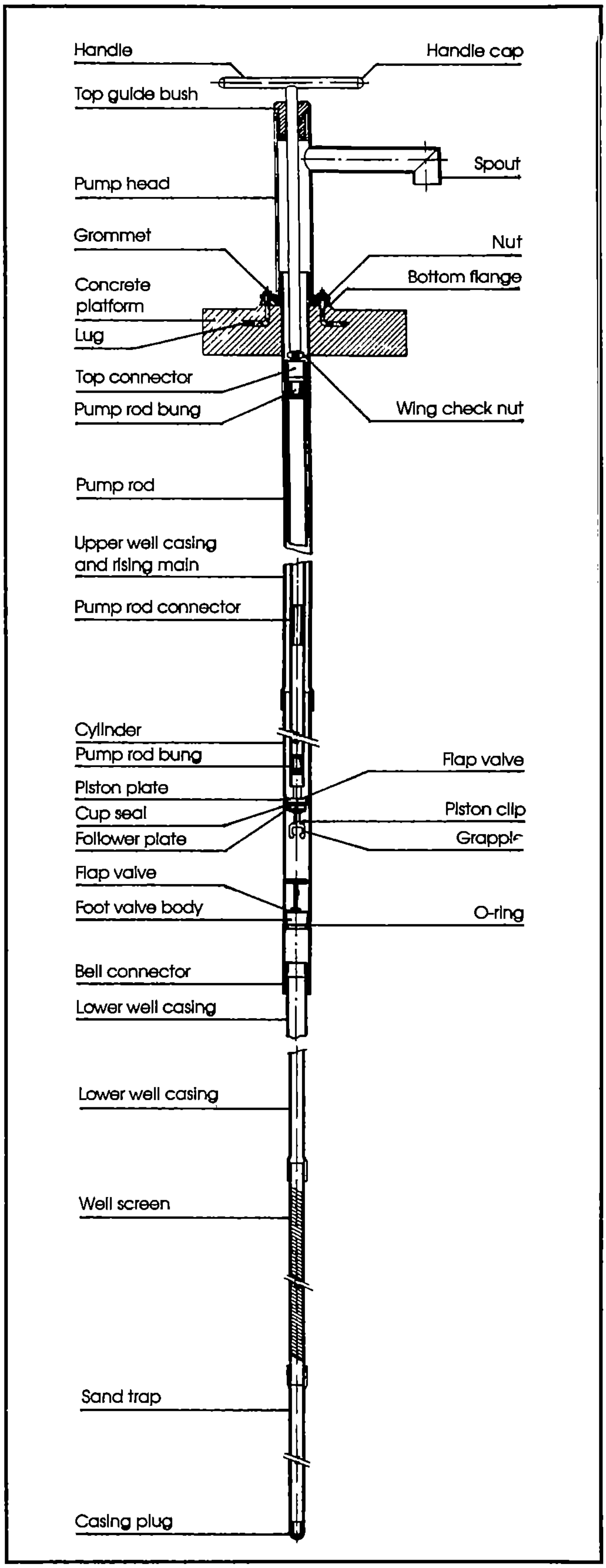
On the way to the final design, a number of alternative materials have been used for different components, including aluminum piston plates and several forms of rubber alternatives to the leather cup seals. The design was planned to develop in an iterative manner, with individual components being replaced from time to time as alternatives were tested, and the most successful elements progressing into the next stage of testing. The sizes and strengths of likely pump operators were among the ergonomic factors taken into account in the pump design. Test criteria included not just performance in the field, but also comparisons on the suitability of the different options for local manufacture and for village level repair and maintenance in Bangladesh.

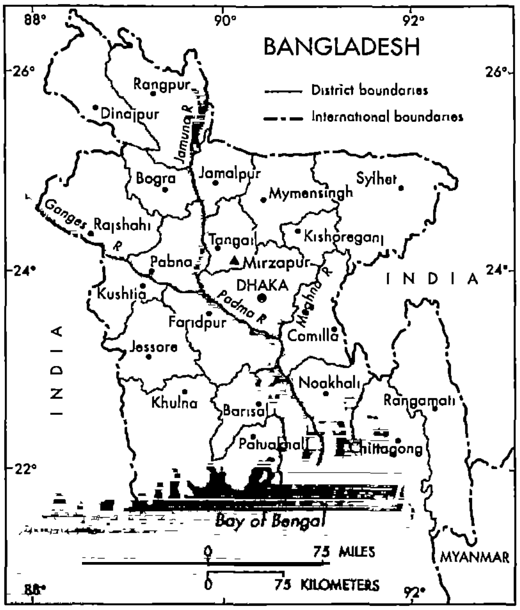
The first prototype pumps, then known as the Bangladesh Deepset Mark I, were produced in July 1982 and installed in 24 test wells. At that stage, the design already included buoyant pump rods and an early version of the novel grappling hook arrangement for lifting the foot valve out of the well for repair. The piston and foot valve designs were based on the successful Rower pump, a high capacity direct action suction pump, manufactured at MAWTS and widely used in Bangladesh for lifting irrigation water from surface sources.

The early tests were encouraging, and the basic configuration of the Tara has remained unchanged, with development focusing on improvements to the pistons, seals, and valves.

The design concept also included careful consideration of the pump apron as a means of maintaining hygienic conditions around the pump and encouraging users to see the pump as a focal point for social gatherings. Large platforms were provided, with room for clothes washing, provision for drainage of spilled water, and a perimeter wall high enough to provide comfortable seating for users and their companions.

The initial 24 installations demonstrated the inherent soundness of the Tara design, but more extensive testing was needed to provide evidence of user reaction and the maintainability of the pumps.

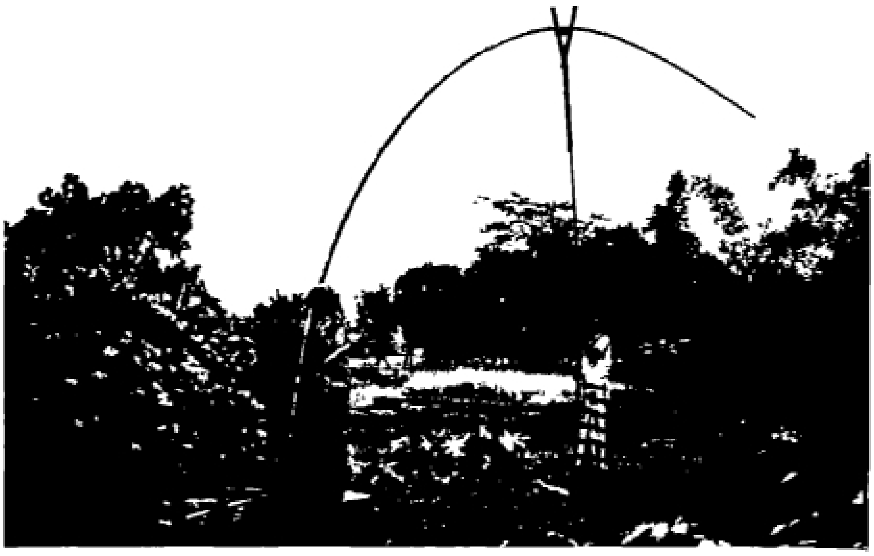




The Mirzapur Handpumps Project

Along with the need to validate the design principles of the Tara, DPHE wanted to ensure that the substantial investments planned for rural water supplies during the International Drinking Water Supply and Sanitation Decade (1981-1990) would achieve maximum impact on the health of the beneficiaries. In 1984, a major collaborative study was initiated, to evaluate the success of an integrated package of interventions, including handpump water supplies, pit latrines, and hygiene education. The Mirzapur Handpumps Project was a collaborative venture involving the UNDP-World Bank Water and Sanitation Program and the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). The Canadian International Development Agency co-funded the project with UNDP; the World Bank acted as executing agency, with ICDDR,B appointed to undertake the operation, monitoring, and evaluation. The Tara design team continued to be responsible for technological improvement of the pump design.

For the Tara design team, the Mirzapur project provided the ideal testing ground. Covering a population of some 4,500 people in a rural area of Bangladesh where water tables in the dry season cause suction pumps to run dry, it is a prime example of the country's general problem and is on a scale large enough to give meaningful results.



A conveniently located tree provides the ideal form of support during installation and removal of the pump rod, but a bamboo pole can also do the job.

The project team carried out a preliminary selection of potential pump locations in March 1984 using data from a baseline water and sanitation survey and choosing groups of households best placed for serving from a Tara handpump. In all, 128 household groups were each allotted one Tara pump, the user group size varying from less than 20 to a maximum of 90 people. The choice of pump site for each group was based on geographical characteristics (house spacing and orientation, availability of courtyards, elevation above mean flood level, accessibility, privacy), the presence of a nearby tree (to support the pump rod during retrieval for routine maintenance and to provide shade for pump users), and availability of enough space to accommodate the platform and its drainage arrangements.

The prospective users' views were then sought on the preliminary plans, and final pump locations chosen based on their preferences. This final phase of site selection also provided the opportunity to sensitize the users to the aims and anticipated benefits of the planned project, and to their own participation in looking after the installed pumps.

From logs of irrigation tubewells in the area, the project team developed a subsoil profile. Investigation of existing handpump wells and local knowledge of dry season groundwater levels helped to set the drilling depths and cylinder settings for the pumps. In fact, the most suitable aquifer for the filter was located at a depth between 50m and 65m, and was divided from the higher water bearing strata by an 18m clay layer. Cylinder depth was maintained at 15m, which took account of any anticipated drawdown during the dry season.

In July 1984, experienced teams hired by the project demonstrated the sludger drilling technique, installation of the first few Taras, and construction of the pump platforms to local contractors and masons. Between July and November, the contractors installed a total of 128 pumps. Another 20 pumps were added in the period June-September 1986.

Between the two major installation periods, a workshop, held in October 1985, reviewed the performance of the initial batch of pumps and laboratory tests at MAWTS on different components and on complete pump assemblies in two purpose-built test rigs. The workshop identified design modifications to be field tested at Mirzapur. In essence, the second generation design specification for the Tara pump resulted from this 1985 Mirzapur workshop. One of the key changes introduced was a switch from aluminum to injection-molded plastic for the piston plates, another important step in the direction of local manufacture of key components. Some pumps were retrofitted quickly with modified components, others changed more gradually, as individual parts needed replacement.

All the Mirzapur pumps were inspected regularly by project staff, and trained mechanics were assigned to carry out any repairs needed. Expert maintenance and fault diagnosis was therefore available continuously. This gives an accurate record of the way that pump performance deteriorates with time, but the rapid response to and correction of performance deficiencies will clearly influence interpretation of the data in terms of predicting likely breakdown frequencies under more normal operating conditions.

Laboratory testing at the Consumer Research Laboratory in Harpenden, UK continued alongside the Mirzapur field trials, and another option of the Tara design was introduced in 1986 in which the complete pump module was enclosed in a separate 3-inch diameter upper well casing. This design allows the module to be extracted easily for inspecting of pump components or for retrofitting of design modifications.

3. Field Experience

Monitoring of the 148 Tara handpumps at Mirzapur extended over more than three and one-half years of field operation, under closely controlled conditions. Under the current UNICEF/DPHE rural water program, another 300 Taras have been monitored at bi-monthly intervals since November 1987, and random monitoring is taking place of a further 1,700 pumps.

The results confirm that the Tara meets the objectives set for it in 1981, and provide a measure of confidence for the long term sustainability of Bangladesh's rural water supplies.

In the seven years during which its design has been evolving, the Tara has been subjected to intensive monitoring and evaluation covering every component. The most detailed data on the pump's field performance have been provided by the three and one-half years of monitoring of the Mirzapur Handpumps Project. In addition, DPHE, UNICEF and the UNDP-World Bank Water and Sanitation Program are collaborating in the monitoring of 2,000 Taras installed as part of the current program, and have carried out retrospective inspections of earlier versions of the design, which provide useful comparative data. The field data have in turn been supplemented by laboratory tests both at MAWTS and at the Consumer Research Laboratory in the UK. In both of these laboratories, different versions of the Tara have been subjected to accelerated tests in purpose-built rigs, simulating from four to twelve years of normal operation.

The Mirzapur data

In analyzing the performance of the pumps at Mirzapur, it is convenient to divide the 148 pumps monitored into four groups:

Group 1: Ten pumps were kept as the original (1984) design.

Group 2: Sixty-eight pumps retained the first generation standard specification, and were only gradually modified to conform with the recommendations of the 1985 Mirzapur workshop, as individual parts needed replacement. Modifications designed after the workshop were also introduced in the same way. The data analysis reported here covers a period of over three and one-half years operation of Group 2 pumps.

Group 3: Forty pumps were modified according to the recommendations of the 1985 Mirzapur workshop, except that the original tubewell was retained, so that the foot valve receiver, cylinder, and upper well casing date from the original installation. The design modifications were carried out quickly after the workshop, even though most components changed were actually functioning normally at the time. Three pumps from this group have been omitted from the data analysis. In two cases, early persistent leakage, probably due to failure of the foot valve receiver, meant that modification of components was meaningless; the other pump for which data was judged unrepresentative was sited at the project field office, where frequent demonstration of the pump to visitors invalidated the record of "interventions." In all, 21 months of data are available on the performance of the modified pumps.

Group 4: Thirty pumps were installed in new tubewells to test a variety of experimental components such as different cylinder geometry and smaller diameter pump rods. The upper well casings of these wells were 3-inch diameter uPVC pipe, into which the entire Tara pump module fits. The module can thus be extracted easily for inspection as necessary.

Comparison of the monitoring data for Groups 2 and 3 provides telling evidence of the way that design improvements to individual components have led to significant reductions in the frequency and cost of pump repairs. The data have been analyzed separately over consecutive six-month intervals to assess whether the number of maintenance interventions increases as the pumps get older.

Taking a general analysis first, the summary statistics for Groups 2 and 3 are:

Table 2. Summary statistics of pump groups

	Group 2		**Group 3**	
	Total	*Per pump/yr*	*Total*	*Per pump/yr*
Total number of pumps	68		37	
Number of users served	2020	30	1390	37
Average water table (m)	5.7		5.7	
Months of data covered	2600	38	767	21
Volume pumped (m^3)	79,700[1]	368	28,600[1]	447
Number of interventions	888	4.1	75	1.2
Parts replaced	854	3.9	69	1.1
Parts cost (Takas[2])	21,700	100	2,200	34

1. Based on Water Use Survey. *2. US$1.00 = Tk30.00 approx. in 1985, Tk33.00 approx in 1988*

Monitoring handpump performance

The method used at Mirzapur for monitoring handpump performance involved two tests; a discharge test and a leakage test.

In the discharge test, the operator pumped a total of 16 strokes of 30cm length within 30 seconds and measured the volume of water pumped. The leakage test was designed to assess whether there were leaking joints, cracks, or faults with the foot valve. After a period of pumping at maximum capacity, the pump was rested for five minutes. Pumping then restarted, with a predetermined stroke length of 30cm, and the number of strokes used before water emerged from the spout was counted.

A pump was rated as functioning adequately if it achieved more than seven liters in the discharge test and less than one full stroke was needed to achieve a discharge in the leakage test. If the discharge was less than two liters, or if it required more than nine strokes to re-establish pumping, the pump was judged to have broken down. Between these two cases, the monitor recorded "poor performance."

The reason for each intervention was also recorded using four categories: breakdown; poor performance; preventive maintenance; and "other" (usually the replacement of parts carried out when the pump was being serviced for other reasons). Analyzed according to the semi-annual interval in which they occurred, the recorded interventions show no clear pattern of increasing maintenance as pumps get older. In the case of the Group 3 pumps, data cover only three six-month intervals, while the Group 2 pumps received updated components as each part required replacement, so that any trend towards increasing maintenance requirements would be masked. The data show that markedly less maintenance was needed for the modified pumps. In this table, the interventions for each pump group have been averaged to indicate the typical number of interventions per pump per year in each time interval.

Table 3. Average interventions per pump by type

		Type of intervention				
	Interval	*Breakdown*	*Poor performance*	*Preventive maintenance*	*Others*	*Total*
Group 2	1	0.0	0.9	0.0	0.1	1.0
	2	0.0	1.8	0.0	0.4	2.2
	3	0.0	1.3	0.0	0.6	2.0*
	4	0.2	1.0	0.0	0.6	1.8
	5	0.3	1.0	0.1	1.1	2.4*
	6	0.4	0.9	0.3	1.1	2.7
	Avge. annual	**0.3**	**2.3**	**0.1**	**1.3**	**4.0**
Group 3	1	0.1	0.1	0.1	0.1	0.4
	2	0.3	0.1	0.2	0.1	0.8*
	3	0.1	0.1	0.1	0.0	0.2*
	Avge. annual	**0.3**	**0.2**	**0.3**	**0.1**	**0.9**

** Figures are rounded, so may differ slightly from the sum of individual columns.*

The comparatively high rate of intervention for Group 2 pumps (four times per pump per year) is partly explained by the experimental nature of the pumps, particularly in the early periods. On the other hand, the monitoring of the Group 3 (latest design) pumps covers only the first 18 months of operation, and so does not include any effects of lengthy service. Detailed analysis of the figures has led the design team to conclude that a long-term average intervention rate should be around 1.5 interventions per pump per year. This is seen as a highly satisfactory performance by the Tara, especially when considered in the context of the simplicity and low cost of the various types of maintenance.

Further encouraging evidence comes from analysis of the maintenance interventions according to the pump component responsible for each intervention. The components were categorized into five major assemblies: the handle assembly, consisting of the handle itself and the top guide bush (HA + GB); the pump rod assembly, including the top connector, pump rod, and bottom connector (TC + PR + BC); the piston seal (PS); the piston element, consisting of the piston valve, piston plate, follower plate, piston clip, and grapple (PE); and the foot valve assembly, consisting of the foot valve body, foot valve guide, O-ring, and flap valve (FV). The number of parts replaced under each heading has been analyzed for each group of pumps, using the same six-month intervals. Note that in the table which follows, the average number of parts replaced per pump is calculated under each heading to the nearest 0.1 (i.e., one part for every ten pumps monitored in the period concerned). Hence a figure of 0.0 may not indicate that no parts were replaced at all in that particular interval, only that less than one part per twenty pumps was required (this qualification is important when this table is compared with the one which follows it concerning the cost of parts replaced). Table 4 shows the average number of parts replaced per pump in each six-month interval.

Table 4. Average number of parts replaced per pump

		Types of assembly					
Intervals (6 months)		*HA + GB*	*TC + PR + BC*	*PS*	*PE*	*FV*	*Total*
Group 2	1	0.0	0.0	0.5	0.1	0.4	1.0
	2	0.0	0.1	1.0	0.2	0.8	2.1
	3	0.0	0.1	0.6	0.6	0.7	2.0
	4	0.0	0.0	0.2	1.0	0.5	1.7
	5	0.2	0.2	0.2	1.5	0.3	2.4
	6	0.3	0.2	0.2	1.7	0.2	2.6
	Average annual	**0.2**	**0.2**	**0.9**	**1.7**	**1.0**	**4.0**
Group 3	1	0.1	0.1	0.0	0.1	0.0	0.3
	2	0.1	0.0	0.1	0.2	0.1	0.5
	3	0.0	0.0	0.1	0.1	0.0	0.3
	Average annual	**0.2**	**0.1**	**0.1**	**0.3**	**0.1**	**0.7**

This table demonstrates the sharp fall in replacement of piston seals (PS) in the Group 2 pumps after the first three intervals. Improved quality of the leather used in the cup seals and better manufacturing and quality control brought about these improvements. The increasing need for piston element (PE) interventions on the Group 2 pumps reflects failure of the piston valves and clips. A design modification has been made, and the Group 3 pumps do not show the same trend. Early handle failures on the Group 3 pumps were caused by fretting between the handle nut thread and the top connector bolt. Again a design modification has overcome the problem.

Costs of the spare parts provided were also monitored. In reviewing the cost data however, it is important to recognize that prices may not represent the true market rate, as a single manufacturer (MAWTS) provided all the spare parts needed. The costs of spare parts (in Takas) on the usual semi-annual interval basis are shown below.

Table 5. Average cost of replacement parts per pump

		Cost of replacement parts (Takas)					
	Intervals	*HA + GB*	*TC + PR + BC*	*PS*	*PE*	*FV*	*Total*
Group 2	1	0.00	0.14	6.17	0.17	18.53	25.01
	2	1.03	0.65	12.17	1.18	41.76	56.79
	3	0.00	3.37	7.05	4.07	42.55	57.04
	4	3.24	3.09	1.94	3.22	31.29	42.78
	5	12.54	9.74	2.51	2.93	14.69	42.41
	6	23.79	12.88	2.55	5.86	12.48	57.56
	Average annual	**13.53**	**9.96**	**10.80**	**5.81**	**53.77**	**93.86**
Group 3	1	5.95	5.85	0.32	0.15	0.00	12.27
	2	5.13	0.34	1.62	0.53	4.66	12.28
	3	8.92	0.00	0.65	0.11	2.16	11.84
	Average annual	**13.33**	**4.13**	**1.73**	**0.53**	**4.55**	**24.26**

The most significant trends in this table are the sharp reductions in the costs of piston seal (PS) and foot valve (FV) replacement, brought about by the design modifications. The average annual cost of replacement parts is likely to rise above the Tk24 per pump per year indicated for the Group 3 pumps, as the length of service of these pumps grows. However, even on the conservative estimate that the spare parts cost might rise to the Tk90 (US$3.00) of the Group 2 pumps, it would still be within affordable limits.

The monitoring also included records of the times taken to accomplish each individual maintenance activity. Again the trends are encouraging, with the total active repair time falling from a peak of a little over three hours per pump per year in the second monitoring period of Group 2 pumps, to a mere twenty minutes in the third period of the Group 3 pumps. The reductions are partly, of course, a reflection of the reduced number of maintenance interventions needed.

It should be remembered that the Mirzapur pumps were closely monitored by an engineering team, and that repairs were undertaken with skilled advice and assistance on hand. Nevertheless, the Tara design team is confident that average annual repair time per pump can be kept below the 2.5 hour average of the Group 2 pumps, and that it could in fact be reduced to about one hour per pump per year. Another key point is that as much as 80% of the expected maintenance work can be carried out successfully by trained caretakers, women or men. This point was verified on a representative sample of 30 Taras. Three volunteer women caretakers were trained to look after each pump and given demonstrations of each anticipated maintenance activity. Their subsequent maintenance of the pumps was reviewed over a 12 month period, during which the number of pumps being satisfactorily maintained rose from 80% to 96%. The women had carried out 86% of the maintenance work needed, calling on the services of the trained DPHE mechanics for the remainder.

Only for comparatively complicated repairs, such as a pump rod breakage requiring cutting and cementing, should the services of a trained mechanic be needed. It is nevertheless worth pointing out that, even if a mechanic were employed to carry out all repairs, at the typical rate of Tk15 per hour, repair costs would be well within the Tara design criteria of US$0.05–0.10 per user per year.

The individual intervention times (minutes per pump) in the six-month monitoring periods for each type of repair are shown in Table 6.

Table 6. Average annual replacement time per pump

		Replacement time (minutes)					
	Intervals	*HA + GB*	*TC + PR + BC*	*PS*	*PE*	*FV*	*Total*
Group 2	1	0.00	1.32	15.44	2.21	22.06	41.03
	2	0.88	11.47	30.44	4.19	47.65	94.63
	3	0.00	4.63	17.65	13.24	44.12	79.64
	4	0.88	3.53	4.85	25.59	30.00	64.85
	5	4.48	6.72	6.27	45.22	15.22	77.91
	6	7.05	13.64	6.36	47.95	13.64	88.64
	Average annual	**4.43**	**13.77**	**27.00**	**46.13**	**57.56**	**148.90**
Group 3	1	1.22	5.63	0.00	3.65	0.00	10.50
	2	1.63	9.33	4.05	4.46	8.11	27.58
	3	2.43	2.43	1.62	1.22	1.62	9.32
	Average annual	**3.52**	**11.59**	**3.78**	**6.22**	**6.49**	**31.60**

The overall conclusion of the Mirzapur study therefore was that the Tara design had reached a stage which fully justified widespread implementation of programs based on the Tara. Further fine tuning is expected to continue, but new developments will be designed to be retrofitted into pumps manufactured to the current specifications.

As part of the Mirzapur study, the project team sought to determine user attitudes toward the Tara. A survey supported by UNICEF and DANIDA was conducted by women volunteers from the user communities. Of the 89 women interviewed, 86 said they liked the pump. Based on a questionnaire, the women were invited to express likes and dislikes, including multiple responses where appropriate. Among the 89 respondents, the main reasons for liking the pump were: good water quality (71); easy to pump (37); good platform (36); good yield (23); nice handle locking (14). Dislikes were: too heavy to pump (25); handle rises too high (16); endure physical pain due to pumping (6); difficult for children to pump (5); physical appearance is bad (4); not appropriate for women (3); low discharge (2). The survey concluded that there was no significant user opposition to the Tara pump, and this conclusion has been confirmed by good user acceptance everywhere.

Other field experience

The Mirzapur conclusion has so far been substantiated by other monitoring of Taras in the field. Through a contract arrangement with the Bangladesh-based NGO Forum on the Water Decade, DPHE, supported by the UNDP-World Bank Water and Sanitation Program, has a continuing Tara Pump Performance Monitoring (TPPM) project involving 2,000 Taras installed in late 1986 and early 1987. A sample of 300 pumps are monitored bimonthly; from the remaining 1,700, 60 are chosen at random every month for monitoring. Baseline information on all 2,000 pumps was collected at the start of the study and is held on a computerized data base.

User feedback

Throughout the evolution of the Tara design, feedback from users has been important. Two examples illustrate the point.

1. Early Taras were fitted with handle end caps for aesthetic reasons. Later, the end caps were omitted, but user reaction was so forceful that they were rapidly reintroduced.
2. The handle retainer was added when it was discovered that users were themselves adding a loop of jute twine to prevent the handle from rising too far due to flotation.

A pump performance test used at Mirzapur has been adopted also for the TPPM project. It involves testing both the discharge of the pump and any leakage in the system. Discharge is measured as the volume of water pumped by sixteen strokes of 30 cm executed within 30 seconds. If less than two liters is pumped, the pump is judged to be "out of operation." The result indicates the condition of the piston seal, piston valve, foot valve, and related components. In the leakage test, the monitor counts the number of 30cm strokes needed to restore flow after the pump has been idle for five minutes. This will indicate any foot valve problems or leaking joints in the upper well casing. If the total is more than nine strokes, again the judgment is "out of operation." The Mirzapur experience is that these two tests provide a good indication of the pump's condition.

During 1988, a total of 2,353 pump inspections were carried out under the TPPM project, with bi-monthly status reports submitted to DPHE, UNICEF, MAWTS, and the project headquarters. Of the 1,800 inspections carried out on the routinely monitored pumps, 120, or 6.5%, recorded the pump as "out of operation." In half of those cases, the pump was back in operation at the next visit. A total of 56, or 18.7% of the 300 pumps were out of action on at least one inspection, but in only two cases were the pumps deemed impossible to repair. In the course of the year, there was a total of 337 maintenance interventions, or a little over one intervention per pump, with an average spare parts cost of Tk21.50, or US$0.70 per pump.

About two-thirds of the expenditure was on piston seals, and 75% of the pumps had seals replaced. The 300 pumps have an average operating age of 1.75 years.

Of the 1,700 pumps available for random inspection, 553 were inspected during the year and 55, or 10%, were judged to be out of operation at the time of inspection. Maintenance interventions were reported to have taken place in 262 cases, only 27 of them being carried out actually during the inspection, indicating that most users had accepted the responsibility of looking after the pumps for themselves. Cost data from this group are less reliable, as not all caretakers have been asked to maintain a record of spare parts used. From the data collected, the spare parts cost averages only Tk8.25 (US$0.25) per pump per year. The average age of the pumps was 1.4 years.

The TPPM is also monitoring the extent to which the Tara pumps are being used, on the basis of whether the platform is wet when the monitor arrives. In the 2,353 inspections carried out in 1988, pumps were found to be in use in 1,416 cases, and the platform was wet in an additional 701 cases. The indication therefore is that in 90% of the inspections the pump was either in use or had recently been in use.

A simple user survey showed 86% of users deemed the Tara discharge rate to be either "enough" or "acceptable," with the remaining 14% decribing it as "low" or "unacceptable." In the first annual report, the TPPM project concludes that results from the two test groups are so similar that caretaker motivation does not depend on the routine visit of the monitoring team, but on the simplicity and ease of maintenance of the Tara design.

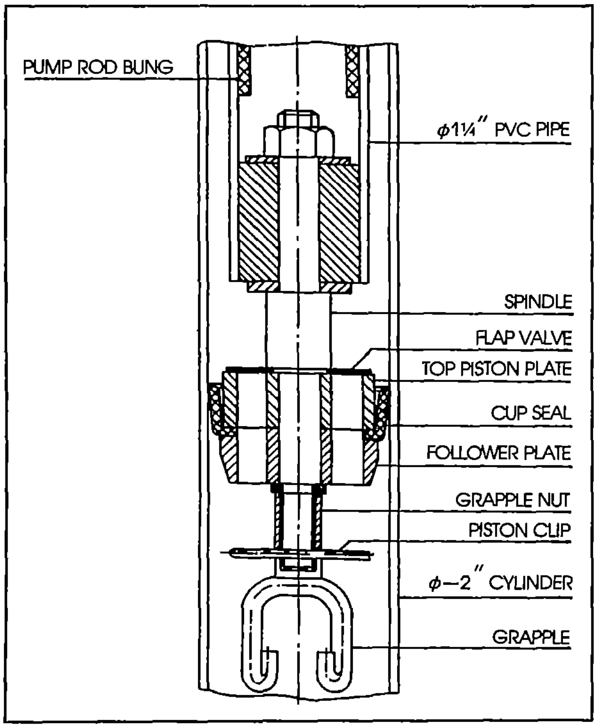
4. The Tara Components

The combination of theoretical analysis with laboratory and field testing has led to evolution of a Tara design which can be continuously modified as experience develops. Factors which have influenced design of the present pump components will also guide future development.

It is helpful therefore to analyze the Tara pump component by component. It is also instructive to look at ideas which did not make it into the final design.

Piston assembly

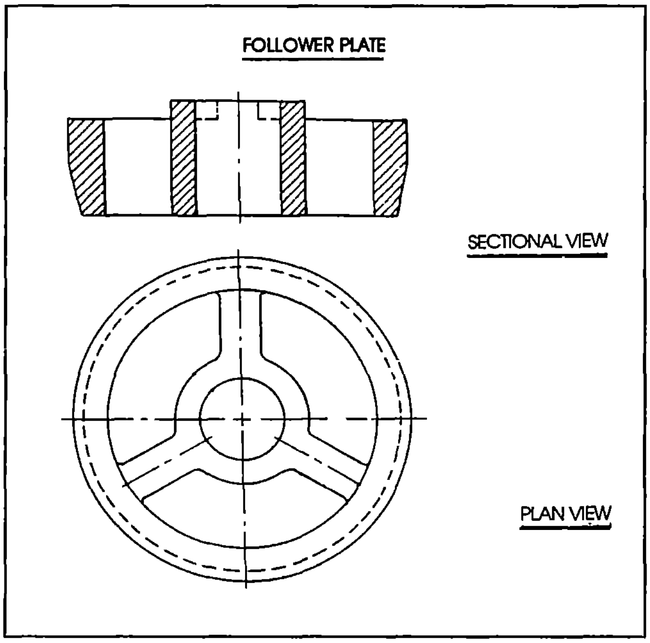
The Tara's piston assembly consists of a central galvanized steel spindle and two plastic (polyamide) perforated plates — a top piston plate and a follower plate. A leather cup seal is clamped between the two plates by tightening the grapple nut on the spindle. The grapple nut is prevented from rotating during operation by a bent stainless steel wire piston clip inserted through the nut and a hole in the spindle. The rubber flap valve, stamped from an automobile tire inner tube, is located in a groove formed between a shoulder on the spindle and the top piston plate. The valve and seal can be removed and replaced by removing the grapple nut and dismantling the assembly.



The piston assembly bears the load of the column of water on the upward stroke of the pumping cycle. The rubber flap valve alternately closes on the upstroke to seal the piston ports and opens on the downstroke to let water pass through to repeat the cycle.

Support for the thin rubber valve and the leather cup seal led to the choice of the twin plate design with a threaded fastener. The Mirzapur study has proved that the assembly can be maintained without hand tools by groups of three women caretakers, and the simple flap valve can be replaced by a piece cut from a tire inner tube.

In the Mirzapur field trials, there was a rising trend of repair interventions associated with the piston assembly (excluding seal replacements, which were recorded separately). The main reasons for those interventions were corrosion of the piston clip and enlargement of the center hole in the piston valve from cutting on the sharp edge of the spindle shoulder. In the later design, the piston clip was changed to stainless steel and the shoulder of the spindle is now chamfered. These two design modifications had a big impact on the life of the two components, and the Group 3 pumps require far fewer interventions. The average life of piston valves has ranged from six months to one year, but the current design is expected to last well over a year.



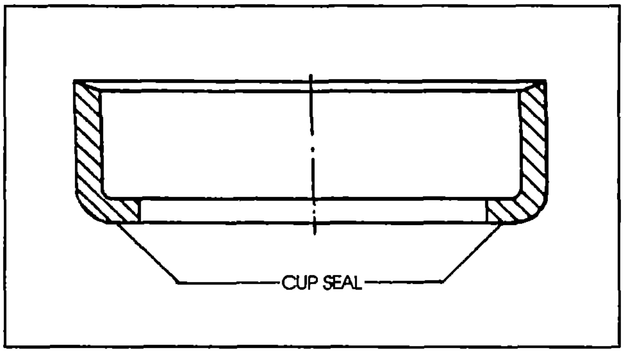
The piston plate and follower plate provide support for the rubber flap valve and a rigid clamp for the leather cup seal. Originally the two plates were made from cast and machined aluminum, and the design was adapted from the Rower piston assembly.

Bimetallic corrosion between the aluminum and the mild steel spindle, coupled with the increasing price of aluminum, led to their replacement with plastic plates. Polypropylene proved too brittle and polyethylene too soft. Polyamide (nylon) was adopted in the 1986 specification, and performed without failure in more than a year of monitoring.

The clamping of the cup seal is achieved by tightening the grapple nut, so called because its grapple attachment is used to capture a T-bar on the foot valve assembly when the foot valve has to be removed for servicing. In the relatively mild waters of Bangladesh, the electroplated mild steel grapple nut has proved to have a long service life, though in more aggressive waters stainless steel would be advisable.

Leather cup seal

The function of a piston seal is to prevent leakage from the higher to lower pressure sides of the piston. This is achieved in the Tara design by filling the space between the piston and the cylinder wall with a flexible resilient material — leather. Good quality, properly tanned leather from cow or buffalo hide is an excellent sealing material. It has the pliability to permit wide tolerances in cylinder diameter, which has made it possible to use standard uPVC pipe as the Tara cylinder. Leather is widely available in Bangladesh at reasonable cost, though there are quality control problems.

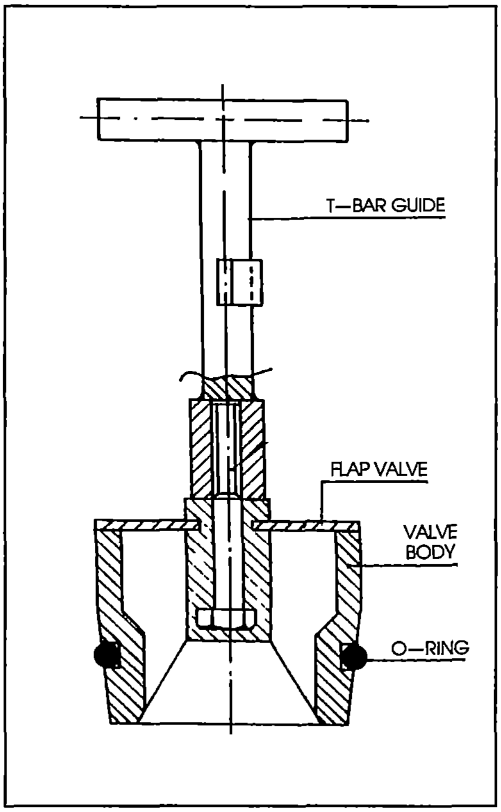


Leather seals are known to be susceptible to failure when the water contains large amounts of sand, particularly coarse sand. In laboratory tests at the

Consumer Research Laboratory in the UK, the addition of coarse sand and kieselguhr* to the water led to eventual siezing of the piston, when sand trapped between the leather seal and the uPVC cylinder wall gouged out slivers of plastic, which then accumulated above the seal. This effect does not occur in Bangladesh, where only medium to fine sands are encountered.

Nevertheless, initially, leather seals required a high frequency of replacement. For a period, a nitrile rubber seal was substituted, but the tight tolerances needed for efficient operation would have ruled out a locally produced cylinder. The Tara designers therefore reverted to leather and concentrated on developing the optimum leather seal by changing dimensions and improving quality control. The progressive reduction in the frequency of seal replacement in the Mirzapur field trials shows that these efforts were successful.

Foot valve assembly



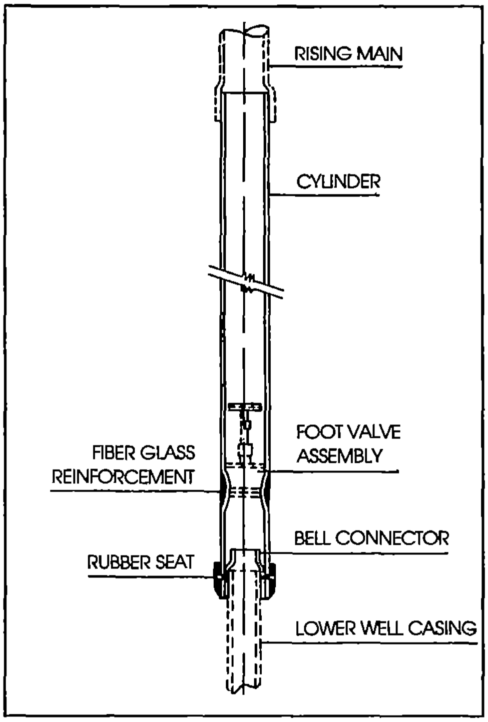
The foot valve assembly bears the weight of the column of water and prevents it from leaking while the piston is moving down. The foot valve then opens to allow water into the cylinder on the upstroke. The assembly consists of a molded body of high density polyethylene with triangular apertures covered by a flap valve again cut from inner tube rubber. A bolt molded into the valve body connects to the double T-bar guide and an O-ring makes a static seal against the walls of a tapered receiver at the lower end of the cylinder. As with the piston valve, users can, if necessary, cut their own replacement rubber flap valves from old inner tubes. The valve body is cheap and simple to make with rudimentary thermoplastic injection molding equipment.

Several design changes resulted from early problems with the foot valve assembly. The angle of seating in the receiver was changed, to prevent the O-ring from rolling out when the foot valve was extracted for repair. The tapered foot valve seat at the base of the cylinder was reinforced on the outside with fiberglass, to prevent creep of the plastic. And the connection between the foot valve body and the metal guide or centralizer is now made through a bolt molded into the body and screwed to a nut attached to the guide. This replaces the original arrangement, in which a threaded spigot passed through a hole in the valve body and was secured by a nut. The twin advantages of the new design are the elimination of leakage and avoidance of pressure on the plastic foot valve body, which could have led to cracking or creep.

With the latest design, the foot valves are proving long lasting and comparatively cheap to repair or replace.

** Kieselguhr is a fine abrasive material with a particle size of 7.5μm. Concentration was 1.00g/l.*

Cylinder and upper well casing



One of the Tara's great advantages is the use of standard uPVC pipe for the cylinder, without the need for any special processing. This helps to simplify production and keep costs low. The 2m long cylinder is more than double the required amount for the pump stroke. This means that when wear roughens the cylinder surface over the lower part of its length, the piston setting can be raised by shortening the pump rod, to make use of the remaining cylinder length.

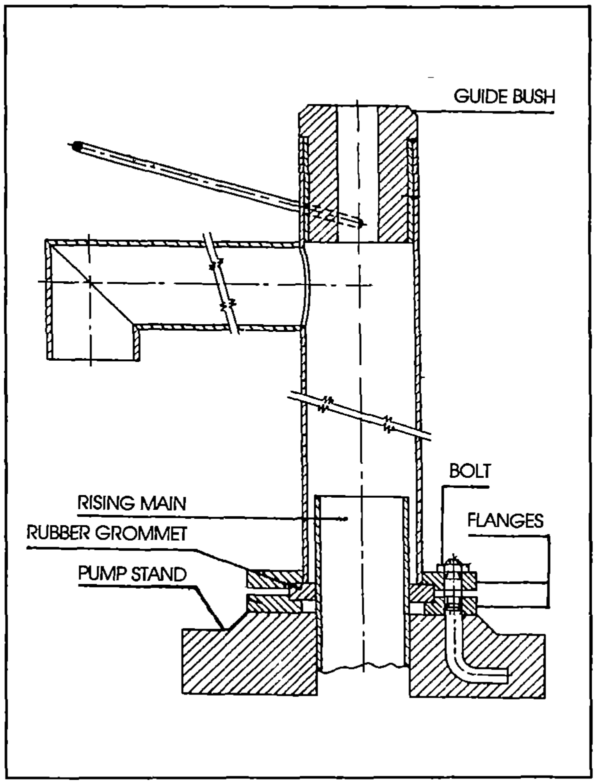
The Tara cylinder is a 2 inch NB BS 3505 Class C rigid uPVC pipe, specially selected from a normal production run for good internal finish and minimum variation of wall thickness (54.3 mm ± 0.3). The standard specification has been modified to reflect the closer dimensional tolerances needed. The foot valve receiver is a tapered section at the bottom of the cylinder, which is heated and formed in a mold then reinforced on the outside with fiberglass. The same uPVC pipe is used for the rising main/ upper well casing, which connects directly to the top of the cylinder. At its base, the cylinder is connected by a reducer to the lower well casing.

In the standard Tara design, the upper well casing and cylinder are the only parts of the pump module which are inaccessible for repair, as they are integral with the tubewell module and so permanently installed. In the Consumer Research Laboratory (CRL) tests and in MAWTS tests, the Tara pumps have been subjected to accelerated wear tests equivalent to about 11 years (CRL) and 7 years (MAWTS) of normal operation. Except for the sand tests at CRL, which are not considered to be representative of conditions in Bangladesh, the uPVC cylinders and upper well casings have shown no significant signs of wear.

Based on this experience and the growing records of Tara installations in Bangladesh, the design team conservatively estimates the working life of the pump's cylinder and rising main to be about 12 years under typical Bangladesh conditions, which are taken to be: daily discharge of 2,000 liters; water with a trace of sand; preventive maintenance carried out when required; and no mishandling of the pump installations.

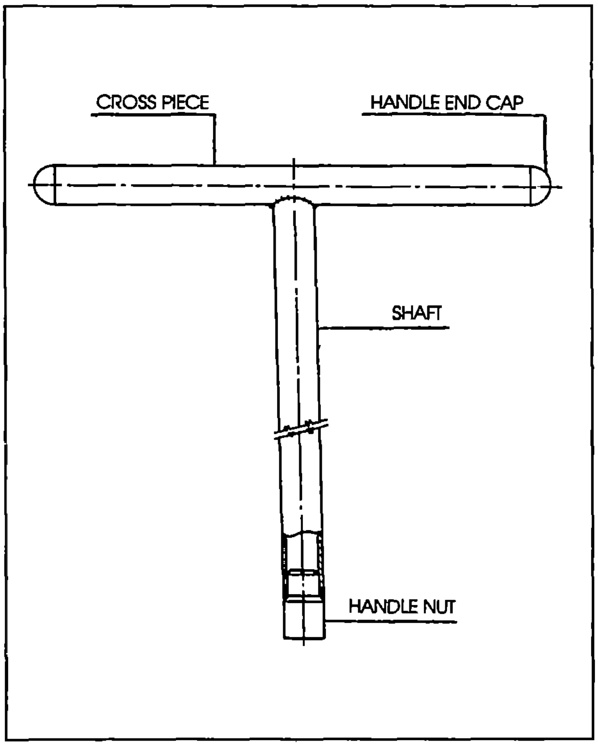
At one point, the design team experimented with sacrificial rubber pump rod guides, as a way of avoiding any abrasion caused by contact between the flexing pump rod and the rising main. The idea was abandoned because of poor results and because field tests showed that abrasion is unlikely to be a serious problem. Should perforation of the upper well cylinder later turn out to be a problem, it is thought that the use of larger diameter upper well casing combined with smaller diameter pump rods may be a feasible solution. To date, however, the team knows of only two pump failures associated with failure of the upper well casing, from among all the Taras installed in the field, and both are blamed on poor quality of manufacture and/or installation.

Pump head and handle



The Tara pump head is fabricated from 2-1/2 inch and 2 inch standard mild steel water pipe and a base flange. The assembly is hot-dip galvanized after welding. It is anchored to the concrete platform by bolting it to a flanged base. The two flanges compress a rubber grommet around the upper well casing as they are tightened, and this forms a sanitary seal between the pump stand and the casing.

The T-bar handle assembly needs to be more rigid and abrasion-resistant than the uPVC pump rod, because of its sliding contact with the guide bush and side loading applied by users. Fabricated from 3/4 inch mild steel water pipe by welding the cross-piece to the shaft and the handle nut to the bottom, the assembly is then hot-dip galvanized. It has an overall length of 750mm, which, after allowing for the length of the bush, permits a random stroke length of up to 650mm. At its lowest position, the cross-piece is about 470mm above the standing level of users, so that children have a comfortable starting position. For adults, the preferred stroke starts higher.



The guide bush is made from a tropical hardwood (sal) soaked in vegetable oil and encased in a sheet metal sleeve to contain swelling. Though the zinc is rapidly removed from the handle by rubbing against the guide bush, this does not lead to corrosion, because of the daily polishing in normal use.

Some early handle replacements were necessary because of fretting and corrosion of the handle nut, which results in a loose fit between the handle and the top connector bolt. A manufacturing error was responsible and has been corrected by improved quality control. A number of design modifications were also attempted, before the final design substituted a wing check nut for the previous locking ring.

Field trial experience suggests that the working life of the Tara handle assembly is at least four years and probably more.

Pump rod assembly

The pump rod assembly transmits the mechanical force applied by the operator from the pump handle to the piston assembly. In the case of the Tara, the pump rod has another important function: it divides the operating force between the up and down strokes, making it easier for the operator to pump. It is this feature which enables Tara users to pump from the 12m to 15m lift range.

The pump rod assembly consists of top and bottom connectors and segments of standard 1-1/4 inch nominal diameter uPVC pipe permanently joined by a standard jointing technique. The top connector joins the uppermost uPVC pipe segment to the steel pipe handle. The handle must be removed to service the lower elements of the pump, so a detachable connector was needed. The connector chosen was a threaded bolt inserted into a uPVC bush machined to fit into the end of the pump rod. The assembly has been updated by injection molding the uPVC bush around the end of a threaded rod. The threaded connector is locked with a winged jam-nut, which may be tightened by tapping with any of a variety of implements found in villages — a sickle, for example.

The bottom connector joins the piston assembly to the lower end of the pump rod. It consists of a galvanized steel spindle threaded at both ends. The steel spindle was chosen because of the need to detach the piston assembly from the pump rod to change the valve and seal.

The 3m-long uPVC pipe segments are solvent-cemented together using internal connectors consisting of short pieces of a specially extruded uPVC pipe. These internal pump rod connectors replaced earlier bell and spigot joints, because of the tendency for abrasion to be concentrated at the wider bell on the pump rod and on the upper well casing touched by the bell. Initially, rubber grommets were installed as a sacrificial element, but internal connectors, quality control to maintain pump rod pipe straightness, and effective packaging resolved the problem of abrasion concentrated at one point.

5. Tara Production

A critical element of VLOM pumps is local manufacture. In Bangladesh, the success of DPHE's rural water program a decade ago was bolstered by a network of manufacturers producing massive numbers of the New No. 6 handpump.

The same production network is needed for the Tara. It will take time to establish, but some important steps have already been taken.

Production schedule

As of the end of 1988, an estimated 5,000 Tara handpumps have been installed in Bangladesh, and the program is continually picking up pace. UNICEF invited tenders in 1988 for supply of 4,000 Taras, and in all, DPHE's current program is expected to need a total of 60,000 Taras over the next five years. Such a rapid build up in production requires careful controls to prevent poor manufacturing quality from erasing the achievements of the rigorous design process. It is also vital that adequate spare parts are on hand to ensure that pumps can be repaired promptly by local caretakers.

Production manual

Once the current Tara design was accepted by the Government of Bangladesh as the standard deep set handpump, UNICEF in collaboration with MAWTS and the UNDP-WB Handpumps Project began preparation of a production manual for the pump. Originally intended for use in UNICEF procurement of Taras for the DPHE rural water program, its aim was to encourage and help interested manufacturers to undertake production of the Tara in Bangladesh. Because of the commitment of the UNDP-WB Handpumps Project and UNICEF to dissemination of the direct action pump technology, an international version of the manual has also been produced. This is being made available so that governments, development organizations, and manufacturers in other developing countries can either set up production of the Tara or develop their own version of the pump suitable for local needs. All aspects of the Tara design are freely available in the public domain; there is no copyright protection.

The Tara Production Manual contains detailed drawings and production details of every pump component. It includes appropriate international standards; descriptions of the materials, equipment, tools and processes needed to produce the component concerned; and critical checks needed to ensure adequate quality control. The manual is produced in a looseleaf format and is continually updated as design improvements are incorporated in the Tara specifications (see the final page of this report for further details).

Manufacturers

To date, manufacture of most Tara handpumps has been carried out at MAWTS, where the design was developed. Based on successful experience with the New No. 6 in Bangladesh and the India Mark II in India, UNICEF is helping Bangladesh to establish a nationwide network of prequalified manufacturers, who will be invited to tender for supply of Taras according to a rolling program.

The Tara Production Manual has been made available to any interested manufacturer, and by the end of 1988 six companies had passed UNICEF's prequalification criteria. The first invitation to tender, based on a planned order for 4,000 Taras, showed that competitive pricing will be an important feature in future procurement.

The recent bid price was a little higher than previous Tara orders, but the increase was accounted for partly by higher costs of raw materials and partly by the introduction of third party quality assurance inspections, which adds to production costs. UNICEF and DPHE are convinced that quality assurance is essential, and that the small extra cost is well justified by improved quality of components and hence fewer problems in the field.

In addition to establishing a network of manufacturers of the complete Tara pump assembly, smaller enterprises are expected to develop markets for regularly needed spare parts, such as leather cup seals and this will be encouraged so as to ensure easy availability and low costs for such items. An approval system is needed to safeguard pump users from poor quality products.

Packaging

Once manufactured, the components of the Tara handpump still need to be delivered safely to the site. Lengths of uPVC pipe can easily become distorted during transport or storage, and there is always a danger of parts being lost or damaged en route. The Tara design team wanted to ensure that all pump components reach the site safely and devised a comprehensive packaging specification to achieve that goal. The declared objective of the specification is to ensure that all parts arrive in a sealed package with a guarantee that the contents are complete. In addition, the packaging forms a rigid unit to minimize bending of pipes during transport or storage.

The packaging specification includes a full listing of pump components with detailed instructions on protective wrappings for each. For the piston assembly, for example, the instruction reads ".. to be dusted with chalk powder and covered with polythene bag (3" x 8" x 0.6). Bag to be sealed onto uPVC pump rod with adhesive tape (2" wide plastic)." A drawing illustrates the instruction. Further instructions specify the way to pack two modules together, and the outer wrapping is specified as five-ply corrugated cardboard with jute backing, a waxed external surface, screen printing on the ends of the two boxes, and 1/2" wide x 28 gauge metal straps securing each carton.

6. The Tara Abroad

As news of the Tara development has spread among those involved with low-cost water supply, it has become apparent that there is a need for similar low-cost direct action handpumps in a number of other developing countries. Investigations are under way into ways of introducing Tara-based designs in Asian, Latin American, and African countries.

Meanwhile, the first actual implementation of a program based on the Tara design has started in Bolivia.

A Case Study from Bolivia

Project setting

In Bolivia's Altiplano region (the departments of La Paz, Oruro, and Potosi), most of the rural population live in dispersed small settlements of only a few houses. Coverage of safe drinking water supplies is low. The main occupation is subsistence farming, and the capacity to pay for water is therefore limited.

The groundwater depth ranges from 3m to 10m and soil conditions are such that hand-dug wells are possible. The conditions are therefore appropriate for consideration of a low-cost direct action handpump as a means of providing safe water.

Evaluation of pump types

Bolivia is one of the countries in which the UNDP-WB Handpumps Project has been conducting field trials of different types of handpumps. One aim of such trials is to recommend models suitable for local manufacture. The field trial results were presented at the first National Conference on Handpump-Based Water Supplies held in Oruro. This conference endorsed the VLOM concept, including local handpump production.

One of the conference conclusions was that Bolivia should make a concerted effort to start production of a direct action drinking water pump with a maximum lift of 10m. During the UNDP-WB Handpumps Project field trials, Tara pumps imported from Bangladesh created great enthusiasm among users and local engineers; so much so that a local derivative, the INTI pump, was produced. Unfortunately, this early effort lacked a professional approach, and the INTI had problems with bad workmanship and inadequate design adaptation.

After the conference, the UNDP-WB Handpumps Project agreed to assist a local manufacturer in setting up production facilities for the Tara pump. The Swiss Centre for Appropriate Technology (SKAT) conducted a survey of small-scale industries which showed an interest in handpump manufacture. Discussions were also held with prospective pump users to assess the potential market. The conclusion was that the technical capability to produce direct action pumps was available in the country, but considerable inputs in training of personnel and introduction of appropriate production engineering processes would be necessary.

The UNDP-WB Handpumps Project established close collaboration with the Oruro-based company CASAM to set up production of a Tara-based pump. An immediate name change was needed though — in the local language, "Tara" translates as "lazy old bum." Not surprisingly, the Bolivians preferred a more marketable name, and the pump acquired the name "Yaku," meaning "water." At the same time, plans were made for production of a pump based on the Rower, which was given the local name "Remadora."

Tara interest spreads

In addition to Bolivia, several other countries have expressed an interest in demonstrating the Tara pump technology in their rural water supply programs, and the number of requests is increasing. In most cases, an initial successful demonstration has been followed by requests for more Taras from Bangladesh. It is apparent that the Tara will serve a useful purpose beyond its benefit to Bangladesh by providing the basis for several standard low lift pump designs. Countries which have so far initiated trials of production Taras are:

Country	*Number of pumps received*
Burma	120
China	10
Fiji	1
Guatemala	120
India	190
Indonesia	20
Nepal	120
Nigeria	5
Pakistan	100
Sri Lanka	25

Technical assistance

SKAT provided technical assistance to CASAM in four fields.

- **Design adaptation.** The two types of handpumps were altered to meet local conditions. Choice of materials was based on local availability of raw materials, production facilities available at CASAM, and the skills needed. Installation methods and operating conditions in rural areas of Bolivia also influenced the design adaptation selected.
- **Specifications.** As with the Tara in Bangladesh, once the design was finalized and prototypes had been tested, a detailed specification was drawn up for every component, and assembly

details, installation requirements, testing specifications, performance standards, and packing requirements were spelled out.

- **Production engineering.** Though the design of Tara-type pumps is based on simple technologies, it does involve a wide range of different production processes. SKAT employed an experienced Bolivian engineer to assist with the tooling-up for some of the production processes previously unknown to CASAM. The engineer visited Bangladesh to familiarize himself with production and quality control measures on the Tara before implementing manufacture in collaboration with the CASAM management. As well as mastering the new manufacturing processes, new management procedures were necessary that involved production planning, raw material procurement, production cost calculation, placing of orders with subcontractors, supervision of delivery schedules, financial management, and quality control.
- **Extension and promotion.** Alongside the production work, motivation of local communities and training of users in community-managed maintenance was given a high priority. A village level education program starts before the pump is installed. It employs *extensionistas* — female extension workers recruited in the villages, and includes health and hygiene education as well as user training.

7. Conclusions

Development of the Tara pump, from a novel design concept to a finished product adopted as a national standard pump for Bangladesh's large rural water supply program, is a success story of the International Drinking Water Supply and Sanitation Decade, of which the Government of Bangladesh, the United Nations family and member governments can be proud. It is instructive to examine the set of circumstances which enabled so many organizations and individuals of diverse backgrounds and interests to work together successfully.

Perhaps the most important ingredient for success was that time constraints were not forced on the development exercise. This created a working environment in which carefully planned and thoroughly tested design development became the focal point. Another important feature was that design team members were full-time employees of organizations engaged in other activities in the water supply and sanitation sector. This brought to the team a richness of feedback from the field, from implementing agencies, and from the end users.

Finally, the design team was not formally constituted or bureaucratically encumbered. Instead, productive intercolleague relationships were established and nurtured through several years, even as some members left and others took their places.

While intensive field monitoring has demonstrated that Tara pumps are performing satisfactorily in the field, design refinements are still being evaluated and demonstrate the continuing process of improving and adapting the pumping technology as the environment changes, new insights become available, and new technological processes come on stream in Bangladesh. New developments are not likely to be adopted, however, unless they are compatible with the present proven system.

The establishment of improved processes of development and evaluation is a legacy which is arguably as valuable as the Tara handpump itself. This legacy includes:

- A deliberate and orderly process of introducing changes into the pump specifications;
- Introduction of quality control requirements of manufacturers and quality assurance inspections to buyers;
- Regular field monitoring and feedback to the management of the rural water supply program; and
- Establishment of complete local manufacture of the Tara pump and all the other components of an on-site water supply system.

The Tara Support Package

To facilitate the wide-scale utilization of the Tara handpump for community water supply in Bangladesh and the expansion of its role in low-cost water supply in other countries of the world, a Tara handpump support package is under development. This package will include:

- Tara Production Manual	Available from UNICEF
- Tara Pump Use and Maintenance: Video Documentation	Available from the UNDP-World Bank Program
- Tara Installation Manual	Available from UNICEF
- The Tara Handpump: The Birth of a Star	Available from the UNDP-World Bank Program
- Tara Caretakers Training Package	Under preparation by the UNDP-World Bank Program
- Tara Pump Performance Monitoring System	Under development by the UNDP-World Bank Program
- Tara Pump Maintenance Slide and Sound Module	Under preparation by the UNDP-World Bank Program

For further information regarding the Tara support package please contact:

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