SUSTAINABLE GROUNDWATER IRRIGATION TECHNOLOGY MANAGEMENT WITHIN AND BETWEEN THE PUBLIC AND PRIVATE SECTORS

Guidelines of good practice, based on the experiences of Bangladesh and Pakistan

Principal author: David Sutherland [dcsutherland@wsatkins.co.uk]
Project manager: Peter Howsam [p.howsam@cranfield.ac.uk]

GUIDELINES

Findings of DFID funded research project (R6877) on 'Technology Transfer and Sustainable Rural Development' to develop guidelines of good practice for (a) technology transfer in relation to the full or partial transfer of tubewell irrigation from the public to the private sector, and (b) associated rural development, 1997-1999.

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1. INTRODUCTION

These guidelines have been prepared in fulfilment of a UK Department for International Development (DFID) research project (R6877) based in the UK, Bangladesh and Pakistan.

The Goal of the project is the "improved availability of water for sustainable food production and rural development". The Purpose of the project is "To facilitate the optimisation of technology transfer, community involvement and beneficial rural development in the transition from public sector/central government to private sector/'local' authority/rural community run tubewell irrigation".

These guidelines draw primarily from experiences in Bangladesh and Pakistan. They result from literature surveys and from interviews, field visits and questionnaire surveys. A large range of wells have been looked at, from those still under complete government ownership and management to those totally developed, owned and managed under the private sector. In addition, information has been used from other countries in South-East Asia, primarily India, where appropriate to this study.

2. GUIDELINES' STRUCTURE

The output is presented in two volumes (see Box 1). Volume I is a background document which includes an introduction, useful reference information in support of the guidelines, and wider conclusions and recommendations from the research carried out for this project. Volume II (this volume) contains specific guidelines for technical feasibility, affordability and manageability.

Volume I is designed to be an office based document covering wider policy issues and more general guidelines, whilst these guidelines (Volume II) are designed to be more for use in the field.

Box 1: Structure of the Guidelines

VOLUME I - REFERENCE MANUAL		VOLUME II - GUIDELINES
Introduction Technical Feasibility Affordability Manageability Associated Rural Development Conclusion and Recommendations References	⇔	Introduction Technical Feasibility Affordability Manageability

In Volume II, where specific guidelines are presented, they will, where appropriate, take the form of subject, context, risks, benefits, guidelines, and target audience. These components of the guidelines are explained below.

2.1 Subject

The guidelines are presented with the approach that there are four main themes which need to be considered in the successful development and management of groundwater irrigation. These are technical feasibility, affordability, manageability and associated rural development benefits. Whilst many of the subjects dealt with in these guidelines fit discretely into one or other of these themes, there are overlaps between the themes and these are dealt with as they occur.

2.1.1 Feasibility

Feasibility includes:
- technology
- environment

The feasibility of groundwater irrigation technology refers to the technology itself and its efficiency and efficacy within the environment in which it operates.

Technology

The main technology components of any groundwater irrigation scheme are the pump, motor, well and conveyance system. The options available under these three categories can be interchangeable but more often than not there is a link. For example, a shallow tubewell will almost always have a suction mode pump operating with an unlined canal for distribution, whereas a deep tubewell will usually have a force mode pump in operation with a combination of lined and unlined canals or buried pipe systems for distribution. Indeed the pump technology required (for given aquifer conditions) is what usually determines the type of well used. The prime movers for all wells are either diesel or electric powered, varying in horse power depending on the depth from which water is being pumped. The guidelines concentrate on mechanised groundwater irrigation, providing only brief suggestions for manual powered pumps.

The 'Technical Feasibility' Guidelines provide definitions of the technology types in Bangladesh and Pakistan.

The guidelines cover technology specifications, and various methods of technology installation, operation, management and replacement both in isolation and in matching technology to the environment in which it operates.

Environment

The environment in which the technology operates varies greatly within and between Bangladesh and Pakistan and the environments have important implications for the selection, operation, management and replacement of groundwater irrigation technology.

Among the key environmental features which have an influence upon appropriate matching of technology are static water level, topography, climate, groundwater quality, soils, and cropping systems. Each of these can have impact on the feasibility of given technology choices and operation methods.

2.1.2 Affordability

Affordability includes:

- costs
- cost-recovery
- financing

The affordability of groundwater irrigation technology refers to the costs of irrigation (purchase, replacement/change and O&M costs), to the adequacy of cost recovery through water use and water selling, and to the financing of groundwater irrigation.

There are many decisions to be made when selecting or taking over technology, many of which may not be taken into account currently. The guidelines attempt to illustrate clearly that when buying new technology the cheapest capital option is not necessarily the most cost effective in the medium to long term. The economic performance of groundwater irrigation technologies varies considerably according to the management of the technology and the environment in which it operates. A lack of capital resources may appear to restrict the choice to the cheapest available. Therefore, methods are considered, by which greater capital can be made available, individually or through groups, to purchase the most efficient and economic technology or take over the technology and run it in the most economic manner.

The guidelines examine costs of technology, from purchase, through operation and maintenance, management and replacement. Issues such as credit availability, rates, use and pay-back are considered. Trade within the market place in technology exchange and organisational issues are examined. In addition, approaches to, and methods of, water selling and cost recovery in a variety of circumstances are given close attention. There are many examples, throughout Bangladesh and Pakistan, where cost-recovery on single wells or groups of wells, is either successful or very poor. Reasons for both levels of performance are examined.

2.1.3 Manageability

Manageability includes:

- management system
- type
- scale
- effectiveness

The manageability of groundwater irrigation technology refers to the management system for the technology, its type, scale and effectiveness in satisfying the needs of water sellers and water users or buyers.

Manageability refers mainly to those wells which are owned/managed by groups rather than individuals, such as the DTWs in Bangladesh and the SCARP tubewells in Pakistan. In these cases there are often many owners/managers and large numbers of users over a wide area. There are many examples of good and poor well performance as a result of management practices from both countries. The contexts within which these management practices have succeeded or not are examined and reasons contributing to success or otherwise are suggested.

These examples of management practices are taken from both public and private sectors and the inter-changeability of these practices between sectors is examined.

2.1.4 Associated Rural Development Benefits

Associated rural development:

- direct
- indirect
- women
- communication

The associated rural development benefits are those which may be gained from the successful operation of groundwater irrigation technology (see Box 2). There are rural development benefits which may be gained directly from successful operation of groundwater irrigation technology. The direct benefits include increased food production and employment, and, hence, income, leading to an improvement in clothing, nutrition, health and education. Another direct benefit, where achievable, is drinking water during the drier months of the year.

However, there are also many indirect but associated benefits which may accrue from successful groundwater irrigation and the decisions and management developed to achieve the success, particularly where management is to be by a group. These include: working as a group to finance and manage technology, increased confidence in agriculture, and dealings with outside individuals and agencies. The indirect benefits may be taken beyond irrigation and irrigated agriculture into other spheres of the water sellers or buyers life. Many of the examples of this are taken from work done by NGOs in Bangladesh and Pakistan in irrigated agriculture and wider areas of rural and community development.

Box 2: Rural development benefits associated with successful groundwater irrigation

Irrigation status		Direct benefits		Indirect benefits
Technically feasible Affordable Manageable	➡	Increased crop/food production Employment (in agricultural and non-agricultural sectors) Income Education Clothing Nutrition Drinking water Health	➡	Market awareness Group awareness Financial management Increased confidence Development of the non-agricultural sector Taken into all walks of life

MULTIPLIER EFFECT ➡ ➡ ➡

The role of women in the groundwater irrigation markets and in irrigated agriculture in general, and the benefits which may be provided for them will also be looked at in some detail.

The 'Associated Rural Development' Guidelines also look at ways of communicating information to potential beneficiaries, owners and/or users.

2.2 Context

For each of the subjects covered in the guidelines, different contexts under which they may occur or by which they may be influenced have been identified.

There are many examples where no one context can be looked at in isolation and where one context can have an impact on other contexts. For example, the reliability and continuity of electricity supplies where electric pumps are used has a major impact on social cohesion. When electricity is in short supply, great pressure is put on relationships within the command area. Many wells where co-operation between farmers is most evident have diesel powered pumps or electric pumps in areas where electricity supply is reasonably reliable. Reducing pressures on co-operation is a key issue for the guidelines.

2.3 Risks

Where appropriate for the subjects covered, in addition to the contexts given, there is information on the risks and benefits involved with each subject matter. Groundwater irrigation, whether it is in the hands of the public or private sector, involves elements of risk. The transfer of irrigation from the public to the private sector also involves risk. Taking on a capital asset in an unpredictable environment cannot help but have risks attached. Therefore, for each subject or function details are given on the nature and scale of risk and for whom (people or organisations) or what (technology or environment) the risk is present.

2.4 Benefits

As with risks, many of the guidelines' subjects have benefits for certain people, or groups of people, or for the technology or environment in which it operates.

Where appropriate for subjects covered in the guidelines, an indication of the nature and scale of potential benefits is given, along with identified beneficiaries.

2.5 Guidelines

Where appropriate for subjects listed in the guidelines, specific guidelines are given on ways in which the subject should be handled for the given contexts, and ways in which risks may be minimised and benefits maximised. These guidelines are, on the whole, universal except where certain contexts or situations are stated.

2.6 Target audience

The guidelines will be disseminated to a variety of organisations for which the guidelines should be a useful reference document or source for training materials. Not all organisations will be interested in, or require information on, all subjects in the guidelines. Therefore, for many subjects, those types of organisations for which the particular guidelines will be of use, or from whom further information on the guidelines should be sought, are shown. In addition, recommendations are made, where appropriate, for where such information could or should be made available.

GUIDELINES - TECHNICAL FEASIBILITY

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1. INTRODUCTION

The feasibility of groundwater technology as it is transferred to, or developed within, a particular sector is determined by the specifications, attributes, and practical management of the technology, and the physical environment in which it operates. The technical component of the guidelines is concerned primarily with ways of improving the quality and performance of existing technology and making suggestions for technologies or ideas which may be new to many.

2. SUCTION MODE TECHNOLOGIES

These guidelines are based on observations from work carried out by the National Minor Irrigation Development Project in Bangladesh, Enercom in Pakistan, and Tushar Shah and Frank van Steenbergen in India. In addition, issues have been identified during field surveys and meetings with well owners, farmers and distributors in Bangladesh and Pakistan.

2.1 Well Installation

Installation of the STWs is a relatively simple and inexpensive operation, using hand dug and/or manually operated percussion rigs, and it is not intended to go into this in detail in these guidelines. There are, however, a few points concerning practices which can reduce well resistance (often in the region of 13 -22 feet) and increase the viability of groundwater irrigation for marginal entrants to private sector water supply. See Boxes 1 to 4 for details.

2.2 Well Modification to Extend Operation Limits for Suction Mode

The main form of well modification in Bangladesh and Pakistan is **deep setting** of wells. This section summarises the reasons for, and specifications of, deep set wells in Pakistan and Bangladesh. Diagrams of typical unlined and lined deep set wells from Bangladesh are shown in Boxes 5 and 6 (with March 1997 prices).

Deep setting can be seen as a legitimate solution in areas where the static water levels are below suction limits throughout the year but in areas where pits are used for only part of the irrigation season they could be seen as a failure in effective water management for the early part of the irrigation season.

Deep set wells are constructed so that suction mode technologies can access water from greater depths. With a suction limit of 21 feet suction for most pumps, if water is required from greater depths, without changing to expensive force mode technologies, then the traditional answer is to lower the pump below the ground surface, in a pit. Pit construction requires only labour and materials (e.g. bricks or reinforced concrete) which are cheap. Therefore, deep setting of wells is usually a cheaper option than a change to more expensive force mode technologies.

Selection of materials

The main physical components of a well, which enable groundwater to be pumped to the surface are the gravel or sand pack and a screen.

A gravel or sand pack may be created (natural) or put in (artificial) to "...produce an envelope of material with enhanced permeability and physical stability adjacent to the screen. The enhanced permeability reduces well losses and incrustation of the screen and the physical stability reduces the amount of sediment drawn into the well by pumping." (Clark, 1996, p.21)

Box 1: Selection of materials for wells - 1

Feature:	**Good practice in selection and use of materials for gravel or sand pack**
Contexts:	In many cases a gravel pack is not used. Physical contexts on alluvial aquifers determine that in many cases there is little artificial gravel pack material available. Where it is used, material is usually prepared by the drilling company/ individual with no scientific method for gravel pack selection.
Risks:	1. Without an effective 'envelope' around the well, clogging of the screen and sand pumping are significant risks. 2. Many cases were observed where the gravel pack was less than 2" thick. Below 2" thickness the gravel pack is only an expensive formation stabiliser and does not act as a filter. (In theory a 0.5" would do but the problem is that it is very difficult to ensure placement in a narrow annulus.) 3. In the absence of a artificial gravel pack, screens with smaller slot sizes tend to be used and this (i) reduces the volume of smaller particles which can be pumped away, (ii) significantly reduces permeability, and (iii) reduces hydraulic efficiency.
Benefits:	An effective gravel pack enables screens with larger slot sizes which contribute, along with adequate open area, to hydraulic efficiency.
Guidelines:	1. In the absence of suitable materials with which to create an artificial gravel pack, it is extremely important develop the aquifer thoroughly post-installation to create the most effective natural gravel pack possible (see 'Aquifer development' below for details). 2. Proper aquifer development will only be effective if the slot sizes in the screen are sufficiently large to allow the smaller material through. The temptation to use smaller slot size screens should be avoided. In creating a natural gravel pack, the smallest 40% of particles around the well should be allowed to pass during development, leaving an annulus of coarse, more permeable material. 3. Artificial gravel pack selection and installation is a complex procedure which needs to be approached thoroughly. Where the decision is made to use artificial gravel packs, reference should, if possible, be made to well construction guides. For, example, the 'Field Guide to Water Wells and Boreholes' by Lewis Clark (1996) contains a thorough explanation of gravel pack selection and installation.
For whom:	1. Well construction companies are a key source for this information. Farmers should also be aware of the fundamental points so that they are able to ensure that the best possible gravel pack for their context is provided. 2. Possible conduits for information include Extension Officers, NGOs or credit institutions who could specify standards of service in well construction and development. It would be in the interests of the credit supplier to have a well operating at maximum potential to increase pay-back rate.

A well screen is used in formations which are unstable or liable to collapse. It prevents the formation from collapsing and also prevents formation material from entering the well, whilst allowing water to pass through into the well.

Box 2: Selection of materials for wells - 2

Feature:	**Good practice in proper selection and quality of materials, and slot size, for well screen**
Contexts:	Before construction of shallow tubewells. Material usually purchased either by the farmer or by the drilling company. Often in the context of what is available at the equipment supplies stores in the towns and villages. In Bangladesh and Pakistan, primarily PVC. In India, especially North Bengal, a selection from galvanised iron, brass, fibre glass, PVC or bamboo. Selection used made on cheapest available and easiest to transport.
Risks:	1. The screen is a crucial element of the well. Poor selection of materials, slot sizes, quality of slot cut can all have serious negative implications for well performance and profitability. 2. Slot sizes are often too small because of attempts to restrict the entry of aquifer material where gravel packs have not been properly developed. In PVC in particular slot sizes should not be less than 1 mm wide or they will be at significant risk of clogging. In India and Bangladesh slot sizes of less than 1 mm were frequently seen. 3. Where slots are saw cut the burs should be thoroughly cleaned from the slots otherwise the risks of clogging will be increased significantly. In many irrigation equipment supply shops in Bangladesh screens were seen where the slots had not been cleaned following cutting.
Benefits:	On the other hand, the right selection of screen can prolong the life of the well, reduce pumping costs, increase discharge and increase the profitability of irrigation. The correct choice in screen does not need to be expensive, just informed. Checking of small details can make large differences in the performance and life of a well.
Guidelines:	1. Think carefully about the materials, slot size and quality of well screen, even for small, cheap wells, the choice of screen can make large differences to the well. 2. Solutions do not have to be expensive. For example, in North Bengal in India, experiments have been carried out looking at the differences in cost and performance between PVC and bamboo/mosquito netting screens. Results were as follows: PVC pipe: Slot size: 0.2mm SWL: 3m Yield from 5hp pumpset: 7.5l/s Cost: Rs2400 Bamboo/net: Slot size: 1.0mm SWL: 3m Yield from 5hp pumpset: 12 l/s Cost: Rs1500 (Cost is for 10m depth in Indian rupees, 1997 prices) 3. Make sure that the slot size provides a sufficient ratio of slot to screen wall thickness - usually greater than 1 mm - otherwise screen will be likely to clog. 4. Make sure that the slots are cleaned and free from debris left after slot cutting. This will greatly reduce the risk of clogging.
For whom:	Primarily screen manufacturers, but small tips, such as cleaning the screen thoroughly could be given direct to farmers/drilling contractors.

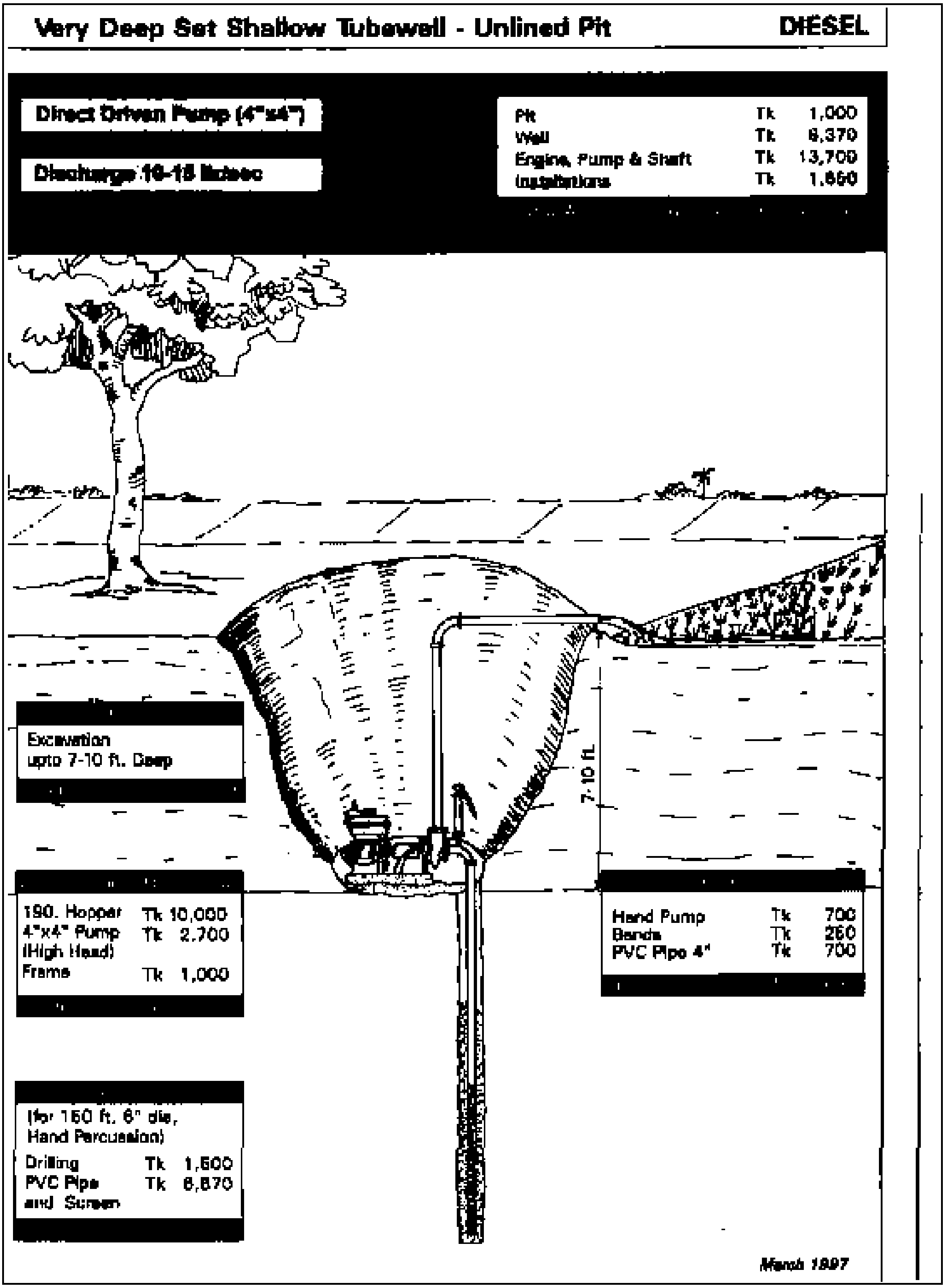
Box 3: Well development

Feature:	**Cleaning well following installation - particularly cleaning cow dung where used as slurry and stabiliser**
Contexts:	No specific geographical, economic or social contexts, general throughout Bangladesh and India. Used by private drilling contractors in the construction of shallow tubewells. Cow dung used as a matter of course by contractors, whether entirely necessary or not. Not generally used in Pakistan in their private tubewells.
Risks:	Difficult to remove by flushing alone, but even flushing alone is often not properly carried out (see aquifer development), and filter slots are blocked as a consequence, creating high well resistance and poor performance.
Benefits:	Increase in discharge and decrease in fuel consumption. Work in India (van Herwijnen and Ray, 1997) suggests that by flushing and jetting, discharge improves by 20% on average, with a consequent decrease of 20% in use of fuel
Guidelines:	1. Make sure that the formation in which the well is being drilled requires stabilising. In many cases stabilisers may not be necessary. It is also worth considering taking the risk of having to drill a second or even third well rather than use a stabiliser. In the long run this will be worth the extra time for the improvements in well performance. 2. If a stabiliser is required and cow dung is the only material available, then ensure thorough cleaning of the well. Methods available include surging, bailing, pumping and jetting. (see Clark, 1996 for details)
For whom:	1. Farmers are a priority. Field surveys suggested that many of the drillers were aware of the techniques required but did not complete the job adequately on time and money grounds. Farmers should be in a position to check that the work being carried out is correct. 2. Possible conduits for information include Extension Officers, NGOs or credit institutions who could specify standards of service in well development. It would be in the interests of the credit supplier to have a well operating at maximum potential to increase pay-back rate.

Box 4: Aquifer development

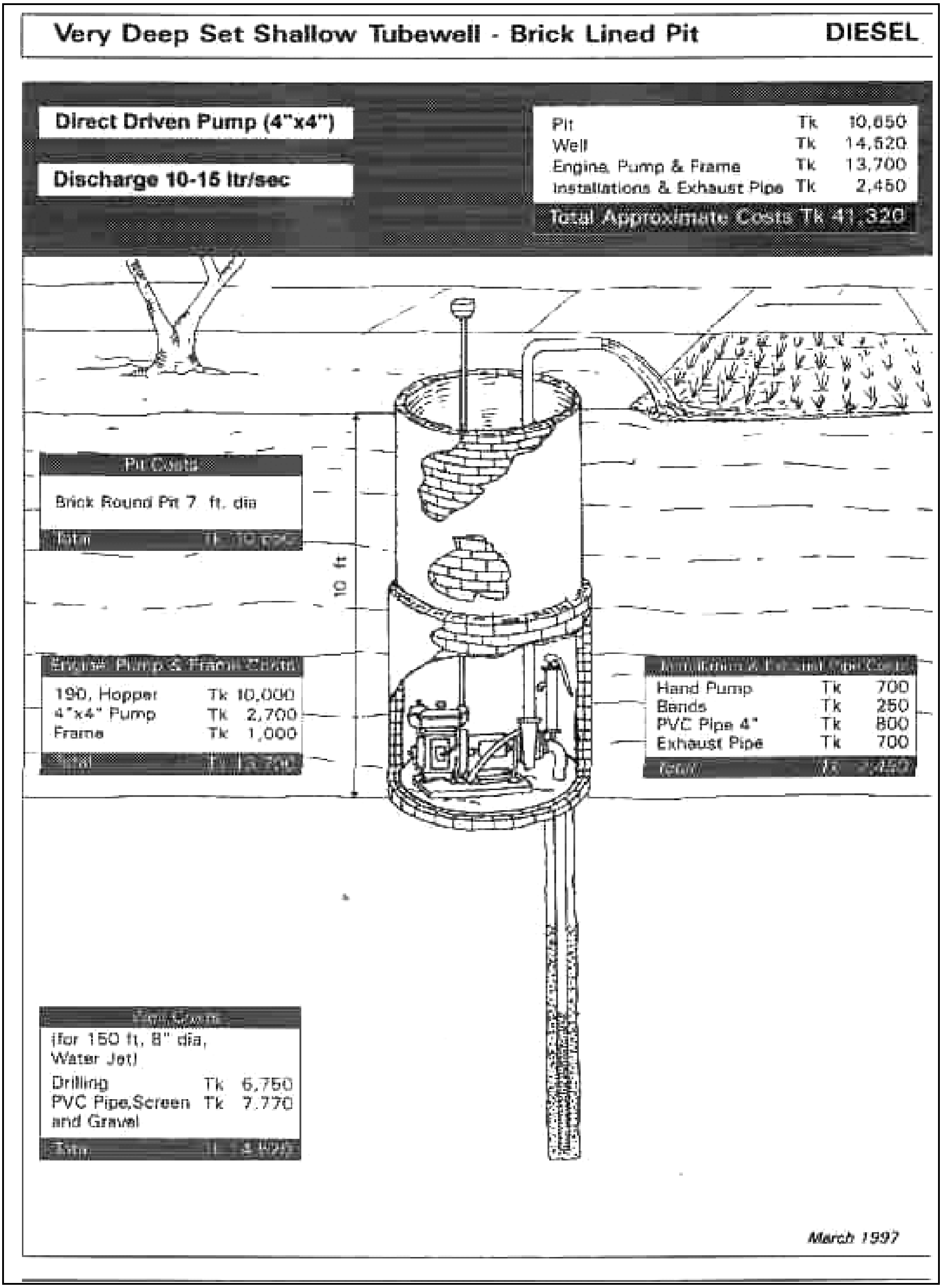
Feature:	**Developing disturbed aquifer around well - for natural or artificial gravel pack.**
Contexts:	No specific geographical, economic or social contexts, general throughout Bangladesh and India. Work largely carried out by private drilling companies with large workloads and sometimes unqualified technicians.
Risks:	Improper development of the well post-installation will lead to blockages in the aquifer wall where slurry or a stabiliser has been used. Even if slurry has not been used, the lack of development will lead to the non-removal of fines and increase the entrance velocity of water to the well. This can cause damage to the well screen.
Benefits:	Proper development of the well will increase the porosity and hydraulic conductivity around the well and reduce the velocity of water entering the well. The stresses on the well are therefore reduced and performance and longevity increased.
Guidelines:	1. As a minimum the well should be pumped continuously for 12 hours during development with an engine with 50% greater horse power than that which will be used for irrigation. 2. The well constructor should provide his own engine and pump to develop the well. This is to prevent damage to the farmer's equipment whilst fines are being removed. This risk should be incurred by the driller within the charge for well construction. Many cases in Bangladesh were observed where the farmer's own new engine and pump were being used. This can damage the farmer's equipment even before it is used for irrigation and also does not enable development of the well at 50% greater horse power.
For whom:	1. Farmers are a priority. They should be able to know these facts and ensure that this is carried out as part of the construction process. 2. Possible conduits for information include Extension Officers, NGOs or credit institutions who could specify standards of service in well development.

Box 5: Methods of Very Deep Setting (Unlined) of Wells in Bangladesh



(after NMIDP, March 1997)

Box 6: Methods of Very Deep Setting of Wells (Lined) in Bangladesh

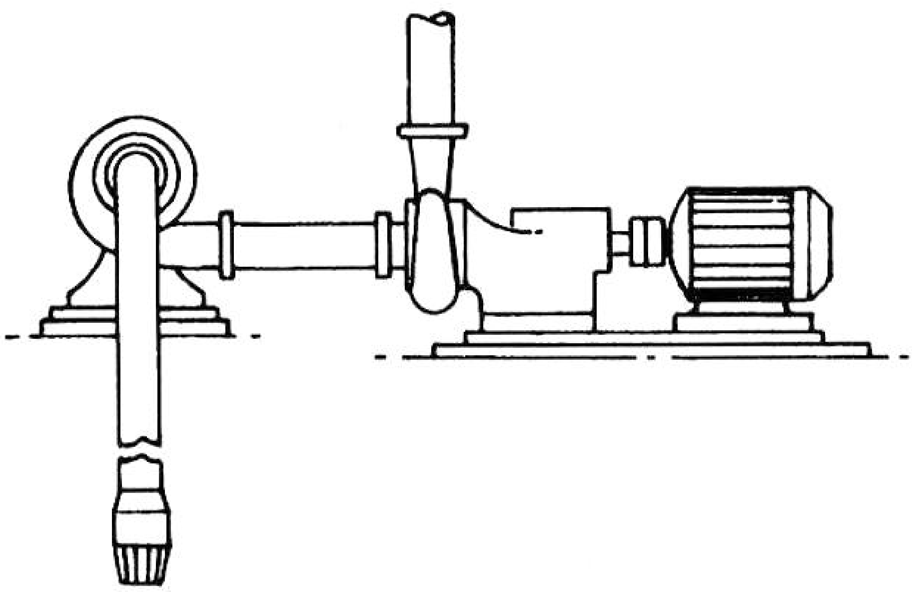


(after NMIDP, March 1997)

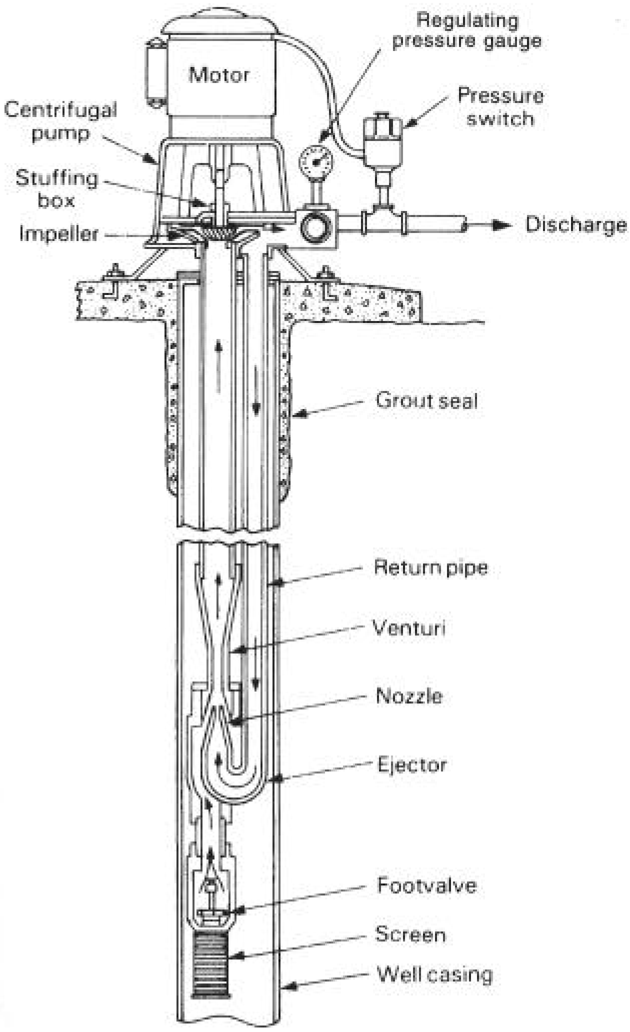
2.3 Other Methods for Extending Suction Mode Pumping Limits

Two main methods could be seen as practical for Bangladesh and Pakistan. One method is to use two suction mode pumps in tandem. Using them in series increases the total operating head and using them in parallel increases the total discharge. Another is to modify the inlet and outlet pipes of the pump to create a borehole jet pump installation. Details and explanations are provided in Boxes 7 to 9 below.

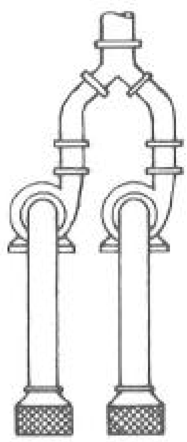
Box 7: Increasing operating head - 1

Feature:	**Two suction mode pumps in series**
Contexts:	1. Where water levels out of range of 21 ft suction limit. 2. Where cost of lined pit is greater than cost of second pump and engine/motor. Where land is extremely important for agricultural production. 3. Where a water seller or pump owner wants to irrigate at more than location. 4. Where need for greater head is for only part of the season.
Risks:	1. Double the pumping costs, more technically complex - mechanics may need training. 2. If much greater depths required, then unlikely to be able to get two pumps in the pit - though one in the pit and one on the surface could be a possibility.
Benefits:	1. Head is doubled with no loss in efficiency (provided second pump of the same standard as the first) or discharge. Therefore, heads up to 50 ft would be obtainable. 2. Second pump and prime mover available as back up for rest of irrigation season in case of major breakdown to first pump set.
Guidelines:	1. When pumping required for water levels beyond suction limit, consider options of pit against second pump set. 2. If land area of extreme importance, mobility of pump set currently or potentially reuired, or second pump set cheaper than pit, consider purchase of second pump set.
For whom:	Farmers, product manufacturers, traders/distributors, mechanics, NGOs.
Examples:	 (after Fraenkel, 1997)

Box 8: Increasing operating head - 2

Feature:	**Borehole jet pump installation**
Contexts:	1. Where water levels out of range of 21 ft suction limit. 2. Where land is extremely important for agricultural production. 3. Where pits are not an option and force mode is too expensive.
Risks:	Efficiencies are low and discharge is reduced as some of the outflow needs to be recycled.
Benefits:	1. Maximum lift of a jet pump is 80 ft, although about 50% of the discharge needs to be recycled to achieve this. 2. A workable solution where no other suction mode options are feasible and where force mode technologies are too expensive. 3. The design is simple and relatively cheap and it is easy to use.
Guidelines:	1. The jet pump operates by returning some of the discharge to the rising main under pressure. The high velocity of this returning discharge through a narrow nozzle reduces pressure in the rising main and water from the well is sucked up through a venturi (widening pipe). 2. The ejector nozzle should be covered at all times by at least 5 ft metres of water. 3. Should only be used as a last resort since efficiencies are low and, hence, fuel consumption is relatively high. 4. Prime use at present in both Bangladesh and Pakistan is for domestic water supply where direct into supply discharge is not so important because of storage.
For whom:	Farmers, product manufacturers, traders/distributors, mechanics, NGOs.
Examples:	 (after Fraenkel, 1997)

Box 9: Increasing discharge

Feature:	**Two suction mode pumps in parallel or more than one well per pump set**
Contexts:	1. Where greater discharge is required than can be provided by one suction mode pump. 2. Where higher discharge force modes are too expensive.
Risks:	1. If both rising mains are to be in the same well, then the diameter of the well needs to be increased accordingly. This may cause difficulties in installation by inexperienced well technicians. Well components such as screen and rising main may not be available at an affordable price. Components with larger diameters may be available from force mode installation companies but may be expensive. 2. The volume of water produced by the aquifer may be the constraint upon discharge and if this is the case then increasing the suction may damage the well.
Benefits:	1. Where the aquifer can sustain the increased demand then this is a relatively cheap way of increasing discharge. 2. Discharge is not doubled because the increase in flow usually results in an increase in total head but a considerable improvement in discharge is achievable. 3. Greater discharge can be achieved without increasing the horse power of current prime movers or increasing the speed of the prime mover. Increasing the speed of the prime mover puts pressure on the pumping system, increases the risk of breakdown, and shortens the life of the pump set.
Guidelines:	1. It is very important to establish whether restrictions on discharge are because of aquifer constraints or pumping power constraints. Increasing the suction on an aquifer that cannot safely yield greater discharge will only damage the well. 2. In some cases in the Ukia district of Bangladesh where aquifer yield is low one pump is used to extract water from four very deep set wells to increase discharge. These four wells yield approximately 0.5 cusec. (Also in Ukia, there was an example of where three low discharge submersible pumps were also installed. The yield from all seven of these wells is 1 cusec).
For whom:	Farmers, product manufacturers, traders/distributors, mechanics, NGOs.
Examples:	 A (after Fraenkel, 1997)  B (One pump, from two pipes from four STWs)  C (Discharge from three submersibles and the STW combination shown in B)

2.4 Pump manufacture and selection

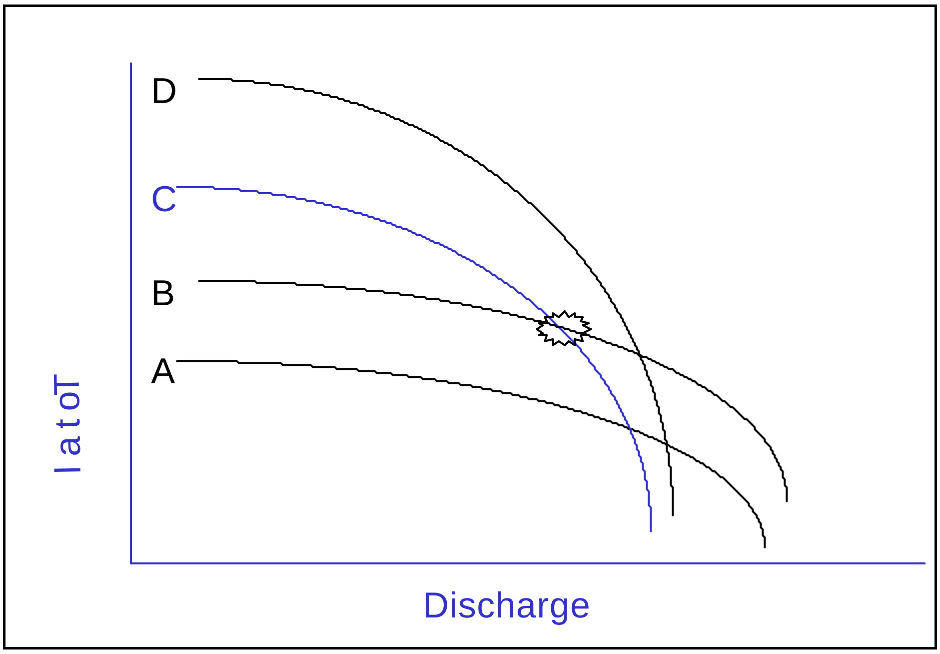
The difference in performance (and hence profitability) between a pump with a steep head/discharge curve and one with a shallow head/discharge curve is considerable.

Observations from site visits and literature reviews indicate that there are several shortcomings in the standards of pump manufacture and selection. All pumps perform to a certain standard and should, in theory, have their own pump performance curve. The pump performance curve is a function of discharge and head. For different heads against which the pump is operating, different discharges may be achieved. The greater the head against which the pump is operating the less the discharge available for any given power input. To maintain discharge as head increases greater power (and cost) is required. The main importance of the pump performance curve is where static water levels change significantly during the irrigation season, or where pumping takes place against higher heads.

The 'duty point' is the discharge/head point at which the pump will normally be operating (Kay, 1998). In Box 10, of the four pump performance curves and duty point shown, Pump C would be the best choice. Pump B would suffice if it was a lot cheaper but it is close to the top of its performance curve. Pump C would be much the better option if water levels were to fall and total head was to increase. Guidelines on pump performance curves are shown in Box 11.

The selection of materials is important for pump quality and longevity. The relative merits of different materials for pump components are shown in Box 12.

Box 10: Examples of pump performance curves



Box 11: Pump manufacture and selection

Feature:	**Pump performance curves - head against discharge**
Contexts:	Anywhere suction mode technologies are in use. Particularly important in areas with significant changes in static water levels during irrigation season. For example, Bangladesh, where static water levels may fall by 5 metres during the irrigation season. Many pumps made simply and imprecisely and are prone to reduced performance when put under stress. Often no knowledge about pump performance curves for any of the suction mode pumps.
Risks:	In areas where static water levels increase during the irrigation season, an inappropriate pump selection may lead to a serious loss of discharge and loss of yield/crop/command area later in the irrigation season. Pumping costs will increase with a wrongly selected pump. Higher HP engines may be used to increase discharge, again with higher costs, but which may also damage the well.
Benefits:	Where the correct technology for the conditions is selected the costs savings over an irrigation season can be reduced significantly. In addition, the length of life for the equipment is likely to be increased. The locally made pump itself, for suction mode technologies, is the cheapest component but correct selection of pump can increase the life of the whole well, particularly where it means that higher horse power engines do not become a perceived requirement.
Guidelines:	1. Where possible, pumps should be tested and pump performance curves created by manufacturers for use by suppliers and farmers. Companies that produce relatively high performance pumps should see the development of these curves as a good marketing tools. 2. When these head/discharge curves are converted into head/cost curves the elasticity of performance and implications for costs can graphically persuade farmers that a little bit more money on the better quality models of the cheapest component of the well system could lead to significant cost savings. Farmers are well aware of the impact of the fall in static water levels (many interviewed in the field were asking for information on SWLs in their locality) and these graphs should make sense and provide a clear message to the users. 3. Farmers should look for curves which have the least change in discharge for change in head.
For whom:	1. Pump manufacturers are a priority, particularly those who produce better quality pumps. This should be pushed as a powerful marketing tool. Until manufacturers produce this information there is no urgency in informing the farmers, unless it was to encourage the farmers to press for a response from manufacturers.

Box 12: Relative merits of materials for pumps

Material	Strength	Corrosion resistance in water	Abrasion resistance	Cost	Typical application
Mild steel	High	V. Poor	Moderate to Good	Low	Shafts, pump rods, nuts & bolts, structural items
Cast iron	Moderate	Moderate	Moderate to Good	Low	Pump casings
Stainless steel	High	V. Good	Good	High	Nuts & bolts, shafts, Impellers, wet rubbing surfaces, valve components
Brass	Moderate	Good	Moderate to Good	High	Impellers, pump cylinders, wet rubbing surfaces
Bronze/gun metal	High to Moderate	V. Good	Moderate to Good	High	Impellers, pump pistons, wet bearings & rubbing surfaces, valve parts
Phosphor bronze	Moderate	Good	Good	Moderate to High	Plain bearings & thrust washers
Aluminium & light alloys	High to Moderate	Moderate to Poor	Poor	Moderate to High	Pump casings & irrigation pipes
Thermoplastics PVC, polythene	Moderate	V. Good	Moderate to Good	Moderate	Pipes and components
Thermoplastics Filled plastics & composites	High to Moderate	Generally Good	Moderate to Good	Moderate to High	Pump casings, components, bearings

(after Fraenkel, 1998)

The engine selected should match the energy requirements for water extraction and the capacity of the pump.

2.5 Engine manufacture and selection

The issues relating to engine manufacture and selection are similar to those for the pump. The engine selected should match the energy requirements for water extraction and the capacity of the pump. Ideally, performance curves should be available for several combinations of pump and engine capacity. Often throughout the sub-continent engines with higher than necessary power inputs are being used.
There are a few improvements which could be made to the design and manufacture of the engines currently available in the market places in Bangladesh and Pakistan to improve fuel efficiency in particular. Foremost among the improvements is to reduce the speed of the engines and to improve the water pumps in the engines. The high speed models use more fuel than performance warrants. The water pumps are often absent from the engines, or if not absent, not in good working condition. See Boxes 15 to 17 for details.

2.6 Procedures for selecting prime mover power requirements

There are two procedures suggested below for selecting the most appropriate prime mover. One relates to aquifer conditions and one relates to irrigation water requirements. **It must be emphasised, however, that both procedures require information on pump and/or prime mover efficiency.** No accurate selection can be made without this information and creation of this information is strongly recommended in both Bangladesh and Pakistan.

2.6.1 Based on aquifer conditions

This method comes from work done by the National Water Management Plan in Bangladesh (NWMP, 1999) and considers the requirements for given discharge and groundwater levels, and for known pump and prime mover efficiencies. Theoretically, the hydraulic work done (measured as WHP) and the energy required can be calculated as follows:

$$\text{WHP} = \frac{\text{Discharge (l/s)} * \text{Total Head (m)}}{76}$$

$$\text{Input HP} = \frac{\text{WHP}}{\text{Pump efficiency} * \text{prime mover efficiency}}$$

2.6.2 Based on irrigation water requirements

A nomogram has been developed (Fraenkel, 1997) which in theory enables a reasonably simple analysis to be carried out to determine the most appropriate power requirements for pumping in any given situation. The procedure is explained in Box 13 and the nomogram is shown in Box 14 below, along with a worked example. Despite the lack of available data on pump efficiency (approximate figures could be used), the procedure will be illustrated as a quick and efficient way of deciding on prime mover energy requirements.

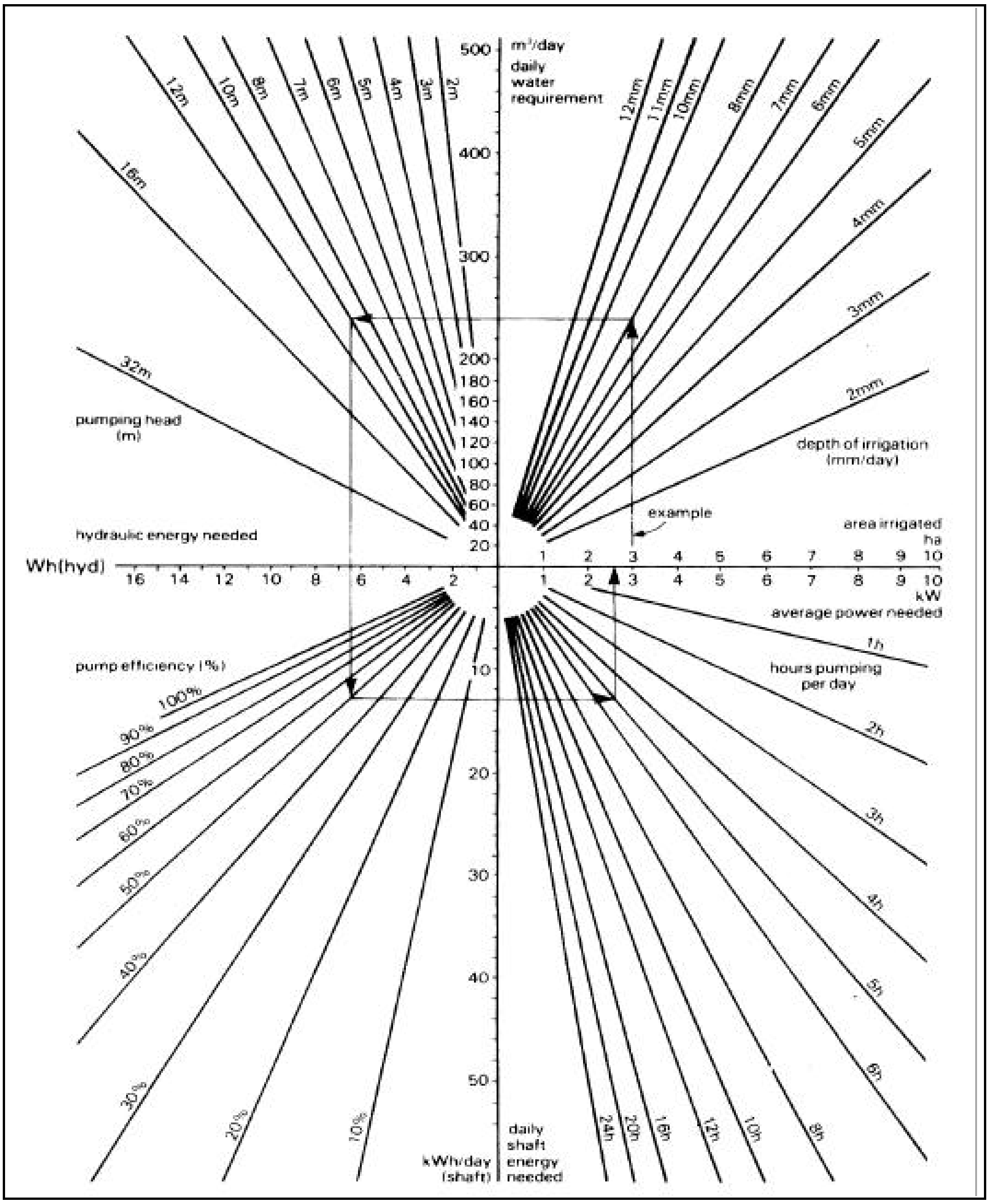
Although the nomogram works in metric units, it could be modified to suit local measurements (e.g. bigha instead of hectares, feet instead of metres)

.

Box 13: Process for assessing power requirements for groundwater irrigation

Step	Method for completing step	Nomogram example
Determine area to be irrigated (ha)	Estimate area of own irrigation plus area to which selling water - in hectares	3 ha
Determine average daily depth of irrigation (mm/day)	Estimate gross irrigation requirement (including conveyance and field losses). First estimate crop requirement: 1. Water depth required for crop season 2. Days of crop season 3. Total season water depth/days in the season Then account for: 1. Conveyance losses (typically 5% pipe system, 50% earth channel) 2. Field losses (for rice basin irrigation on clay soils typically 10%) Then calculate gross irrigation requirement: Crop requirement + conveyance loss + field loss = depth of irrigation to be provided in millimetres per day	500 mm say 100 5 mm/day say 50% say 10% 5 + 2.5 + 0.5 = 8 mm
Determine average pumping depth (m)	Estimate pumping water level, i.e. static water level plus drawdown, in metres	10 m
Determine pump efficiency (%)	This requires a full pump performance curve and would simply be read off the chart. Pump efficiencies generally range from 30-80% and it is likely that the locally roughly made pumps will be towards the bottom of this range, say 30-50%. An estimate of 40% would probably be acceptable.	50%
Determine average hours pumped per day over irrigation season	Estimate on average how many hours per day the pump will be used. The longer the pump is running without stopping, the better it is for the technology (stopping and starting puts strain on the technology), and the less will be the energy requirement.	5 h
Read off the average power needed	The answer is given in kilowatts (kW). The conversion factor to convert to horse power is 1.34. Therefore, for the example shown, the energy required is 2.6 kW, which equates to a 3.5 HP prime mover. However, ***it should be noted that the nomogram works on average figures. The maximum daily requirement for peak season is likely to be at least twice the average requirement.*** So an engine/motor of about 7-8 HP would be ideal.	2.6 kW

Box 14: Nomogram for calculating power needs for given area, depth of irrigation and head



(after Fraenkel, 1997)

2.7 Matching pumps to prime movers

Reviews of groundwater irrigation in Bangladesh (IIMI et al, 1995) and Pakistan (van Steenbergen, 1997) suggest that the process of matching pumps to prime movers is not an exact science. There are many cases in the IIMI survey of considerable over capacity in prime mover power. Many farmers interviewed reported that their solution to increasing discharge was to increase the horse power of their engine. This may produce greater discharge but at considerable risk of damage to the well. Matching prime movers to pumps is not a simple process and one for which their is little in the way of prescriptive information.

2.8 Pump operation

Common themes relating to pump operation are found in Bangladesh, Pakistan and India. Results from experimental work carried out in India (Jan Bom and van Steenbergen, 1997) have shown 50% improved fuel efficiency in diesel run pump. These steps are: increasing the temperature of the water coolant, reducing suction friction losses and reducing the speed of the engine (see Boxes 15 to 17). The total cost of these three steps was equivalent to just 70 running hours. Total fuel consumption was reduced from 1 l/h to 0.5 l/h with no decrease in pump discharge.

Box 15: Modifications to pump operation procedures - 1

Feature:	**Temperature of water coolant**
Contexts:	Anywhere suction mode technologies used, with cheap diesel engines in operation. Main problems occur when the engine is cooled directly using water direct from the well. There is often no water pump made for the cheap diesel engines and if there is they are usually not operational.
Risks:	Water temperatures direct from the well are largely in the region of 30-40^{o} C rather than 80-85^{o} C. The engine as a consequence is difficult to start, causing wear and tear and uses more fuel than necessary. Engine life is shortened and operating costs are increased.
Benefits:	Operating and replacement costs are reduced. Low cost modification.
Guidelines:	1. In India this problem has been overcome by fitting thermo syphon drum cooling units to the engine which raised water temperatures to 80^{o} C. This cheap technology decreased fuel consumption by 13% on average. 2. Where the above technology is not available, the simplest way of increasing water temperatures is to reduce the diameter of the water intake, so reducing the flow of water and allowing the temperature to increase. This is practised in some areas of Pakistan where problems in starting the 'cold start' engines have been encountered.
For whom:	Farmers, through extension agents, NGOs and equipment suppliers and mechanics.

Box 16: Modifications to pump operation procedures - 2

Feature:	**Hydraulic friction losses in the suction pipe**
Contexts:	Anywhere suction mode technologies are in use with suction pipes which include check valves.
Risks:	1. Higher operating costs through higher friction of water in pipe as it enters the pump. 2. Technical advice is preferable and may not be available.
Benefits:	Cheap and simple solution leading to a reduction in operating costs.
Guidelines:	Remove the check valve from the suction pipe, if one exists. In India, this step was found to decrease fuel consumption by 18% on average.
For whom:	Farmers, through extension agents, NGOs and equipment suppliers and mechanics.

Box 17: Modifications to pump operation procedures - 3

Feature:	**Engine speed**
Contexts:	Anywhere suction mode technologies are in use with an engine that is oversized (too great a horse power) for the needs of the particular well.
Risks:	1. Higher operating costs. 2. This is technical matter which requires a degree of technical competence. Incorrect modification may do more harm than good.
Benefits:	Cheap and simple solution leading to a reduction in operating costs.
Guidelines:	Reduce engine speed in engines that are oversized. In India a reduction in engine speed for a 5 HP from 1500 to 1100 rpm lead to a reduction in fuel consumption of 20%.
For whom:	Farmers, through extension agents, NGOs and equipment suppliers and mechanics.

3. FORCE MODE TECHNOLOGIES

There is no doubt that many of these pumps are technically feasible in most areas of Bangladesh and Pakistan. The prime concern with these technologies is their affordability and manageability. Therefore, the technical guidelines for these types of pump will be brief.

3.1 Well installation

Force mode technologies include submersible pumps (low or high discharge) and turbine pumps in DTWs. Very few new DTWs are being installed for irrigation in either Bangladesh or Pakistan since the end of the DTW and SCARP groundwater projects respectively. Therefore, these guidelines will not cover well installation, some of the main DTW types, contexts and reasons for use in Bangladesh and Pakistan are shown in the 'Reference Manual' - Technical Feasibility, section 4.1

3.2 Well rehabilitation

STWs are cheap to install and, if well performance deteriorates, the solution is usually to drill a new one. For DTWs, well construction is expensive and if the performance of the well deteriorates, then well rehabilitation recommended. Rehabilitation is the process of restoring the well to its original performance.

3.2.1 Identifying a problem

The need for rehabilitation will depend on the awareness of a deterioration in performance. The method of rehabilitation will depend on what is causing the performance of a well to deteriorate.

Deterioration in performance can be due to two main factors - aquifer losses and borehole losses. Borehole losses are attributable to a problem in the well and are the ones that may result in the need for rehabilitation of the well. Aquifer losses would need regulation for aquifer management solutions.

The most common way to determine deterioration in performance is to carry out periodic step-drawdown tests, whereby the pump is operated at progressively increasing discharge rates and pumping water levels recorded. The Jacob equation is then used to identify which is laminar flow (aquifer losses) and which is non-laminar flow (well losses). A straight line graph (specific drawdown against discharge) can be derived from this equation and compared to the original line to

identify the nature of changes. Box 18 below shows the equation and graphical examples of changes in performance.

Once it has been confirmed that there is a problem with the well, the next stage is to identify what is causing the problem. There are four main processes which cause damage to the well. These are shown below, along with the method of diagnosis:

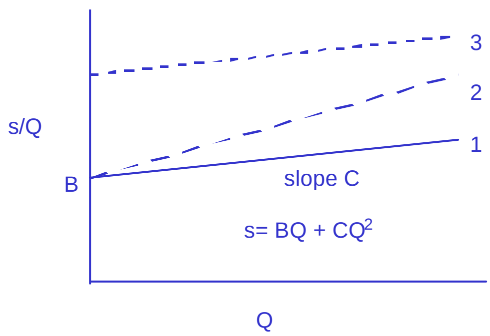
(i) particle redistribution	- direct observation of particulate matter in system
(ii) abrasion	- direct observation of component condition - observation of particulate matter and well velocities
(iii) biofouling/ incrustation	- direct observation of component condition - down-hole coupon testing for iron related bacteria - monitoring water quality parameters (pH, iron, etc)
(iv) biocorrosion/ corrosion	- direct observation of component condition - monitoring for water quality (especially sulphate related bacteria, pH, chloride, carbon dioxide

Box 18: Method for analysing well performance

Jacob equation: $s = BQ + CQ^2$

where:
s = drawdown (PWL-SWL)
Q = discharge rate
B = time dependent aquifer loss factor
C = a well loss constant

(from the graph, specific drawdown v discharge, B is the point at which the line crosses the Y axis and C is is the slope of the graph - see graph below)



1 Original step test
2 Later step test showing increase in C, but same B suggesting a deterioration in borehole condition
3 Later step test showing increase in B, but same C suggesting a deterioration in aquifer condition

(after CIRIA, 1995)

3.2.2 Remedying the problem

Many processes can be treated through the use of high pressure jetting, brushing, or airlift pumping and surging to loosen and lift material from the well. If well performance has declined, it is not clear what is the cause and this equipment is available it is worth trying these methods to try and enhance performance.

High pressure jetting requires a rig with small nozzles (2-3mm) to produce small discharge at high velocity (minimum 30 metres/second) to remove deposits from well components.

Brushing uses a wire or stiff nylon brush, rotated and oscillated, to remove deposits from the casing and/or screen.

Airlift pumping uses a hose to pump air into the well to lift material from the well. ***Surging*** uses a block with rubber seals to create pressure in the system to loosen material. These two methods are usually used together.

3.3 Pump manufacture and selection

Normally agencies invite tenders to procure the pumping unit with a pre-determined schedule. The quoted price is the main or sometimes only criteria for selection of the pump. This should not be the only criteria. Good practice in pump selection is provided by BMDA, who incorporated a clause for reducing its operating cost in respect of electricity consumption. For evaluation of the bid, price and also the electricity consumption for the operating period is considered.

Criteria are:
- capital cost;
- minimum of 60% efficiency; and
- least energy consumption per hour.

As a result, submersible pump manufacturers have become more attentive to their products and have been encouraged to improve their expertise.

3.4 Engine/motor manufacture and selection

The biggest shortcoming is not matching HP to the design discharge of the well. The same principles apply to the selection process for suction mode power requirements detailed in 'Reference Manual' - Technical Feasibility, section 3.6 and in 2.5 above.

4. CONVEYANCE SYSTEMS

Each of the main types of conveyance system has its own standard of performance, in terms of transit efficiency and an associated cost, and these are shown for different types of system and for different materials in Box 19. There is a trade off between performance and cost and the decision will often depend upon the management system in place.

4.1 Guidelines for conveyance systems

Each of the main types of conveyance systems has certain advantages and disadvantages, depending the management system and context. These will be looked individually, with guidelines given (Boxes 20 to 23), and then certain general suggestions made in relation to all conveyance systems.

Box 19: Performance and costs of different conveyance systems

Type of system	Materials	Transit efficiency %	Capital costs (Tk/ running m)	Annual maintenance costs (Tk/ running m)
Compacted earth channel		50	20	20
Lined channel	Pre-cast CC slab (trapezoidal)	70	120	5
Lined channel	Pre-cast asbestos sheet (trapezoidal)	70	300	12
Lined channel	Pre-cast ferro cement (trapezoidal)	70	170	9
Lined channel	Pre-cast ferro cement (semi-circular)	70	160	8
Lined channel	Cast in-situ CC (rectangular)	70	122	6
Buried pipe system	Asbestos	90	350	-
Buried pipe system	PVC	90	300	-
Buried pipe system	CC	80	250	-
Surface pipe system	Rubber	90	35	-
Surface pipe system	High density polyethelene	90	15	-

Box 20: Unlined earthen channel

Advantages	Disadvantages	Guidelines
1. Cheap capital cost 2. No great skill required in construction and maintenance 3. Whole system visible. Damage and need for repairs quickly identified.	1. Takes up large area of land 2. Low transit efficiency. High water losses. 3. High annual maintenance cost if system is to be kept running at full potential.	1. To keep land use to a minimum do not over-design channel. Keep size only to discharge requirements. 2. Most suitable where soils have high clay content. 3. Most suitable in small command areas.

Box 21: Lined channel

Advantages	Disadvantages	Guidelines
1. No great skill required in construction and maintenance, particularly if sections are pre-cast and delivered. 2. Significantly higher transit efficiencies than unlined channels. 3. Whole system visible. Dam age and need for repairs quickly identified.	1. Take up land 2. Expensive capital cost and fairly expensive maintenance cost, though degree of expense depends upon materials selected. 3. Depending on local manufacturers of slabs/sections, it may not be possible to keep channel size to the minimum required for well discharge.	1. To keep land use to a minimum do not over-design channel. Keep size only to discharge requirements if possible. 2. Most suitable where soils have high sand content. 3. Suitable in larger command areas. 4. If larger command area is supplied with these systems it is advisable to employ a lineman to check condition and arrange repair. 5. Ensure thorough maintenance otherwise transit efficiencies will very quickly fall with leakage through damaged sections of channel.

Box 22: Buried pipe system

Advantages	Disadvantages	Guidelines
1. Does not take up much land, only for the rising mains and air valves. 2. Significantly higher transit efficiencies than unlined and lined channels.	1. Great skill required in construction and maintenance, since can be dealing with quite complex hydraulics issues. 2. Expensive capital cost. Highest capital costs of all systems, whatever the materials selected, though degree of expense depends upon materials selected. 3. If any part of the buried system is damaged, leaks may go undetected for a long time.	1. Best used in support of a successful management system, where the system is to the liking of the farmers and farmers from a wider command area want to join. Allows increased revenue per well. 2. Indian well companies use the buried pipe systems to ensure quality of service, not to reach as many people as possible (Shah, 199*). This is fine if it fits in with the philosophy of the farmers and they are producing high value crops. 3. Suitable in larger command areas. 4. Partial buried pipe systems can be a trade off between quality and reliability of supply, or extended command areas, and costs.

Box 23: Surface pipe system

Advantages	Disadvantages	Guidelines
1. Does not take up any land. 2. Cheap, light and extremely flexible - water can be taken to wherever you carry the pipe. 3. Can be extended or shortened year on year as command area changes. 4. No skill required, except maybe in ensuring joints are sealed in the case of rubber. 5. Could conceivably be used at more than well.	1. High density polyethelene maybe prone to cuts but these can be repaired or sections simply cut away if close to the ends. 2. Not especially suitable for large command areas because of the need to carry the pipe around.	1. Ensure pipes are of sufficient size to carry well discharge. Rubber and HDP pipes are manufactured in a variety of sizes. 2. Contact RDA or BRRI in Bangladesh or WRRI in Pakistan for more details on HDP manufacture and sale.

4.2 General guidelines

Many farmers use unlined earthen channels because they perceive all alternatives to be more expensive. Systems are coming onto the market that are cheaper and have higher transit efficiencies. Given that conveyance systems are seen as a major problem for farmers, education on alternatives is a priority. This could potentially be done by credit agencies who could advise/ensure that an appropriate system is developed as part of the loan agreement. Dealers can also play an important role in providing advice.

In rural Balochistan, where many submersible pumps are now being installed to pump water from great depths, they suffer from persistent low voltage and can only achieve low discharges. Where this is the case, many farmers have installed lined ponds within the conveyance system so that they can pump overnight and allow the pond to fill and use the greater volume of water for irrigation the following day (see Box 24 for illustration of pond). The pond is usually located close to the village/house, which is also usually the highest part of the conveyance system, and is also used for washing and bathing.

Box 24: Incorporating ponds within conveyance systems - Balochistan

GUIDELINES - AFFORDABILITY
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THESE GUIDELINES DRAW PRIMARILY FROM EXPERIENCES IN BANGLADESH AND PAKISTAN. THEY RESULT FROM LITERATURE SURVEYS AND FROM INTERVIEWS, FIELD VISITS AND QUESTIONNAIRE SURVEYS. A LARGE RANGE OF WELLS HAVE BEEN LOOKED AT, FROM THOSE STILL UNDER COMPLETE GOVERNMENT OWNERSHIP AND MANAGEMENT TO THOSE TOTALLY DEVELOPED, OWNED AND MANAGED UNDER THE PRIVATE SECTOR. IN ADDITION, INFORMATION HAS BEEN USED FROM OTHER COUNTRIES IN SOUTH-EAST ASIA, PRIMARILY INDIA, WHERE APPROPRIATE TO THIS STUDY......1

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1. INTRODUCTION

When considering the economics of groundwater irrigation it is important first to identify the main interested parties. There are three main interested parties:

- the farmer or water user
- the well owner or operator, and

2. GENERAL TUBEWELL ECONOMICS

This section on general tubewell economics will seek to look at the costs and benefits of agriculture irrigated from groundwater sources, and ways in which changes can be made to the operation and management of groundwater irrigation to improve its profitability and fuel and water efficiencies.

2.1 Tubewell costs - constant groundwater levels

Studies in India and Pakistan show that significant savings could be made in fuel consumption (and, hence, costs) by making small changes to the existing technology used. Patel (1988) in a study in Gujarat showed these could be up to 50%, and van Steenbergen (1998) in North Bengal and Reinemann and Saqib (1991) in Pakistan suggested savings could be up to 70%. These changes are a combination of general and location specific changes. Box 1 provides a summary of the nature of the savings which could be achieved and Box 2 describes reasons for the current situation and makes suggestions on how the cost-saving changes could be introduced. The greatest savings are through modifications to the pumpset, followed by changes to the well and then by changes to the conveyance system.

The fuel cost savings are considerable and the technology modification costs are small, resulting in very short payback periods.

The fuel cost savings are considerable and the technology modification costs are small, resulting in very short payback periods. Indeed, some of the recommended methods of well construction and water distribution are cheaper than common current practice.

Box 1: Ways of cutting fuel consumption costs in diesel powered suction mode irrigation

Technical component	Improvement	Savings in fuel consumption
Well technology	Most suction mode wells are developed without a gravel pack and there is often a lack of proper well development, particularly where cow dung is used as a slurry. In these cases, ***the use of bamboo/mosquito netting filters is more fuel efficient than using PVC pipes with very narrow slot sizes (0.2mm) and is also cheaper:*** Slot size SWL Yield from 5HP pump Cost PVC pipe: 0.2mm 3m 7.5 l/s Rs2400 Bamboo/net: 1.0mm 3m 12.0 l/s Rs1500 (Cost is for 10m depth in Indian rupees, 1997 prices) For existing wells, ***rehabilitation, in the form of jetting or flushing***, can reduce fuel consumption significantly. Cost of this operation is minor (in India, Rs100, 1997 prices)	Savings of about 30% Savings of about 20%
Diesel pumpsets	***Increasing the engine operating temperature*** through alteration of water cooling system. For example, by fitting thermo syphon drum cooling increases operating temperature from 35°C to 80°C. ***Removing the check valve from the suction pipe*** to reduce hydraulic friction losses. ***With oversized engines, reduce the speed of the engine.*** For example, reduction from 1500 to 1100 rpm on a 5HP engine reduced fuel consumption from 1 l/h to 0.5 l/h with unchanged discharge. (Cost of the three measures above could be recovered in about 70 hours of pump operation). ***Reducing the size of the engine.*** (5 HP engines very common in India but in many cases 3.5 HP engines would suffice. In Bangladesh, many cases where 12 hp engines are used for suction mode pumps to try and increase discharge, when 8 HP would be sufficient). Optimisation of the pump through ***adapting impeller vane angles***.	Savings of about 13% Savings of about 18% Savings of about 20% Savings of about 20% Savings of about 20%
Conveyance system	***Use of high density polyethylene (HDP) tubes***, as opposed to unlined compacted earthen channels, reduces pumping times by decreasing steady state and transient water losses and requires no land. In Bangladesh, HDP tubes (at Tk 13/- per running metre) is cheaper than compacted earthen channels (at Tk 20/- per running metre) Use of ***soil cement channels*** (1:1:4 - sand, cement, soil) are about 20% of the cost of brick lined channels and also reduced water losses significantly.	Savings of about 15%

Box 2: Reasons for current inefficiencies in technology market and ways of introducing cost-cutting measures

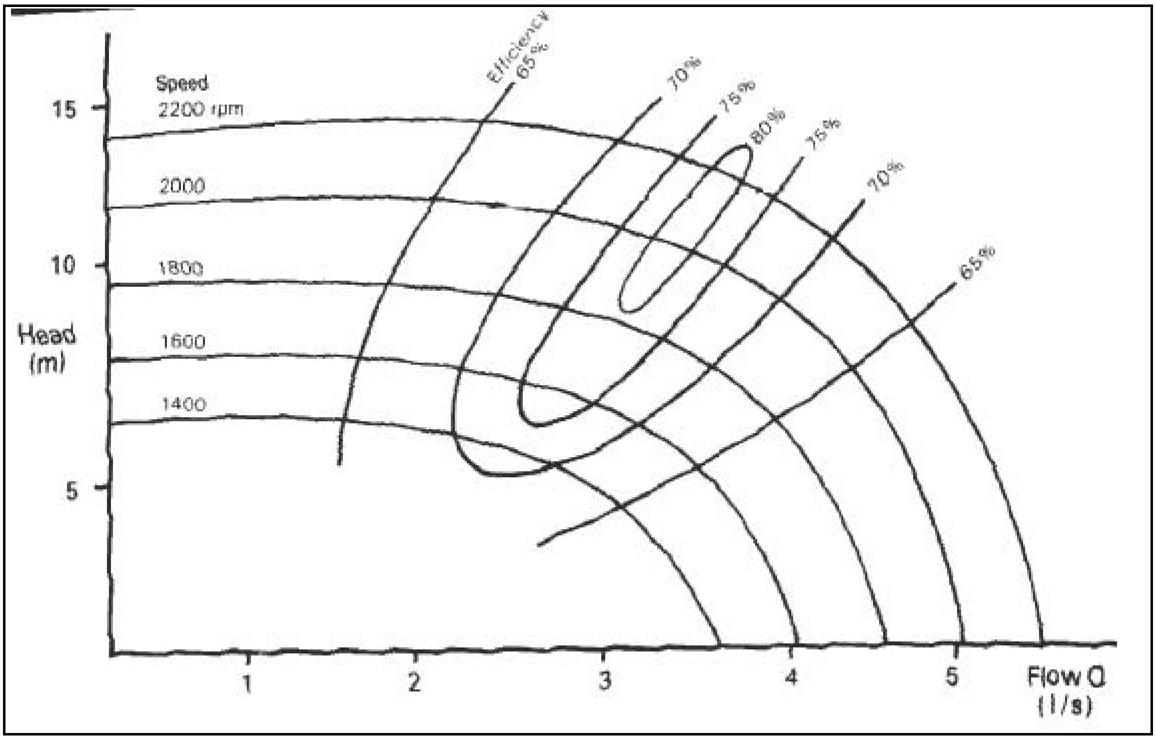
Current inefficiencies	Ways to introduce cost-cutting measures
Technology choices are never part of systematic agricultural extension and are usually through imitation rather than informed decision-making. Fragmented service industry - farmers may go to different suppliers for well and pumpset. Optimisation is unlikely in these circumstances. Pumpsets are often made by different manufacturers and assembled in local workshops without considering best combinations. Pumpset manufacturers are often small or medium sized businesses with little or no resources for R&D and where they do not dominate they do not want their product to stand out from the rest and expose themselves to risk. Those larger firms that do R&D and test equipment are priced out of the market. For example, KSB have developed novel pump designs for NMIDP but will not risk major development and manufacture because they will be copied and manufactured at less cost by smaller firms. Well installation is in the hands of artisans who do not normally face serious competition and who provide a standard installation whatever the circumstances.	Training of farmers, mechanics, tubewell drillers and dealers. For example, this has been carried out under the North Bengal Terai Development Project with the results than one in six farmers who attended demonstrations have adopted modified pumpset systems and several village mechanics and well drillers have taken on board advice and provide it as part of their service. Educate entire tubewell delivery service sector - through industry and suppliers. Also through large tubewell buyers in the public sector, so setting new standards in technology. For many of the modifications suggested, strongly held traditional views of farmers and mysteries need to be changed. The best way of doing this is through practical demonstration rather than by word of mouth or images - 'seeing is believing' (see 'Research Recommendations' in Chapter 5 for more on this).

2.2 Tubewell costs - changing groundwater levels

Costs are incurred by:
- longer pumping time to get the same volume of water → increased operating costs, and
- increased workload for the engine to extract water from greater depth → reduced effective life of engine and increased maintenance and spare part costs.

Many assessments of financial or economic performance of wells above, are based on constant water levels. This is fine for comparative analysis between technologies or accounting for changes in input/output prices year on year. However, most types of pump perform differently in different conditions. The amount of discharge from all pumps is influenced by the head (height from which water is lifted or pushed) against which it is pumping. When pump performance is evaluated it is done so by measuring changes in discharge with changes in head, to produce a pump performance curve. Discharge decreases with increases in head. One pump may produce greater discharge than others when pumping against low values of head, whilst another may produce greater discharge than others for higher values of head, and another may outperform others for all values of head. Box 4 provides examples of performance curves for different specifications of a given pump.

Box 3: Examples of pump performance curves showing the relationship between head, discharge, speed (rpm) and efficiency for a given centrifugal pump



(after Fraenkel, 1997)


Pump test centre, Bogra

Pump testing facilities:
- Pakistan (KSB, near Islamabad, Meco Pumps in Lahore, and Golden Pumps in Gujranwala)
- Bangladesh (University of Engineering and Technology, BUET, in Dhaka, and BMEEG Pump Test Centre in Bogra).

In situations where static water levels can change significantly during the irrigation season, this has major implications for irrigation costs. Costs can be incurred in two main ways:

(i) longer pumping time to achieve the same volume of water required, increasing operating costs, and

(ii) increased workload for the engine/motor to extract water from greater depth, increasing maintenance and spare part costs and reducing the effective life of the engine/motor.

The extent of the change in both of those costs depends upon the pump's performance as water levels change. It is very difficult to assess the impact of these changes in water levels upon performance because very few of the locally made pumps are tested. Pump testing is an issue which should be given priority for technical and economic evaluation of much of private sector groundwater irrigation in Bangladesh and Pakistan.

3. IRRIGATED AGRICULTURE IN THE SMALL-SCALE PRIVATE SECTOR (FARMERS - INDIVIDUALS/GROUPS)

This section looks at situations where wells are in the hands of the farmers themselves and not owned and managed by any organisation , whether public or private. Revenue from both farming and pumping accrues to the well owners and transaction costs are, in theory, reduced. However, there are still transaction costs incurred where there are a large number of users.

3.1 Financing Irrigation

3.1.2 Guidelines for improving credit supply for groundwater irrigation

Farmers interviewed in the questionnaire survey indicated a preference for reliability and quality in their pumping equipment, but are constrained by:

- lack of capital themselves (constraining their ability to buy quality), or
- lack of long term credit, or
- the price of crops etc. which may render a high initial capital cost and long pay-back period unattractive, even if credit is available. If the pump is bought on credit, the annual cost of repaying the credit over several years, becomes, to the farmer, one of the running costs of the farm. He will have to calculate whether the likely benefits exceed costs sufficiently to give him an attractive return to his labour and risk-taking. If the return is unattractive, no credit scheme will succeed. Irrigation often requires complementary short-term credit to finance investments in new seed, fertilisers, etc. These are smaller investments, but the poorer farmer may require credit for these as well.

Examples are given of how effective procedures and methods have been used to extend capital provision for groundwater irrigation technology or for associated development needs - see 'Reference Manual - Affordability' - Boxes 4 to 7..

The ideas and themes from the examples, along with other suggestions are shown in Box 4.

Box 4: Guidelines for increasing success rate of credit delivery for groundwater irrigation

Feature	Explanation
1. Farmers have a constant ally with them at all stages to guide them through the process and to ensure repayment	From the examples above, these allies include: • pump dealers • activists from within the community • Farm Managers living within the community • project staff who have worked with the farmers for some time
2. Allies are in tune with the farmers	Allies either have the same objectives as the farmer, or have carried out extensive needs assessment studies.
3. Farmers exercise a degree of control over the credit process	In the credit delivery examples above, the terms and conditions of the credit agreement were negotiable and not imposed from outside.
4. Keep the application process simple	If possible, make the application a one-stop process
5. Credit agreements are flexible	Terms and conditions can be changed. Repayments can be scheduled and rescheduled and not set. Long/short term credit arrangements are possible.
6. An element of saving is incorporated in the credit agreement	In two of the examples above, a proportion either of the loan or repayment was set aside for personal savings or for an emergency fund. This provided both a means of capital growth and insurance against unforeseen situations. It also developed the concept of saving and a culture of group banking beyond the immediate credit period.
7. Field staff in a supervisory role with subtle control of the process	This is a point advocated by Wood and Palmer-Jones (1991) when seeing one of the shortcomings of previous credit provision as field staff being in a mobilising and facilitating role only.
8. In-group mechanisms were in place to restrict opportunities for deception	This is another point highlighted by Wood and Palmer-Jones (1991). Peer group pressure, social collateral and transparency were all evident in the examples above.
9. Credit agencies were not 'credit only' agencies.	The agencies above performed many other functions, either in support of credit utilisation or in community development in general.

3.1.3 An alternative to credit for groundwater irrigation

Given the difficulties encountered by credit schemes for groundwater irrigation technology, it is worth considering the possibility of enabling farmers to operate savings/capital generating schemes themselves. The main concept in this is the rotating savings and credit associations (ROSCAs).

<u>Rotating Savings and Credit Associations</u>

These guidelines borrow heavily from the work of Rutherford (from Wood et al., 1997) concerning ROSCAs. ROSCAs are not a new concept, they have been around for hundreds of years and operate the world over. However, as a concept for capital accumulation in the most rural areas of Bangladesh and Pakistan they are relatively new. Rutherford argues that NGOs could learn from ROSCAs in their financial services.

The premise of ROSCAs is that financial services are about creating lump sums out of normal income flows.

The premise of ROSCAs is that financial services are about creating lump sums out of normal income flows:

- savings create liquidity by foregoing some income now in return for a later lump sum, whilst
- loans create a lump sum now in return for foregoing some income in the future.

At present, NGOs credit schemes offer only the loans option whilst ROSCAs offer both options. ROSCAs are also known in Bangladesh as *loteri samiti, khela samiti* or *serial* and are numerous in Dhaka but also found in other cities, towns and country bazaars. There are two kinds of ROSCA, to be called loteri samities and fund samities, and these are explained in Boxes 5 and 6 respectively.

Box 5: Loteri samiti explained

Description of loteri samiti:

1. A group of people (5 to >100) get together informally to form a loteri samiti. They may be single or mixed sex.
2. Each member contributes a fixed amount (this may vary between samities, according to the financial status of the samiti, but not usually within the samiti) on a regular basis (daily - most common, weekly or monthly).
3. Meetings are held regularly (usually weekly or monthly), when a draw is made and the winner takes all the money.
4. The winner may not enter the draw again but continues to contribute.
5. After each member has won the money then the loteri samiti closes.

Features of loteri samiti:

1. They are essentially ways of turning household income into capital.
2. They are for a known fixed time period.
3. Deposits are standardised and regular for each samiti, an essential ingredient.
4. People can be members of as many samities as they want.

Advantages of loteri samiti:

1. The nature of the samiti is fixed once created but the terms are flexible and agreed prior to set up. For example, the winners may be decided by draw, or by consensus or even auction if one member requires capital urgently.
2. Samities are usually safe investments (Rutherford's survey should 86% satisfaction of members with their samiti), since the members are there voluntarily and usually know each other, and dealings are transparent.
3. They can be used easily by the illiterate, since at each meeting they see who is contributing and who is receiving.

Risks of loteri sameti:

1. There are risks of mismanagement, though usually seen as small. The risks of mismanagement increase with the size of the samiti and, hence, size of the pot, particularly where samities are managed by an outsider.
2. There are risks of non-payment of contributions once someone wins but these are small, due to peer pressure and the dynamics of the samiti, and the risks increase with larger groups where people may not know each other.

(after Rutherford, in Wood et al., 1997)

Box 6: 'Fund' samiti explained

Description of fund samiti:

1. A group of people (10 to >100) get together informally to form a loteri samiti. They may be single or mixed sex.
2. Each member contributes a fixed amount (this may vary between samities, according to the financial status of the samiti, but not usually within the samiti) on a regular basis (daily, weekly or monthly). These times are also the times when loans may be taken out.
3. The fund runs for a set period of time, at the end of which members receive their full savings plus a dividend.
4. The funds accumulated during the fixed period may be withdrawn by members as a loan. Once a loan has been taken out interest is to be paid at the time of regular deposits at a fixed rate. The principle is to be repaid before the end of the fund's life. The interest paid on loans creates the dividend at the end of the fund's life.

Features of fund samiti:

1-4. As for loteri samiti

5. Usually run by a 'fund manager' who keeps accounts of deposits, withdrawals and interest payments.

Advantages of fund samiti:

1. They are more flexible than loteri samiti - capital can be acquired as and when needed.
2. The group can change features of the fund as and when required, such as loan amount (say from a maximum fixed amount to a proportion of personal savings accumulated), to rate of interest (say, if loans are not being taken out, by reducing the rate of interest).

Risks of loteri sameti:

1. There are greater risks of mismanagement than for loteri samiti, because of the greater complexity and reduced transparency of the fund.
2. There are risks of non-payment of interest or contributions

(after Rutherford, in Wood et al., 1997)

Implications of ROSCAs for NGOs and for groundwater irrigation

The advantage of ROSCAs is that people may both save as a matter of course and borrow when necessary.

Rutherford's survey suggests that one of the prime motives for the ROSCAs is to save. This is not only borne out by responses from samiti members but in the difficulty some samities were having in disbursing loans. The current policy of most NGOs is to encourage people to borrow. The advantage of ROSCAs is that people may do both - save as a matter of course and borrow when necessary. In addition, savings create interest and further build capital whilst borrowing loses interest and reduces the effective size of the capital.

The samities require safe and thorough record-keeping and management to be guaranteed success and these are skills that many NGOs pride themselves on. Many NGOs also have experience in collecting payments, through loan recovery. NGOs are in a strong position to introduce this concept and manage funds in the rural areas where the idea is relatively unknown (loteri samities have only grown significantly in number in Dhaka in the last few years). The process of managing these funds is potentially easier than current credit agreements, since terms and conditions are flexible and agreed and set by each group, and finance is provided by the group rather than from a central fund under strict terms.

This concept lends itself:
- to providing capital for groundwater irrigation equipment, or
- as a means of restructuring payments over the year, and reduce the financial out-goings at harvest time.

This concept lends itself to providing capital for purchasing groundwater irrigation equipment or as a means of restructuring payments over the year, and reduce the financial out-goings at harvest time. The loteri samiti requires no payment of interest, whilst under the fund samiti, only the interest is paid on a regular basis. The capital sum needs only to be paid before the end of the fund's lifetime, and, particularly if fund samities are running for a year which is most common, this means that the capital sum can be repaid at harvest. Indeed, if fund samities are running for a year, there is the potential for the capital to be repaid from two or three harvests.

3.2 Payment systems

There are three main times to pay for water: before the irrigation season, after the harvest following the irrigation season and during the irrigation season ('pay as you use'). Each has benefits and risks associated with them, for both the water supplier and water user. The currency used in the payment for water is closely related to the timing of the payment and so these two features have been combined in the guidelines below. The main currencies are cash, crop-share and coupons. See Boxes 7 to 9 for details and guidelines.

Box 7: Payment before irrigation season- individual wells

Feature:	**Payment before the irrigation season** 1. Payment before irrigation season is exclusively by cash, since crop-share not an option. 2. Payment before irrigation season is almost always as a lump sum paid for the whole season. 3. Initial payment may be lower where users provide their own fuel, in the case of diesel engines.
Contexts:	1. More commonly in those areas of lower risk of crop damage or failure (higher land, double- or triple cropping, less susceptible to flooding) 2. Usually in areas with wealthier water buyers who are able to mobilise funds in advance of irrigation season. 3. Can be in areas where the owner has considerable influence and is able to enforce payment collection. 4. The use of cash payments in advance tends to increase as private irrigation increases and the water markets mature. 5. Most common form of payment for individually owned wells visited in Bangladesh in 1998. 6. System not used by corporations, with the exception of the BWDB project in NW Bangladesh, to cover electricity bills. In this case, no penalties for non-payment are imposed on users and attempts at fee collection drag on through and after irrigation.
Risks:	1. Mainly to the water user, since payment made (usually non-refundable) whatever the outcome of the irrigation season. 2. Where the water seller is not in a position of power (e.g. landless group selling to influential farmers) collection can be a problem. 3. In areas historically under subsidised government well programmes where a background of late or non-payment of water fees exists collecting fees can be a major problem for the water sellers.
Benefits:	1. Water seller has capital at the beginning of the season to (i) pay for o&m of the well and (ii) to be able to plan variable costs against a known fixed income. 2. This system increases the chances for less wealthy water sellers to participate in the market place, since income becomes available before operational expenditure. 3. Water user has an incentive to maximise agricultural returns beyond the known water fee.
Guidelines:	1. In some cases where inherent or contractual trust is present, the water seller may be able to collect the money prior to purchasing the pump, or purchase the pump on a hire purchase agreement, in order to enter the water market. 2. In the case of some group managed wells surveyed, it was suggested that a key factor in reducing the risk of corruption was to set the rate at such a level that there was little potential for large operating profits.

Box 8: Payment during irrigation season- individual wells

Features:	**Payment during the irrigation season** Notes: 1. Payment during the irrigation season is almost exclusively by cash in the case of privately owned wells. 2. Payment during the irrigation season is almost always on a pay as you use basis, usually on an hourly basis. 3. Payments may be lower where water users provide own fuel, in the case of diesel engines, or users make use of their own tractor to drive the pump.
Contexts:	1. More common in the case of STWs where there are usually fewer users than for DTWs. 2. Under corporately managed systems where the corporation is set up so that payment is made in the form of coupons, purchased from the corporation, and given to and recorded by the pump operator. Allows detailed accounting of water consumption. See section *.* on coupon system. 3. The most common form of payment in Pakistan for pumps of all power sources. In the case of diesel engines (including power take-off (PTO - tractors) modes) hour rate plus buyer-brings-fuel is the most common form of payment during the irrigation season.
Risks:	1. Risk is shared between the seller and the buyer. The sellers cover their variable costs plus a little extra towards the capital costs. The buyer only uses what is paid for. 2. Depending upon the number of users, and the power of the water seller, the system can become quite anarchic and reinforce access and tail-ender problems.
Benefits:	1. Overall water efficiency may be increased as farmers make best use of the water for the limited time they have paid for. Water has a specific real monetary value and is used in a more efficient manner. 2. The water seller has an income throughout the irrigation season and increases the chances for less wealthy water sellers to participate in the market place. 3. The water seller risks losing his return if he cannot sell water for the whole season, so he is motivated to ensure supply.
Guidelines:	1. On the whole, a flat hourly rate throughout the irrigation season is charged, despite the fact that pumping costs may increase as the SWL falls (see section 2.2 in 'Tubewell economics') or canal water becomes scarce for planned or unplanned reasons. In the buyer-brings-fuel systems this is not important but, in calculating the flat rate for cash only systems, the water seller must account for increases in pumping costs over the whole season. A flat rate is advisable because it reduces transaction costs and reduces the risk of water sellers being seen to be exploiting buyers in times of water scarcity. Important when sellers and buyers usually operate in a socially close environment and in a variety of economic circumstances. 2. Because of the informal nature of this system, and to provide security for both water sellers and buyers during the season, it is worth considering drawing up contracts between sellers and buyers detailing prices, areas irrigated and times for irrigation during the season. 3. Within corporate systems with sufficient infrastructure, the use coupons, purchased by the buyers from the corporation, has proved to be successful. The system takes money out of circulation, so reducing the temptation and opportunity for corruption, and enables detailed accounts and records of water purchase and use to be made. This system is explained in more detail in the second guideline box in section 4.3.

Box 9: Payment after irrigation season- individual wells

Features:	**Payment after the irrigation season** Notes 1. Payment after the irrigation season is almost exclusively by crop share, both in the case of individually and group/corporately owned wells. The share of the crop given in payment may either be a set weight per unit of land (e.g. 4 maund/bigha) or a percentage of the yield (e.g. 25%).
Contexts:	1. More common in areas where there is a shortage of farmers' capital at the beginning of the season. 2. More common in areas where there is a higher risk of crop failure and in younger water markets. As markets develop and mature and the benefits of irrigation are realised there is a tendency to move to cash payments in advance of, or during, the irrigation season. 3. More common in private projects run by NGOs with storage and marketing facilities. Often linked to other 'credit' related functions such as monetary credit and purchase of agricultural inputs. 4. In Bangladesh, Pakistan and India, this system is often linked to the irrigation of higher value crops, sensitive to moisture stress, such as tomato, onion, maize, sugar cane (and rice and barseem in Pakistan).
Risks:	1. Capital outlay is required and so this system favours wealthier investors. Poorer potential investors would have to borrow/use credit (where available) to install the system, at considerable risk. 2. The risk is greater to the seller if under a percentage yield payment system. The buyer takes a greater risk under a set weight per unit of land system. If the yield is poor then the seller may have rights to a high percentage of the harvest. 3. The seller takes the risk initially by bearing the costs of irrigation until harvest. If the harvest fails then the seller has incurred most of the penalties. However, the seller has an interest in maximising yields, just as much as the farmer and would seek to ensure supply. 4. The value of the crop share to the sellers may vary greatly and is hard to predict. If prices are high then the sellers may make considerable returns on their investment, but at times when prices a low the sellers may make a loss. 5. Particularly in areas historically under subsidised government well programmes, where a background of late or non-payment of water fees exists, collecting crop shares can be a major problem for the water sellers. This is especially the case where the sellers do not have much power, such as the landless water sellers supported by NGOs.
Benefits:	1. Farmers who may otherwise be unable to purchase water in advance of the harvest are able to afford irrigation, especially if the agreement includes land and other agricultural inputs. 2. Since the seller has an interest in the success of the crop there is a greater security for the buyer that water will be supplied when needed. 3. The buyers have an incentive to maximise agricultural returns beyond the known crop-share water fee (when payment is fixed weight per unit of land).
Guidelines:	1. Written contracts between buyer and seller are important security, particularly in cases where the power of the seller to collect the fees is restricted by status. 2. In cases where the water seller has limited resources available, risk-sharing agreements may be signed with the buyers, whereby the buyers would contribute to the operational costs of the well (say pay for the fuel) in return for a reduced fee at the end of the season.

3.3 Alternatives to new tubewell purchase

There are two main alternatives to purchase of new tubewells. These are hiring of irrigation equipment and purchase of second-hand wells. The first refers to suction mode technologies (for STWs) and the second refers to force mode technologies (for DTWs).

3.3.1 Hiring of irrigation equipment

There is no history of hiring STW pumpsets in Bangladesh or Pakistan. However:
- Bangladesh, hiring of LLPs in Khulna (south) is common practice. Also, a majority of power tillers are hired, either from project authorities or from private dealers.
- Pakistan, an informal form of hiring exists, where farmers use someone else's well and pump and use their own prime mover (tractors).

There is scope for increasing the use of suction mode pumps through hiring. This would apply mainly to the smaller land owners or sharecroppers who are unable to afford pump sets. The use of a pump would still require a well but the cost of a well is considerably less than the cost of the pump set and prime mover (the average percentage of well capital costs to total capital costs is 24% in Bangladesh and 29% in India). In addition, these capital costs would be incurred less frequently than those for the pumping equipment. The pumping equipment would only be on a pay-as-you-use basis and so expenditure may be infrequent or rare, say in times of drought. This is something that should be encouraged amongst traders to promote, since if they can promote this idea successfully, they may make more money out of hiring than out of selling.

3.3.2 Purchase of second-hand equipment

There are still areas (close to the major markets) and cropping systems (high value vegetable and salad crops) which are conducive to profitable agriculture, and areas recognised to be home to progressive, co-operative farmers. The second-hand DTW relocates wells from areas of poor profitability to these more profitable areas.

Some of the larger contractors are buying second-hand DTWs (including the casing and screen, where possible) and relocating them where requested by farmers. New screens are often required and where this is the case the brass screens are being replaced by PVC screens. Reconditioned prime movers and pump sets are also supplied by the contractors. Given the growing demand for this service, and given the number of disused DTWs in Bangladesh and India, and the number of SCARP tubewells being withdrawn from service in Pakistan, this is an issue which merits further consideration.

4. IRRIGATED AGRICULTURE IN THE CORPORATE SECTOR (GOVERNMENT OR PRIVATE AGENCY)

4.1 Introduction

Key attitudes:
Mutual TRUST & CONFIDENCE

The research has identified two key attitudes amongst water selling organisations and water users that lead to a higher level of success in cost recovery. These are trust and confidence. If water users have confidence in the guaranteed supply of water throughout the irrigation season, then they are prepared to pay for it, even to pay a premium for it. In many cases, non-payment of irrigation charges results from disruption to water supply and a consequent loss of yield (income). The research also suggests that if water sellers are confident that they will receive payment for supply, then greater efforts are made to ensure sufficient supply. This confidence stems from trust between the water seller and the water supplier. In many cases, this trust can be gained directly from the payment systems used. This section will attempt to show a variety of ways in which different payment systems can influence the level of trust between buyers and sellers and, hence, increase the level of cost-recovery. This applies equally to wells in the public or private sector and to wells going through the process of transfer from the public to the private sector where a new payment system under the new regime is being considered.

4.2 Water pricing

4.2.1 Setting the price

The level of the water price within the corporate sector can depend very much upon the objectives of the organisation. Objectives in water pricing include:

- recovery of energy costs,
- recovery of all operation and maintenance costs,
- contribution to well replacement costs,
- profit maximisation, and
- as a policy instrument for controlling the level of water use.

All objectives are legitimate but it is important to be clear about the objectives, to set financial targets consistent with the objectives, and to set the price accordingly. Those organisations which have been more successful in achieving their objectives are those who have a clear water pricing strategy which is transparent and which the farmers understand.

The Barind Multi-purpose Development Authority (BMDA - independent government agency) calculates an hourly water charge based on the electricity bill, plus all operating costs, depreciation, repair and replacement charges, paid by coupon. The detailed basis for water price assessment used by BMDA is shown in Box 10 as an example.

Box 10: Assessment of hourly irrigation charge for a organisation - an example

Feature	Components	Example figures (B'desh Taka)
Basis for charge is: (A × B) + C, where:	A = Average electricity consumption per hour B = Unit charge for electricity per hour C = Corporate and well operating costs	
Average hourly electricity consumption (A)	Averaged for all electrified wells in the project	20 kwh
Unit charge for electricity per hour (B)	Based on agreement with electricity supplier (In Bangladesh either Power Development Board (PDB) or Rural Electrification Board (REB))	PDB: 1.75/kwh REB: 2.35/kwh
Corporate and well operating costs, based on an average of 1000 hours operation for well each year (C) $= \frac{\Sigma(a+b+c+d+e+f+g+h)}{1000}$ where:	a = operator's total annual remuneration b = co-ordinator's remuneration (per tubewell/year) (based on 1200/month for 5 tubewells) c = expected annual repair cost of deep tubewell (DTW) d = expected annual repair cost of distribution system e = annual depreciation (straight line method = (P-S)/L, where: P = purchase price of DTW S = salvage value of DTW L = service life of DTW) f = Security deposit for electricity supplier over life of DTW g = risk of one transformer burn out or theft over life of each DTW h = miscellaneous unplanned costs Therefore C in this case = (12000 + 2880 + 2500 + 2500 + 17167 + 450 + 1667 + 1000)/1000	12000/yr 2880/yr 2500/yr 2500/yr 17167/yr 550,000 35,000 30 years 13500/30 yrs = 450 50,000/30 yrs = 1667/yr 1000/yr 40.2
Hourly charge for water for (A × B) + C	For PDB = (20 × 1.75) + 40.2 = For REB = (20 × 2.35) + 40.2 =	**75.2** **87.2**

(based on electrically powered wells of BMDA, Bangladesh)

The Grameen Krishi Foundation (GKF - non-governmental organisation) which took over the ownership and management of in excess of 500 DTWs from BADC. The basis for water pricing is maximisation of profits and different bases for charging have been developed which suit different DTW contexts. There are three main types of system, one for selling water, and two for renting wells (one where farmers pay for fuel and one where GKF provide fuel on credit terms).

In general, GKF have found that the water selling system is more profitable (for GKF) for DTWs with command areas over 40 acres and that for DTWs with command areas under 40 acres the well rental systems are more profitable. The rental system, where the farmers supply the fuel, is seen as particularly appropriate where command areas have excessively sandy soils, since irrigation time and fuel consumption is greater, and this system reduces GKF's liability for fuel.

4.2.2 Communicating price information to farmers

Communication to the farmers of the basis for water price levels, and the use of the income, has been strongest in the case of BMDA. BMDA have also managed to arrange with central government that all revenue will remain in the hands of the Authority with none returning to the Government, so keeping it in the region. This has been stressed to the farmers and has been well received. It gives the farmers further trust and confidence in the water-selling organisation.

4.3 Currency for payment

The three projects shown above all use different currencies for payment and illustrate the benefits and risks associated with each form of currency. Those most successful in collecting revenue are those that do not deal directly in cash. The three main currencies for payment of water charges are described below, in Boxes 11 to 13.

Box 11: Payment in cash - corporate systems

Features:	**Payment in cash** (Based loosely on experience of ***North Bengal Tubewell Project***, Bangladesh. Objective of charging and reason for level of water charge - cover electricity bill plus 20% for O&M)
Contexts:	1. Under corporately owned/managed systems, either in the public or the private sector. 2. For either electric or diesel energy sources. 3. Usually based on a flat rate per unit of land, rather than based on water usage or crop yield. 4. Where a system is in place for collection of revenue from farmers, either through some form of farmers organisation or through project staff. 5. In cases where facilities for printing/selling coupons and/or collection and/or storage of crop share are not available. 6. If paid on a lump sum basis, rather than a pay-as-you-use basis, usually needs to be after the harvest of crop.
Risks:	1. Without clear accounting systems this method of payment can be open to abuse by both farmers' representatives and project staff. Under the North Bengal Tubewell Project, the money is collected by the Secretary of the elected well Executive Committee and paid into a bank account. The Secretary receives 10% of income as payment for collection duties. In the absence of transparent accounting systems the Secretary is able to retain much more than 10% of the revenue collected, depositing a great deal less than that collected into the bank account. 2. Without a system of enforcement or penalties for non-payment, collecting cash can be a time-consuming and fruitless exercise. 3. If payment is made at the end of the irrigation season, then payment will only be forthcoming if farmers are satisfied with the service. In the case of the North Bengal Tubewell Project, no contract for power was agreed with the Electricity Board and frequent and persistent power shortages resulted. Payment for irrigation under these conditions covered only 25% of the total electricity bill.
Benefits:	1. Price of water is fixed and not dependent upon the value of the crop. There is an incentive to increase productivity to increase income over fixed known costs, without the penalty of a higher financial contribution under a percentage crop share arrangement. 2. Usually a flat rate per unit of land so smaller landholders pay less. 3. Where money is collected and paid into a bank account, interest may accrue on the income.
Guidelines:	1. If at all possible do not use cash as the currency for payment. Cash should only be used at points in the system where open thorough accounting can take place with arrangements for the production of receipts, such as project offices. 2. If farmer's representatives are responsible for cash collection then it should be a legal duties with enforceable penalties for abuse of the system. More than one representative should have collection duties. 3. If cash has to be used then a pay-as-you-use system would be preferable.

Box 12: Payment by coupon - corporate systems

Features:	**Payment during the irrigation season using the coupon system** (Developed by the ***Barind Multi-purpose Development Authority***, (BMDA). Objective - charging and reason for level of water charge - to cover all O&M costs and well replacement costs.)
Contexts:	1. Under corporately owned/managed systems, either in the public or the private sector. 2. Organisation needs network of offices to enable farmers easy access for coupon purchase. 3. Each well requires a reliable operator permanently stationed at the well during the irrigation season. BMDA tries to use young women operators, providing them with a salary and an education. Young women seen as more reliable and also a chance to develop responsibilities for women in the community. Not easy in more remote locations - security. 4. In the case of BMDA, this system is used only for those wells which are powered by electricity. A contract is made with the electricity suppliers to guarantee supply and the use of electric pumps enables women to operate the wells. The diesel engines require heavier maintenance and greater strength to operate.
Risks:	1. A new idea which needs careful explanation and pilot testing to illustrate the concepts and to show the benefits. 2. Still relies on a motivated efficient workforce to make the system work effectively. 3. The system of payment should in theory be secure, but the order in which farmers receive water at the critical time of year is still open to abuse. Operators may make unofficial money by supplying water to the highest bidder first. However, this system usually results in farmers using only what they need and in many cases observations showed that all farmers received the water they required. 4. As with any other system, cost-effectiveness and command area actually irrigated still relies on a reliable supply of power and an efficient distribution system.
Benefits:	1. Overall water efficiency may be increased as farmers make best use of the water for the limited time they have paid for. Water has a real value and is used more efficiently. 2. Authority revenue and power and water usage is accounted for in detail. On a project scale patterns of usage and better/ worse performing wells can quickly be identified, and reasons for these differences in performance can be identified through follow up investigation..
Guidelines:	1. Hourly rate for water determined through procedures shown in Box 10. For the last few years this has been set at Tk. 75/hour. 2. Coupons Government security printed to a variety of values (from Tk 1/- to Tk 500/-) so that farmers can purchase water for hours and for fractions of an hour. For example, a Tk 50/- coupon will purchase 40 minutes of water. 3. Coupons may be used at any well within the project area, since farmers may well have land in more than one well command area. 4. Coupon purchased at Authority outlet. Coupons take the form of three sections, separated by perforations. Two sections given to the farmer, one retained as proof of purchase and to account for money into the Authority. 5. Farmer gives one coupon to the operator at the time of water need and retains last section of coupon. Operator records time of electricity usage against coupon number. All electricity usage is therefore accounted for. 6. Each year a draw is made, from those coupons which have been purchased during the year, using the section of the coupon retained by the Authority. Prizes are given for each value of coupon, rising in value with the price of the coupon. Farmer must present his/her own copy of the winning coupon to collect the prize money. The draw provides good publicity for the Authority and encourages purchase of the coupons. 7. Success in terms of coupon purchase is still only a reality if a reliable, continuous service is provided by ensuring that the pump is always in good working order.

Box 13: Payment in crop share - corporate systems

Features:	**Payment after the irrigation season on a crop share basis** (Based largely on ***Grameen Krishi Foundation*** (GKF), Bangladesh. Objective of charging and reason for level of water charge - to maximise income from DTWs.)
Contexts:	1. Under corporately owned/managed systems, either in the public or the private sector. 2. Organisation needs wide network of collection and storage facilities for crop share. 3. In situations where historically cash based payment systems have been abused. 4. In situations where irrigation water supply can be virtually guaranteed, so ensuring good harvest. Requires reliable energy sources and reliable well operator with corporate back up. 5. In situations where there has been evidence of conflict within well user groups. Crop share agreements usually between organisation and individual farmer.
Risks:	1. Payment is after the irrigation season and, hence, after outlay on irrigation costs. Farmers may refuse to pay. 2. Costs of irrigation are largely constant, whilst the income from crop share is reliant upon the price at which the crop is sold and can fluctuate wildly. In a high yielding season the income may be low whilst in a low yielding season the price may be high and the farmers may resent the value of crop they have to give. In the latter case GKF have lost farmers who, when the value of crop share is high, see shallow tubewell water charges as highly competitive.
Benefits:	1. In situations where water supply can be virtually guaranteed then income is virtually guaranteed. Where harvest has suffered elsewhere and the price of the crop share is high income may be significantly above expectations. 2. With a fixed weight of crop share, farmers have the incentive to maximise yields above crop share so increasing productivity. 3. In an area where both shallow and deep tubewells are operating, deep tubewells which are inefficient or inappropriately located, for whatever reason (be it physically, economically or socially) will cease to be profitable and will close, giving way to shallow tubewells which are often more efficient in these areas.
Guidelines:	1. Ensure adequate water supply to ensure crop yields and farmer satisfaction. GKF are converting wells to electricity but keeping diesel engines in place as back up in case of problems with electricity supply. Farmers appear willing to pay a premium, in terms of higher charges, in return for guaranteed water supply. 2. Keep corporate staff close to the farmers to build a relationship and to deal with any problems at short notice. If trust is built between the organisation and the farmers then revenue collection becomes an easier process. GKF operate their DTWs as 'Primary Farms' and have Farm Managers residing at all Primary Farms to provide assistance to farmers, to administer crop share agreements and to ensure collection of crop share during harvest. 3. The organisation should arrange to collect the crop share free of charge to the farmer. This makes life a little easier for the farmer and also ensures higher rates of payment. The amount and quality of the product can be ensured if corporate staff are present at the point of payment. 4. Organisation staff are encouraged to maximise returns through setting up crop share agreements and collection dues if they are on financial incentives to achieve targets. 5. Penalties for non-payment should be enforced. GKF do not operate DTWs if the farmers refuse to pay their bills. 6. To ensure crop yields are high, and with the requirement for agricultural facilities such as storage for the crop share basis, GKF have also set up infrastructure for input provision. GKF also have contracts with farmers for seed production. In several cases, DTWs would not be profitable if irrigation water only was paid for. Payment, again through crop share, for inputs has enabled some DTWs to become profitable.

4.4 Effective cost recovery

Those organisations which have been more successful in collecting money have done so largely because of the nature, structure and motivation of the organisation and its staff. The economic guidelines for effective cost recovery are shown in Box 14 and include summary of those points mentioned above, where relevant.

Box 14: Economic guidelines of good practice for effective cost recovery for organisations

Guideline	Explanation
1. Set price of water to be profitable but not extortionate	A price needs to be set to cover costs but if the price is set too high water users may be unable or unwilling to pay, whatever the penalties for non-payment are. If the price is based on a detail analysis of costs and is too high, the well may either be uneconomic and alternative technologies should be considered, or ways in which the costs can be reduced should be looked at.
2. Explain to water users why they are being charged the price they are and what they will receive for that price.	If water users are informed of why they are being charged the price they are, and where the money they pay is going, they are often more willing to pay up.
3. Remove cash from payment process at the earliest possible point	Payment in cash is normal in most developed countries, because it is much more convenient for both payer and receiver. However, in countries where the temptations to corruption are high, and levels of literacy and numeracy are low, the coupon system is advantageous. Cash is an elusive commodity which can easily disappear if there are too many stages at which it is transferred (e.g. water user → water-users representative → bank or project) and which can be used for any number of purposes. Coupons can only be used for irrigation and money is transferred to the organisation before irrigation with the coupon acting as a receipt for payment. Crop share involves no money transfer at all. The main problem may tampering with crop share. Hence guideline 4.
4. Maintain high corporate control over the payment process and control of revenue	Corporate control may be through collecting money prior to irrigation and only allowing irrigation on proof of payment, such as through the coupon system. It could also be by having staff placed close to the water users and supervising cost recovery to ensure full and (in the case of crop share) uncontaminated payment.
5. Make provision for detailed accounting procedures at any time payment is made	Whether payment is made before, during or after irrigation, anypayment should be accounted for. Accounting systems should be as tight as possible to prevent 'leakage' of money from the system. For example, in the case of the coupons, the coupon acts as a receipt of payment and any coupon sold at organisation offices will have money received which project staff will have to account for. Well (and, hence, energy) use is accounted for against coupons received from the water users. Time not set against coupons must be explained by the operator. In the case of crop share, an agreement is drawn up prior to irrigation for a given weight of crop. These are accounted for, for each water user, in organisation offices. When crop share is collected, the due amount from each farmer is compared to the agreement. Any shortfall can be chased up.
6. Ensure payment is encouraged or enforced through implementation of incentives and penalties	Many water users may try to avoid their financial responsibilities however satisfactory the above systems may be. If irrigation is paid for in advance, then discounts for higher levels of payment may be made. If payment is made after irrigation, then water users may simply refuse to pay, for whatever reason. Penalties for non-payment need to be enforceable and enforced if payment is to be ensured throughout the organisation area. These may be legally enforced penalties such as confiscation of property or crop share, or closure of the well. Organisation staff should also be subject to incentives and penalties.

GUIDELINES - MANAGEABILITY

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1. INTRODUCTION

Manageability of groundwater irrigation technology refers to the management system for the technology, its type, scale and effectiveness in satisfying the needs of water sellers and water users or buyers.

1.1 Key management functions

The research shows the key management functions in groundwater irrigation to be:

- Selection of appropriate technology, or modification to technology, for the well and pump, given local circumstances.
- Provision for regular maintenance and fast emergency repair or replacement, given that the chief priority of farmers is a service they can rely on. Major replacements can be a problem area for private services.
- Organisation of water delivery according to known criteria. A fair system of rationing and conflict resolution.
- Staff management including incentives for good service, and training to enhance skills.
- Financial management to secure financial resources at least sufficient to pay O&M and organisation of water delivery and, if possible or required, eventual replacement costs and, if possible or required, contribution to other rural development needs.
- Providing all the above at reasonable cost, so as to maximise profit to well-owners and/or farmers (by, for example, minimising staffing costs. State systems are often particularly deficient on this, though there are examples such as in Columbia where economies in this were a high priority after transfer of ownership, (IWMI, 1998)) .
- Clarity and accountability.
- Monitoring ground water quantity and quality and scheme performance and acting accordingly.
- Monitoring whether the system has been effective in raising yields and incomes (ability not merely to improve output of previous crops, but to grow more crops per year, or move into higher paying crops).
- Monitoring whether there are any additional noticeable social benefits, particularly if this is part of the mandate of the manager concerned.

2. MANAGEMENT GUIDELINES

2.1 Introduction

The evaluation of the management of schemes and individual wells in the public and private sector, and in wells which are being transferred, shows that there are certain features which can lead to improvements in groundwater irrigation performance. These project and well management features will be summarised in general terms and their contribution to individual management challenges will be proposed. However, there are broad features in the background and context of projects and wells that can influence their success in management in the public or private sector, or in the transfer of management, and these will be considered first.

2.2 Background and context influences on successful management

The main features which appear to have an influence upon successful management are history of the farmers/project/well and the local people, culture of the farmers and the local people, the physical environment in which the project/well operates and the nature of existing management (see Box 1).

Dependency may be either a hindrance or an aid to management, depending on whether it is financial or service dependency.

Considering and reconciling these influences is important when considering options for management transfer. For example, much has been spoken about the restrictions on transfer associated with dependency upon Government. However, dependency may in itself not be a bad thing if the well is being transferred to a less centrally managed agency. It is a hindrance upon management change if the history is one of financial dependency and the water users are being asked to contribute where they didn't before. If it is a dependency upon a service for which the water users are prepared to pay then it may be an aid to transfer, since the water users may not look elsewhere for their water.

Box 1: Influence of background and context on project and well management

Feature	Aid to management	Hindrance to management
History, (including existing management)	1. Where ***no previous irrigation*** farmers are more prepared to accept responsibility and to pay when see benefits. 2. Where ***no previous subsidies*** or services for irrigation provided free of charge, these are not expected so much. 3. A. Where ***migration*** occurs it can create unity amongst immigrants who use wells and these wells may easier to change. B. In areas where family members have ***gone away to work*** in large numbers, they often return with more money, new management ideas and technologies and create a more receptive audience.	1. Where there ***is a history of irrigation*** farmers tend to be more set in their ways, whatever the existing mode of management. 2. Where there has been a ***history of financial dependency***, then changes in financial management are often resisted. 3. ***Migration*** may interfere with local irrigation markets in cases where the indigenous population have one practice (e.g. free use of well to friends and neighbours) and the immigrants have new practices (e.g. selling of water to neighbours).
Culture	Certain areas in most countries are known for their own personalities, strengths and weaknesses.	
	1. Strong areas when considering management transfer are those known for: - ***progressive farming*** (often close to centres of agricultural/development training); - ***innovative irrigation equipment manufacture*** leading to innovative thinking in irrigated agriculture; - ***self-supporting communities***; - areas with ***lower levels of social conflict***.	1. Weaker areas when considering management transfer are those known for: - ***traditional cautious farming*** with few changes made in any sector of agriculture; - ***no manufacturing of irrigation equipment***, often leading to shortage of spare parts, lack of choice and lack of creative thinking in irrigation in the area; - ***communities heavily reliant*** on outside assistance ***financially***; - areas with a ***lack of cohesion*** and a history of conflict.
	2. Close to markets (where volume of, and changes in, demand are quickly responded to) - benefits of irrigation greater.	2. Remote from markets restricting the incentives for new or improved cropping and benefits of irrigation are more marginal.
	Areas with strong entrepreneurial spirit can be either an aid or a hindrance, depending on the type of transfer.	
	3. ***Independent entrepreneurs may make good single owner/managers***; 4. ***Collective entrepreneurs (businesses) may make good transferees.***	3. ***Independent entrepreneurs may disrupt joint ownership programmes***
	The relative status of water buyers and sellers where selling is in private hands is important.	
	5. Placing management responsibility or ownership in the hands of the wealthier is not necessarily bad - educated, ensure cost recovery, influence with outside agents.	5. Where there are wealthier/higher status water buyers then often refuse to pay poorer or lower status sellers.
Physical environment	1. Where aquifers allow only more expensive wells e.g. deep, thin. Fewer alternatives to managed well. Increases cohesion; 2. Close to markets - reducing transport costs.	1. Easily accessible aquifers can often cause problems in well management where competition erodes command areas. 2. Remote from market - higher transport costs.

2.3 Project management structures and components - guidelines

Important management components include motivation, support/supervision, transparency and accountability, thorough training, engineering, and related management/development (Box 2). Guidelines for these are given in Boxes 3 to 8.

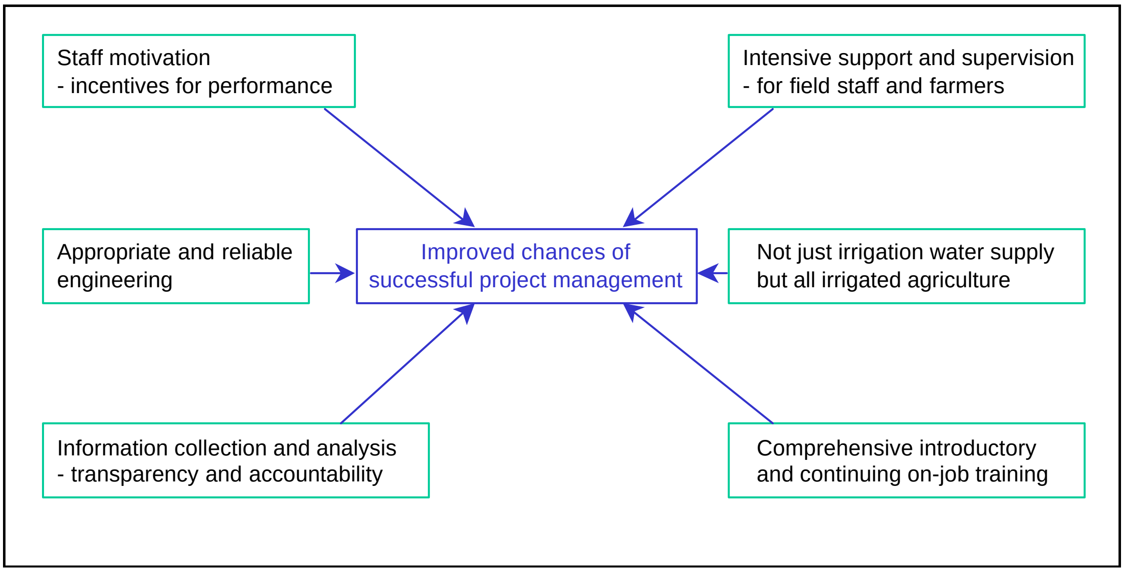
Flexibility is a key component to successful management.

Each well being transferred or facing a change in management has its own unique set of circumstances and a key component of any successful management system is flexibility. Flexibility should be either be:

- inherent within the management system (e.g. through individual contracts between seller and individual buyers as with BMDA), or

- present in dealings with individual wells (as in the PATA Project where rules and regulations are determined by the farmers themselves, with support from project staff). A fixed set of rules and conditions for all wells being transferred may work for some wells, but is unlikely to work for all.

Box 2: Project management issues contributing to greater success in irrigation management in any sector



Box 3: Guidelines for staff motivation

Feature:	Staff motivation through financial reward and penalty
Contexts:	All projects managed by an organisation, whether in the public or private sector. Recognising that irrigation management is a job and not done for any altruistic purposes for the benefit of farmers. Recognising that financial rewards often speak louder than words. Organisations which were looked at that offered financial rewards performed better than those that didn't and the staff appeared more enthusiastic. Particularly important where a scheme is close to full development. Unofficial income may come from the farmers or through the tendering process for development projects. As the development of a project nears completion so attention is turned more towards the farmers.
Guidelines:	1. Incentive schemes are an effective way of increasing productivity and reducing income from unofficial sources. 2. Depending on the responsibility of the staff member, incentives may be based on targets for number of wells operating, area irrigated, and/or charge recovered. 3. Two incentives - (i) individual, based on performance of single or few wells and (ii) organisation bonus based on performance of the whole organisation. 4. For Government schemes another incentive is to make payment of salaries dependent upon project income, i.e. remove them from central Government revenue budget (guaranteed income whatever performance) and place them under project income budget. 5. An incentive scheme requires detailed information and analysis of well performance data for each individual well, including area irrigated, charge recovered, outside influences on well performance (weather, power) and staff job information. 6. Penalties should not be on salary but on allowances and should be held, repayable if performance improves.
Risks:	1. Appreciative words for a job well done not pay bills. A job well done should be officially recognised and rewarded. Without reward for a job well done then the temptation to increase income from unofficial sources increases. 2. The level of incentives should be sufficient to encourage performance, otherwise the pursuit of unofficial income will not be reduced. Incentives should be as a percentage of profit over target, not out of the core income. 3. If performance of a well is the only indicator of success then this may lead to inconsistencies in rewards and lead to resentment. Usually a well is supported by a team of people (operators, mechanics, engineers) and the success of the well may be due the efforts of just one of the team or all of them. Team and individual performance should both be rewarded. 4. Well performance may be affected by a variety of criteria outside the control of staff (e.g. power cuts, weather). Incentives should account for these. Targets should be flexible to account for this. 5. The success of an incentive scheme requires much information, otherwise inconsistencies and resentment may follow. 6. Penalties should not be too punitive or resentment and lowering of morale may ensue and opportunities should be given to recover the penalties through improved performance. 7. Flexibility and discretion should be used to avert resentment, particularly where there are many staff and where some form of staff representative body exists.
Benefits:	1. An effective incentive scheme produces improved well and agricultural performance. 2. Project income is increased. 3. The income of well performing staff is increased.
Target audience:	All organisations, whether public or private - particularly important when management changing.
Examples:	See BMDA and GKF in 'Reference manual – manageability' for project contexts

Box 4: Guidelines for staff/farmer relationships

Feature:	**Staff/farmer supervision and support**
Contexts:	All projects managed by an organisation, whether in the public or private sector.
Guidelines:	1. Have many staff in close liaison with farmers, in addition to the operator. Either by basing field staff close to the well or wells or intensive support service staff regularly visiting wells to provide season round support to the farmers. GKF have Farm Managers who are responsible for one to two wells, depending on management agreement type. They live near the wells. PATA Project have increased staff numbers to provide frequent support. 2. Support functions may include: - quick response to technical problems or breakdowns; - water management and agronomy problems; - supervising provision of inputs, credit, cost recovery; - recording information and keeping accounts. i.e. field staff to be extension officer, irrigation officer, accountant, counsellor all in one. 3. Field staff to be well educated and well rewarded for good performance. 4. Thorough training of field staff in above subjects. 5. Line management to back up the field staff.
Risks:	1. A labour intensive system requiring investment in housing, training and support but results suggest that this is usually worth it. 2. Trouble from some farmers can make positions untenable for Farm Managers and support should be given to staff who face unsubstantiated accusations from some in the community.
Benefits:	1. Increased confidence of farmers in project support. 2. Improved well and agricultural performance. 3. Project income is increased.
Target audience:	All organisations, whether public or private - particularly important when management changing.
Examples:	See BMDA, GKF and PATA Project in ‘Reference manual – manageability’ for project contexts

Box 5: Guidelines for transparency and accountability

Feature:	**Transparency and accountability** All support staff and water users need to know where they stand and what their efforts or payment is achieving. Information is important in day to day management and planning.
Contexts:	All projects managed by an organisation, whether in the public or private sector. All wells, particularly those serving many water users.
Guidelines:	1. Recommended information collection at well level is: - technical data by well- command area. SWLs (daily), hours pumping (and to who), hours power interruptions (if electricity), energy consumed; - agricultural data by field- crops grown (and areas), yields, water applied (hours, no. irrigations), inputs used and source of inputs; - management data - comments, complaints, meetings recorded daily, cost recovery. 2. Data to be recorded and reports produced regularly.
Risks:	1. A time consuming system but manageable with operator and close supervision by field staff. 2. Ideally data management and analysis by computer for rapid analysis and response – equipment and training required.
Benefits:	1. Performance assessment, contingency planning, strategic planning capabilities all improved. 2. Problems identified early or data for use in discussions with farmers and outside agencies.
Target audience:	All organisations, whether public or private - particularly important when management changing.
Examples:	See BMDA in ‘Reference manual – manageability’ for project contexts

Box 6: Guidelines for training

Feature:	Training
Contexts:	All projects managed by an organisation, whether in the public or private sector, particularly in situations where close support and information collection and analysis is to be carried out.
Guidelines:	1. Intensive training immediately upon recruitment, to include: - project/organisation philosophy, goals, methods, roles, responsibilities and expectations; - technical training in well managem ent, water management and agronomy; - management training in accounting, record keeping and organisation management style Training should be both centre and field based wherever possible and tested and licensed/certified upon conclusion. 2. Constant training whilst in service in new ideas and refresher courses.
Risks:	1. A time consuming system requiring investment. 2. Knowledge of systems may lead to knowing how to play the systems.
Benefits:	1. Throughout business throughout the world training has been proved to be a motivation for staff and to produce results in terms of productivity and staff development. 2. Training one member of field staff can lead to training of many farmers.
Target audience:	All organisations, whether public or private - particularly important when management changing.
Examples:	See GKF, PPSGDP and PATA Project in 'Reference manual – manageability' for project contexts

Box 7: Guidelines for engineering

Feature:	Engineering
Contexts:	All projects managed by an organisation, whether in the public or private sector. Particularly high discharge wells with large potential command areas. A well and its conveyance system need to be reliable to increase effective management. Effective management and cost recovery can be extended by increasing the command area through an efficient conveyance system.
Guidelines:	1. Minimise interruptions to water supply by (i) choosing the most appropriate power source for the locality (ii) providing both power sources for each pump (for example, if going through a process of electrification, keep the diesel engine in place as stand by). 2. When an efficient management system is in place that the farmers like, increase the utilisation of the well and potential cost recovery by providing a conveyance system that minimises losses and maximises discharge to the field, through: - partial or full buried pipe systems; - lined channels.
Risks:	1. Potentially costly investments, particularly if full buried pipe systems. Ensure users/potential users are on board before extending/improving system. 2. Increased pressure on well management through increased number of customers. Management structure needs to cope with this.
Benefits:	1. Higher levels of water usage and revenue per well, so increasing likelihood of profitability. 2. Less time in irrigation for each farmer through higher discharges to field.
Target audience:	All organisations, whether public or private - particularly important when management changing.
Examples:	See BMDA and GKF in 'Reference manual – manageability' for project contexts

Box 8: Guidelines for related management/development

Feature:	**Related management/development**
Contexts:	All projects managed by an organisation, whether in the public or private sector.
Guidelines:	1. Greater success is apparent if all aspects of irrigated agriculture are considered by the organisation, rather than just provision of irrigation water. Related features include: - assistance with access to, or direct provision of, other inputs, making sure they are of adequate standard. Payment for these inputs can often create or increase well profitability; - providing formal and informal water management and agronomy training, since extension agencies are often over-stretched and unable to help on a frequent enough basis. This is also in the projects' interest since proper training of farmers can increase productivity and increase income from all payment systems but especially if payment is through crop share; Training may be through field staff or through demonstration wells and farms. - assistance with access to, or direct provision of, credit facilities for irrigated agriculture; 2. Improving local infrastructure beyond the well, such as marketing arrangements, road improvements, transport facilities.
Risks:	1. Potentially costly investments on the infrastructure component, with no immediate or guaranteed return. Would probably require capital investment from Government or grant aid support.
Benefits:	1. Higher potential revenue per well, so increasing likelihood of profitability and sustainability. 2. Requires no extra staffing in the field, just well trained staff in a variety of disciplines.
Target audience:	All organisations, whether public or private - particularly important when management changing.

2.4 Well management - guidelines

For wells that are in the private sector, owned by a group, the structure of management is pretty much the same across the sub-continent. Someone needs to be in charge since the well will not take care of itself and this someone is either the owner, a self-appointed manager or an elected manager, with or without a self-appointed or elected committee. It is usually better if the person in charge is from a wealthier background with a higher level of education and more confidence and authority to deal with outside agencies. It is also usually better if the well is run when seen as a commercial enterprise and there is a clear seller/buyer system in place. So long as the scope for extortion is restricted, the market created by this system can usually assist in effective use, i.e. if the price is too high or supply is not reliable, farmers will not pay, and will either look for other sources of water or reject irrigated agriculture.

Success in individual well management is also enhanced if there is:

- complete autonomy and self-governance
- acceptance of the proportionality concept in capital contribution, water shares, profits and risk taking

- implicit acceptance of the manager
- willingness to put all powers in the hands of the manager and the managing committee, since they are often local business managers too
- costly exit

The most recent groundwater development project in Pakistan, the PATA Project, has tried to address the problem of conflict by carrying out rapid rural appraisals of beneficiary groups prior to development and rejecting potential sites where (i) there is a history of conflict in other areas of the community, (ii) there is a dominant individual or clan, and (iii) there is not sufficient interest in the project.

3. GUIDELINES FOR MANAGEMENT TRANSFER

The transfer of groundwater irrigation has often been carried out for 'negative' reasons, i.e. for the Government to release itself from the heavy financial burden of O&M and support services for wells. The transfer has not been demand led, it is not something that the farmers either requested or necessarily wanted, it was forced upon them. In this situation, it is not surprising that in many cases the attitude of farmers has been unenthusiastic and uncommitted. As in any society, there are those who are dynamic and/or commercially minded, looking for opportunities for improvement or financial gain in all they do, and there are those who lack drive and/or initiative and depend upon others for guidance or support. In the culture of Bangladesh and Pakistan there is also a long history of clan and political loyalties which can and often do lead to conflict. When dealing with large technologies with the need for a large number of people to pay for it, these factors can, and often do, play a significant role in the management of the technology.

Transfer of the wells could be seen as a success on two very different counts, depending on the motives for transfer and perspectives of those involved:

- wells are no longer a drain on Government financial resources and public money is available for other pressing needs. What happens to the wells after transfer is no longer their responsibility and no longer affects public finances. Whether the farmers want it or not is immaterial.
- well performance improves under new management for the benefit of the farmers and the nation, through increased production and income.

The first indicator of success usually requires transfer only to be a one-step process, with no further public involvement. The second measure of success requires considerably more time, energy and resources in the medium term to achieve, but the results are likely to justify the commitment of these inputs.

To increase the chances of successful and sustainable transfer:

- as with many new projects introducing new technology, **farmers should first be made aware of proposals and be consulted**. Given that they will be managing the wells post-transfer, it would be useful either to know how they would like it to be done (if at all), or, if they don't know, to propose measures and note their response.

- **transfer often occurs because wells are not profitable. The reasons for this need to be clear.** It could be because of failings in the management system, the revenue collection system, or that the technology is not appropriate. Knowing this will assist in decisions taken as to what will be transferred and how. With the benefit of hindsight, the transfer of many of the DTWs in Bangladesh was transfer of technology that was not suitable for farmer management in many situations.

- **the transfer needs to be demand led as much as possible.** This demand may be present already or it needs to be generated through information and persuasion. Where demand cannot be generated then maybe the option is closure or use of a different technology.

- **any transfer project should be flexible**, recognising that whilst the technology design may be uniform, the contexts in which it operates are varied. Options on how to proceed should be given to the transferees.

- **transfer should not be a one-off action**. The wells have received support in the past (be it of variable quality) whether through conflict resolution, technical assistance or financial assistance. For many groups, taking on the management of the technology is a new and problematic experience. Intensive training can overcome many of the problems, but practical support and advice is often required, whether it is ensuring that spare parts are available or technical assistance is provided on demand. These would not be free services but they need to be present, either through the public or private sector.

- many of the transfer projects have been, and are still, large scale, involving the transfer of hundreds or thousands of wells in a short period of time. This places enormous pressure on the staff and the system of those agencies carrying out the transfer and reduces efficiency and attention to the needs of the transferees. Despite this, in terms of numbers of wells transferred many projects have been, and are successful. However, it should be recognised that these are major and long term changes it is surely right to make sure that it achieves sustainable development in the future rather than an immediate reduction in public sector financial commitments.

GUIDELINES - ASSOCIATED RURAL DEVELOPMENT

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1. INTRODUCTION

From the research carried out in support of this project, the main priorities in rural development relating to groundwater irrigation technology transfer appear to be:

- the role of, and benefits to, women involved in groundwater irrigation;
- approaches to associated rural development by projects, in whichever sector; and
- methods by which outside organisations, such as NGOs, can produce improved performance from target groups, looking particularly at attitudes and communication strategies.
- the nature of additional benefits which can be derived from improved use and management of the technology, in whichever sector;

In the 'Reference Manual', each of these is covered and general guidelines given. These guidelines will focus on gender issues and on methods of communication.

2. WOMEN AND GROUNDWATER IRRIGATION

2.1 Examples from Bangladesh and Pakistan

Before presenting guidelines on the development of women's roles in irrigated agriculture, examples are given of how one NGO in Bangladesh (Box 1)and one NGO in Pakistan (Box 2) approach development for women.

Box 1: An example from Bangladesh - GKF

1. A ***broad approach***, recognising that irrigation is just one of the activities in irrigated agriculture that need support.
   - where land is required, GKF negotiate on behalf of women to acquire leased land. At present this is on a seasonal basis but they are moving towards finding long-term leases.
   - GKF provide credit, inputs and support for marketing (s ometimes buying direct from women farmers under contract)
   - also supporting more traditional enterprises, and encouraging innovation in traditional enterprises, such as vegetable seed production, tree nurseries and livestock.
   - alongside agricultural support activities, also providing information on sanitation and basic health care through the Women's Support Programme.
2. ***Flexibility and continuous presence*** of field staff through their Farm Manager system (see 'Management Guidelines' for details of this system), enabling:
   - effective communication and monitoring
   - building close working relationships with women (many Farm Managers seen as 'brother' or 'sister')
   - keeping close relations with wealthier farmers who may provide land for lease or who may be affected by loss of labourers following the development of women's own irrigated agriculture and the shift in power relations.

Box 2: An example from Pakistan - Aga Khan Rural Support Programme

1. A variety of credit 'windows' to suit the needs of the borrower:
   - short-term loans
   - medium-term loans
   - WO Credit Programme loans (1 year loans secured against the savings of the WO)
   - micro-enterprise credit programme (MECP) - individual loans for working capital, payable 6 months to 1 year after disbursement
2. A variety of 'production packages' within agriculture to suit the desires of the individual or groups of women, which come complete with basic infrastructure and a set training and after-care programme.
3. Production packages take the form of subsistence packages (concentrating on basic practical needs) and of graduated packages with lead towards greater commercial activity.
4. Women are not only invited to raise their voices at meetings but expected to do so.
5. AKRSP do not directly interfere with the evolution of the structure of the group.
6. Women are reported to be more interested in increased productivity and income than any concern about increased workload.
7. The initial meetings are about capital accumulation by contributions at meetings. This provides equity that drives the loans and savings programmes. Successful groups may end up providing loans to men in the village.
8. Decisions about loans (who will receive, amounts and payback periods and rates) are made by the WO themselves.
9. As a consequence of increased provision of income to the household, women are having greater say in determining household expenditure.
10. Women are increasingly keen to participate in decision-making processes on issues which affect them or their family.

2.2 Summary of key issues regarding women in irrigated agriculture

The evidence from the surveys carried out point to key issues when seeking to improve the situation for women in irrigation. The first points are neatly summarised by van Koppen (in Merrey & Baviskar, 1998):

- explicit targetting of individuals, not households (the empowerment approach);
- protection from expropriation without compensation, aim at more equality in resource rights;
- improvement of access to all inputs, markets and relevant institutions;
- linking water rights to the land user and strengthening the rights to irrigated land;
- linking water rights to investments and, in private sector irrigation, providing appropriate equipment, financing facilities and training; and
- inclusion in planning procedures from the start of any programme.

Other factors which should be considered in the empowerment of women in the management and operation of groundwater irrigation facilities include:

- work, to start with, with strong groups of women. Strong groups are those which are cohesive, active, effective in decision-making and problem solving, able to mobilise their own funds and labour and which have well developed external linkages;
- technical and managerial skills are often less developed amongst women and more care and time should be given to these than for men;
- accounting and book-keeping skills (and the literacy required to perform these) are extremely important factors in enhancing the performance of women in the market place in many aspects of their working life and should be given high priority;
- if groups are being created to manage a well, screening should be carried out to ensure that the groups are not too financially diverse, as this can lead to conflict over money and labour;
- if a group is being formed to run a well, try and take over an existing command area (which has maybe suffered from a well going out of use), rather then developing a new command area. Farmers used to receiving water are more welcoming towards water sellers.

Two other important points refer to the roles of outside agencies in their attitude to women and in their emphasis on the roles of women:

- agencies involved in irrigated agriculture, in whatever sector, should seek to positively discriminate in favour of women in employment wherever appropriate, be it as extension workers, operators, or nursery staff.
- when survey work is carried out in monitoring or researching issues relating to groundwater irrigation, gender specific data should be collected and statistics published.

3. METHODS OF COMMUNICATION

The three main approaches that have been adopted by these guidelines are technical, economic and management. A summary of the approaches and the most effective means of communication are shown in Box 3, along with examples of current or potential use.

In the case of the technical approach, practical demonstration is the most effective tool, based on the premise that 'seeing is believing'. For economics of technology options then demonstration is also effective, both of demonstrating economic savings from technology selection and from technology management. Simple accounting and economic decision-making training can be carried through spoken explanation using examples familiar to the host. Investment decision-making faces many problems in financing and these should be addressed at the earliest possible moment. In the case of management, methods of communication can range from simple explanation for small issues, to broad and comprehensive 'packages' of communication around a common theme for larger scale projects.

To get a message across when developing new groundwater irrigation projects, or seeking to transfer projects from one technical, economic or management mode to another, the likelihood of success can be increased by:

- the new or changed management system should not only be easy to administer, but it should be a system which is easy to communicate to those who have to work with it;
- the hardest aim to achieve is that of replicability, particularly if the target audience is large or is to grow. Effective communication of ideas and concepts to recipients appears to come from intensive and repeated communication, usually involving a great deal of staff time and large numbers of staff. The most effective method of communication, in terms of cost and of chances of success, is to transfer the responsibility of communication to the farmers themselves. This responsibility should be implied rather than explicit. For example, if one farmer can be:
    - convinced that a particular combination of equipment, and/or methods of installation and operation will result in lower total costs;
    - persuaded to place a board near his well that shows the technical specifications and the breakdown of costs, then other farmers walking past will be intrigued by the improved cost figures and will talk to the owner of well about how he has managed to reduce costs. There is no requirement on the part of the initial farmer to 'preach' about his well.
    - if an idea is good, and the farmers like it, and its cost/revenue implications, then the farmers will be very quick to take on the idea. This is how the growth in private sector tubewells occurred in the first place.

Box 3: Methods of communicating technical, economic and management information for groundwater irrigation and associated issues

INFORMATION	TECHNICAL	ECONOMIC	MANAGEMENT
Examples of information to be communicated	1. Good practice in choice of equipment 2. Good practice in equipment operating methods 3. Good practice in distribution channel selection and maintenance	1. Good practice in evaluating cheapest total cost, and selection and operation of equipment based on economic criteria 2. Good practice in investment decision-making 3. Good practice in financial planning and sources	1. Good practice in day-to-day management of wells 2. Good practice in payment and accountancy systems 3. Good practice in management of system maintenance
Methods of communication	1. Demonstration of technical features 2. Directly compare different equipment and relative performance 3. Measure and show performance using easily understood variables 4. Show performance of different distribution systems	1. Whilst showing technical features, stress the financial implications of differences in equipment quality and performance 2. Directly compare costs of differences in equipment quality and performance 3. Publicise differences in total costs for equipment, e.g. by placing boards by wells with higher quality performance and lower running costs.	1. Use a variety of messages with a common theme and characters to get across ideas, such as: - maps - videos - field visits - cartoons/leaflets - radio dramas 2. Use materials and characters immediately identifiable to local people
Examples of methods of communication	See Box 6 of 'Reference Manual - Conclusions and Recommendations'	See Box 8 of 'Reference Manual - Conclusions and Recommendations'	1. Drainage Advisory Service (DAS) of the Left Bank Outfall Drain (LBOD) Project, Sindh, Pakistan A big project covering a large geographical area. Used few staff to communicate with many farmers encouraged to take over maintenance of irrigation and drainage channels of 'scavenger' wells. Field visits were backed up with all of the above methods. Used drawings painted in local style and with a cast of characters common through all media and who became familiar to farmers. 2. PATA Project, NWFP, Pakistan 150 new wells sunk for farmers to be managed by farmers. Higher staff density than DAS. Used maps as basis for well site selection and location of distribution system. Maps designed by local truck decorators and using features familiar to all.