PN-AAT-155
ISN 47791

Report of Three-Week Study in Bangladesh For The Cornell/USAID Water Management Synthesis II Project

by

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14 July 1983

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ABBREVIATIONS

BADC	Bangladesh Agricultural Development Corporation
BRRI	Bangladesh Rice Research Institute
BTU	British Thermal Unit
CARE	Concerned Americans for Relief Everywhere
DTW	Deep tube well
HTW	Hand tube well
HP	Horsepower
IBRD	International Bank for Reconstruction and Development
ILO	International Labor Organization
IRRI	International Rice Research Institute
LLP	Low lift pump
MCC	Mennonite Central Committee
MOA	Ministry of Agriculture
MWM	Morten Worke Mannheim
OEM	Original Equipment Manufacturers

1. INTRODUCTION

Bangladesh consists of 35,551,000 acres - slightly smaller than Wisconsin - with a population of 89,900,000 people or an average of 2.5 persons per acre. Less than one quarter of the population is literate. 21 million acres (60% of the land) is arable with about 55% single cropped, 37% double cropped, and 8% triple cropped. Bangladesh is a flat river delta with most of the country less than sixty feet above sea level. Intersected by the Tropic of Cancer the Country has a tropical monsoon climate and receives from 60 to 200 inches of rainfall of which 90% falls during the monsoon period from May through September. Irrigation is required to grow crops during the dry ("rabi") season from November through March. It is estimated that the annual ground-water recharge is sufficient to support the full development of irrigated agriculture on 16 million acres as compared to the present 3.6 million acres of irrigated land.

Rice is the basic food. Traditionally "Aus" is the broadcast rice crop grown during the early period of the monsoon - April through July. "Aman" (transplanted) is the rice crop grown late in the monsoon period - July through November. "Aman" (broadcast) or "deep water rice" is grown from February through October. "Boro" is the fully irrigated rice crop grown from January through April under irrigation during the dry ("rabi") season.

Sixteen percent of the land has access to irrigation water (Ref.2). Additional tube wells will provide more food production during the dry season as well as in the other season, for the beginning and the

end of the monsoon rains are highly variable. Supplemental irrigation will insure good crops. Over most of Bangladesh there are groundwater aquifers which are suitable for pumping with the exception of an area south of Jessore and Comilla where groundwater is saline, and in the eastern and northern hill areas. At present the groundwater reservoirs is in equilibrium on an annual basis. The water table is high at the end of the monsoon season and on the average twelve feet lower by the end of the dry season (Ref. 12). As an example, BRRI near Dhaka, recorded (Ref. 13) that the water table was 11.5 feet from the surface in September but had dropped to 41.3 feet in March. The water table began to rise one month after the beginning of the rainy season. BRRI experiments indicate that 2,204 liters (77.8 cu. ft.) of water are required to produce one kg of paddy.

Hanratty (pg. 30 Ref. 14) states that the following water requirements are required to grow crops in the dry season in Bangladesh:

Boro Rice	40.4 inches	Jute	10.2
Wheat	15.3	Vegetables (2 crops)	17.9
Potato	15.3	Transplanted Aus Rice	19.0*
Chillies	10.1	Transplanted Aman Rice	12.1*

* Supplementary irrigation

Planners in Bangladesh usually refer to irrigation schemes utilizing tube wells as "minor irrigation" while schemes involving gravity systems, dams rivers and LLPs are referred to as "major irrigation".

The following terms are required to discuss irrigation and crop yields in Bangladesh.

Acre is a land area of 43,560 sq. feet.

Decimal is 1/100 of an acre, 435.6 sq. feet.

Bigha is 1/3 of an acre.

Maund is 40 seer and equals approximately 82 lbs.

Seer is 80 tolas and equals approximately 2 lbs.

Tola is the weight of 16 anna pieces (coins) and is approximately ½ oz.

Gallon in Bangladesh refers the Imperial gallon.

1 Imp. gal. = 1.201 U.S. gallons

A Cusec is a flow of one cubic foot of water per second. It is equal to 449 U.S. gallons (374 Imperial gallons) per minute approximately equal to 1 acre-inch of water per hour.

I arrived in Dhaka on June 25. USAID and the Cornell representative, Dr. Murray-Rust, has provided excellent support for me to obtain information for my task. This has been accomplished although the three weeks in Bangladesh coincided with the lunar month of Ramazan and the Eid-ul-Fitr holiday. Trips were made to Bogra, Rajshahi, Kushtia, Mymensingh and Tangail.

After a period of three weeks, some questions remain unanswered. For example, I was not able to obtain the names or the characteristic of the pumps used in the deep tube wells, the shallow tube wells or the low lift pumps. The many studies of tube wells do not contain pump information although an engine model is sometimes listed.

2. WHAT TYPE OF GROUND WATER IRRIGATION EQUIPMENT IS REQUIRED?

In 1980 3.65 million acres of land were under irrigation. The Government of Bangladesh wants to double the irrigated area to 7.22 million acres by 1985.

In Bangladesh the terms DTW, STW, HTW, LLP, and traditional are used to describe irrigation equipment.

DTW means a deep tube well. A turbine pump sits down in the well. The engine sits on the surface.

STW means a shallow tube well. An engine and a centrifugal pump on the surface suck up water from the well.

HTW means a hand tube well. A manually powered pump is used to draw water from the well.

LLP means low lift pump. An engine driven centrifugal pump is used to draw water from a stream or a pond and pump it into an irrigation channel.

Traditional Irrigation includes the manually powered swing basket or doon for lifting water from a ditch or pond into a field or a shaduf for lifting water from dug well.

Table 1 (based on table 11 of Reference 12) describes the pump population in Bangladesh.

Table 1

Actual And Estimated Pump Population In Bangladesh

Type	Actual, FY 1980 Number	Actual, FY 1980 Area (Mac)	December 1982* Number	Target FY 85 Number	Target FY 85 Mac.
LLP	38,600	1.47	-	50,000	2.05
DTW	10,000	0.55	12,000	25,000	1.50
STW	20,000	0.20	78,000	130,000	1.60
HTW	100,000	0.03	165,000	500,000	0.20
Sub-Total:		2.25			5.35
Minor Irrigation					
Traditional Irrigation (doon, swing basket, shaduf)		1.20			1.00
Major Irrigation (BWDB)		0.20			0.85
		3.65 million acres			7.20

* from Table 1, Ref. 2

There is disagreement among various reports and studies about the amount of land to be irrigated by 1985 and the amount of each type of irrigation (Table 3.2 Ref. 14). These differences are summarized in Table 2.

Table 2

Differences In Total Irrigated Acreage And Percentage Of Total Irrigated Area Under Each Pump Type

Study Group	Total Irrigated (000 Acres)	% of total irrigated acreage in Bangladesh		
		DTW	STW	Manually
MOA	5,710	16	8	17
IBRD Report	4,683	11	11	25
IBRD Model	3,730	18	8	22
Harvard Study	5,992	27	49	-
META Systems	4,392	2	23	23.5

The IBRD macro model assumed 16,500 DTW @ 40 A/well; 53,333 LLP @ 30 A/pump; 35,000 STW @ 8.3 A/Well; 90,000 HTW @ 0.33 A/Pump; 350,000 A by gravity and 800 A* by traditional. I have combined HTW and traditional under manually.

* 800 A is very low and must be a typographical error. 800,000 A is reasonable.

If the goals for extracting ground water are to be met, then between December 1982 and 1985 the following wells for minor irrigation are to be installed:

DTW	13,000
STW	52,000
HTW	335,000

I believe the above schedule is over optimistic, but outside of the DTWs' I don't know how many STWs, HTWs and LLPs will be installed? DTWs have been installed at a rate of about 1000 per year, so over the next three years there will probably be 3,000 DTWs installed.

To date governmental agencies have been the only significant customers for pump sets so the market has been characterized by few purchases but of large quantity. With the move ~~of~~ to privatization the market will be more volatile, particularly for the STW equipment.

A problem in rationalizing the choice of wells and pumping equipment is that a detailed hydrological description suitable for selecting types of wells is not available. If the water table and aquifer in an area are such that STWs and HTWs are satisfactory then there may be no need to install DTWs in that area. The types of tube wells and associated pumps have specific characteristics and should be used in specific conditions in order to obtain the most irrigation water for the investment.

I have read a number of water management and irrigation reports while in Bangladesh, but none of them have provided me with essential information about depth to water or model of pump in the DTW, STW or

LLP under study.

The next two paragraphs are a review of pump fundamentals. If you are familiar with pumps skip down to Deep Tube Wells.

A pump's discharge (cusec), head (feet) and power (HP) are related. The increase of the energy content of the water pumped is expressed in units of energy per unit of mass of water, such as foot-pounds per pound of water. The pound units cancel out so the terms for head is described in feet. The "head" imparted to the water must equal the sum of the suction head (vertical distance from water level to pump), static head (vertical distance from pump to discharge point), friction losses in the pump and suction line, and the pressure head (the height to which the water would rise because of its velocity when it leaves the pump).

The discharge of a centrifugal or turbine pump is directly proportional to engine speed; however the head varies as the square of the speed while the power requirement varies as the cube of the speed. If a pump were delivering 2 cusec at 2000 rpm and consuming 20 hp and the speed were reduced to 1700 rpm, the pump would then deliver 1.7 cusec and require about 12 hp at the pump. However, the head would drop to 72% of what it was at 2000 rpm.

The following section describes the various types of tube wells and pumps used in Bangladesh.

Deep Tube Well (DTW)

A DTW is usually between 150 and 300 feet deep. A typical 300 foot well will have 80 feet of 14-inch diameter well casing, 100 feet of 8-inch diameter well casing, and 120 feet of 8-inch diameter screen.

The DTWs are drilled with rotary drilling rigs. The DTW is equipped with a turbine pump sitting down in the well. The pump is powered by means of a vertical drive shaft and a right angle gear box attached to a 20 or 25 hp diesel engine or 20 hp 3-phase 415 v., 50 cycle electric motor mounted in a pump house at the top of the well. Most DTWs are rated at 2.0 cusec capacity although in the North Bangladesh tubewell project are 377 DTWs with capacities of 3 to 5 cusec.

A typical DTW 2 cusec setup could be a 3 cylinder MWM (Morten Worke Mannheim) D 327-3 3-cylinder diesel engine delivery 25 hp at 1500 rpm, an Amarillo Gear Co. right angle gear drive which speeds up the 1500 rpm to the pump speed of 2000 rpm and a KSB turbine pump. Typical diesel engines used for DTWs are MWM D 327-2 (2-cylinder 20 hp @ 1500 rpm), MWM D327-3 (3-cylinder 25 hp @ 1500 rpm), and Ruston 3 YWA (3-cylinder 20 hp @ 2000 rpm). (Ref. 15).

An insight into DTW performance is available from the CARE program (Ref. 3). In Parbatipur thana in Dinajpur district in Northwest Bangladesh where pumping for the dry season began in January 1982 and continued until the end of June 1982 there are 78 DTWs and 111 STWs belonging to the Bangladesh Agricultural Development Corporation (BADC). Of the 78 DTWs, 66 were "functioning smoothly". Of these, 44 were in the CARE program in which the BADC maintenance was good. The depth to water, cumulative hours on the engines, drive trains, and pumps and model of pumps were not listed. Table 3 summarizes some of the performance characteristics of these pumps.

Table 3

Summary of Performance of CARE Managed DTWs In Parbatipur Thana, Dinajpur District, 1982

Average discharge per DTW per season	1.61 cusec
Highest discharge per DTW per season	1.8 cusec
Lowest discharge per DTW per season	1.3 cusec
Average hours of operations per DTW per season	1222 hours
Average days of operation of DTW per season	98 days
Maximum days operation of DTW per season	128 days
Minimum days of operation of DTW per season	65 days
Average days of breakdown of DTW per season	1.9 days
Highest days of breakdown of DTW per season	8 days
Average diesel fuel consumption per hour	0.72 Imp. gal.
Average area served by DTW	79.2 acres
Highest area served by DTW	111.2 acres
Lowest area served by DTW	34.5 areas
Average acres irrigated per cusec	49.2 acres/cusec

A DTW costs BADC Tk.375,000. Because a DTW must serve a large command area DTWs will remain in the government sector. I have not considered them as a part of the equipment for the Water Management Systems program except in regards to engine and pump mechanics.

Shallow Tube Well (STW)

A STW is usually 80 to 150 feet deep with a 4-inch pipe well casing and strainers. A Centrifugal pump and 5 to 6 hp diesel engine or electric motor are mounted at ground level on top of the well. Discharge is usually 0.5 - 0.75 cusec. Since the pump is at the top of the well, the water must be sucked up from the water level to the pump. The theoretical maximum height which water can be sucked up at sea level is about 33 feet, so a STW will not pump water if the water level is more than 33 feet below the surface. Under actual conditions because of pump imperfections, leaks at joints, etc. the water level should be a maximum of 25 to 30 feet from the surface.

In areas where the water table has fallen it will be necessary to dig a pit around the STW and set the STW pump set in the bottom of the pit so that the suction lift does not exceed 25-30 feet.

The shallow tube well is usually drilled manually by a percussion method. A crew of five can drill a shallow tube well and install 100 feet of 4-inch pipe casing and 40 feet of strainer (4-inch pipe perforated with 3/4 inch diameter holes and covered with fine brass screen) in 3 days. I saw a STW being drilled between Natore and Rajshahi on July 4.

Diesel engines such as the Yanmar TS 180C, Deutz 210, Kirlosker RA2, Mitsubishi 75, are typical of the engines used on STW pumps. I was unable to obtain performance curves for pumps used on STWs.

STW's are easily drilled, the pumps are manufactured in Bangladesh and the 5 to 6 hp one or two cylinder diesel engines can be used to power equipment such as rice mills when not being used for pumping water. The STWs lend themselves to "privatization" as evidenced by the farmers who are purchasing STW's. One danger is that too many STWs are too closely sited, thus reducing well discharges; another is that if STW's are located close to a DTW, the DTW may pull down the water table below the lower operating limit of the STWs.

Low Lift Pumps (LLP)

This study is concerned with ground water. LLPs are used for lifting surface water from irrigation canals, rivers, and ponds. The typical LLP in Bangladesh is centrifugal pump powered by a 16 to 18 hp diesel and delivering 2 cusec against a total head of 40 feet. Smaller LLPs such as manufactured by Milnars in Bangladesh and powered with a 5 hp, 1500 rpm Kirloskar diesel is rated at 0.75 cusec at a total head of 30 feet. The LLP is being discussed here for centrifugal pumps and diesel engines are very similar, and in some cases identical, to the pump sets used for STWs.

If LLPs are to receive some attention, one should consider the Thai type of axial-flow pump which is not used in Bangladesh. The pump is essentially a 6-inch diameter, 12-feet long sheet metal tube, with a propellor at the intake end. The pump just described is the IRRI version which weighs 100 pounds (45 kg) without engine (Ref. 6).

Performance characteristics of this pump are given in Table 4.

Dr. Azharul Haque at the Bangladesh Rice Research Institute (BRRI) has been testing a vertical version of this pump.

Where a centrifugal pump is being used to pump water from a low lift and more power than required is going into the output pressure, a suction nozzle can be attached so that the centrifugal pump becomes a jet pump and pressure is traded off for increased flow. The jet pump nozzle can be detached if a higher head is required. For example a centrifugal pump delivering 0.5 cusec at a total head of 70 feet, when equipped with the proper jet nozzle will deliver 1.0 cusec at a total head of 22 feet (Ref.7). The U.S. Navy uses this principal on some of its shipboard pumps and IRRI has constructed jet attachments for the 5 hp centrifugal pump which mounts to the IRRI pedestrian tractor (tiller).

Although the jet nozzle device might increase the efficiency of LLPs in Bangladesh, I believe there will be a better return in attempting to improve the power efficiency of DTW and STW pump-engine installations and the command area of DTWs and STWs.

Manually Operated Lifting Devices

In Bangladesh the swing basket, doon, and shaduf are traditional manually powered low lift pumps (Ref.16). The "shaduf" is a counter-balanced lift which can be used to lift water from a shallow dug well or a pond or ditch. The doon is a tilting trough. The shaduf and the doon are each operated by one man. The swing basket is operated by two men. Performance characteristics of these devices are given in Table 5.

Table 4

Performance Characteristics of IRRI Axial-Flow Pump

Depth from Water Level to discharge point (ft)	IRRI Axial-flow Pump (Liters/Sec.)	Discharge at 2890 RPM (Acre-in/Hr. or Cusec)
5	50	1.76
10	40	1.41
13	25	0.88

Table 5

Performance Characreristics of Manually Operated Lifting Devices

Method	Cost (Taka)	Lift (ft)	Discharge (Ref.5,8,16) Liters/Sec	Cu.ft./Min.	Acre-in/Hr.or Cusec
Shaduf	150	16	1.1	2.4	0.04
Doon	300	3	4.7	10.0	0.16
Swing basket	5	3	4.4	9.4	0.15

The manually operated indigenous LLPs will continue to be used by farmers in Bangladesh because of low initial cost and the availability of labor to operate them. I know of no way in which a USAID program can improve these traditional water lifting methods within the cost constraints of the present models.

Hand Tube Well (HTW)

A HTW is a well where a manually powered irrigation pump is installed. A typical well will be 60 to 80 feet deep and cased with 40 to 60 feet of 1½ inch galvanized pipe (1.9 inch O.D.) and 20 to 40 feet of strainer.

I have a philosophical dislike of using people to pump irrigation water since the task does not make use of man's assets - the ability to think and the brain-hand servo system. Furthermore since a person is a low-powered engine there is little return in wages for a taxing and boresome task. Pumping water with draft animals, wind energy, internal combustion engines, electric motors, etc. is more to my liking.

However, in Bangladesh where persons are employed to break bricks into aggregates, people are transported by bicycle rickshaws, freight is moved on carts pushed by men, boats are powered by oars, and irrigation water is lifted with the doon and swing basket, I have concluded that man-powered pumps on shallow tubewells is a viable option in those areas of Bangladesh where the water table is within fifteen feet of the surface.

What percentages of an irrigated crop is required to fuel the men irrigating a boro crop of rice?

As an engine a man is about 20 to 25% efficient is converting food energy into useful work. This is about the same efficiency that an internal combustion exhibits in converting gasoline into mechanical work. An adequately fed 35-year old European male laborer working an 8-hour day for a 48-hour week has a power output of 1/10 hp over an 8-hour day. The power output of the above laborer can be expressed as

$$HP = 0.35 - 0.092 \log t \text{ where } t \text{ is in minutes.}$$

The equation is valid for periods of time ranging from 4 minutes to 8 hours.

Over 8 hours a man can deliver work at the rate of approximately 1/10 hp. For one hour the power is 0.18 hp. A man of 20 can generate 15% more useful work than the norm and a 60-year old man about 20% less.

Work is the application of force through a distance. The English unit of work is the foot-pound while a common metric unit is kilogram-meter. Units of work are independent of time. Energy and heat can be expressed in the same units as work. However, it is more common to express energy and heat in special units - the kilocalorie in the metric system and the British Thermal Unit (BTU) in the English system.

One Kilocalorie = 3.97 BTU = 3088 ft-lb.

Power is the rate at which work is performed. The faster the work is performed, the greater the power requirement. The unit ~~is~~ of power in the metric system is the kilowatt. In the English system, horsepower is the power unit. One horsepower (HP) equals 33,000 foot-pounds of work per minute or 1,980,000 ft-lb per hour. One HP = 0.745 kilowatt.

A treadle pump will deliver 1.7 cubic feet of water per minute when pumped from a depth of 10 feet (Ref. 4).

$$\text{Work accomplished/min.} = \frac{1.7 \text{ cu.ft}}{\text{min.}} \times \frac{62.4 \text{ lbs}}{\text{cu.ft.}} \times 10 \text{ feet lift.}$$

$$= 1061 \text{ ft-lb./min.}$$

If the pump were 100% efficient, it would require 0.03 hp input. But pumps are not 100% efficient. Based on other hand pumps (Ref.17) an efficiency of 20% will be assumed. The power input to the pump should be 0.03 hp ÷ 0.20 eff. = 0.15 hp which approximates the 0.18 hp from a man working an hour at a time as calculated above.

1.7 cu. ft. of water per minute is equal to 0.028 acre-inch per hour, or one inch of water on 1/5 acre in 7.1 hours. If 13% of the water from the pump is lost during delivery, then 8 hours of pumping is required.

So, with the two men trading off each hour but delivering 0.18 hp while they pump and considering that hulled rice contains 3600 kilocalories per kg how much extra rice will each man require to pump water?

$$\text{Required energy input} = \frac{(.18 \text{ hp}) \times (8 \text{ hr})}{0.20 \text{ efficiency of man}} = 7.2 \text{ hp-hrs}$$

$$\text{Kilocalories energy input} = \frac{(7.2 \text{ hp-hr}) \times (1{,}980{,}000 \text{ ft-lb/hp-hr})}{3088 \text{ ft-lb/Kilocalorie}}$$

$$= 4616 \text{ kilocalories}$$

$$\text{Kg of husked rice} = \frac{4616 \text{ kilocalories}}{3600 \text{ kilocalories/KG}}$$

$$= 1.3 \text{ Kg for 8 hours of pumping}$$

or 0.65 Kg/man/day.

For full irrigation of rice in dry season, 1100 mm (43.3 inch) of water is required for a rice crop. The weight of husked rice to provide irrigation for 1/5 acre of rice = (1.3 kg/in water) x (43.3 inches of water) = 56.3 Kg or ~~210~~ 281. Kg of husked rice to fuel the irrigation pumping for one acre.

A yield of 50 maund (1863 Kg) of paddy will give 1242 Kg of husked rice. Thus 11½ maunds of paddy or 23% of the crop is required as fuel for the men to pump enough water to grow an acre of rice.

Irrigating with water from a manually powered pump is only feasible for small areas because of the problem of water infiltration. For example if a bigha (1/3 acre) were a circular area with the pump in the center, the water would need to travel 68 feet to reach the edge of the bigha. Closer to actuality the bigha is a square field with 120 feet on a side. If the pump were on the bund at the center of one side, the water would need to travel 134 feet to reach the furthest corner. In sandy soils HTWs may not be practical except for small areas unless measures are taken to minimize water loss. For example, water could be ponded on a sheet of plastic and then released to flood portions of the bigha.

The "Number 6 pump" is a cast-iron lift pump used primarily for pumping drinking water. It has an internal diameter of 3.5 inches and a stroke lengh of 8.5 inches. The handle is about 30" long. The base of the pump is threaded to receive a threaded 1½ inch galvanized steel pipe. In 1976 USAID entered into a loan agreement to finance a Small Scale Irrigation Project (SSIP) which was to use the No.6 handpump as an irrigation pump. About 160,000 No.6 hand pumps, were sold through this program (Ref.19).

The rower-pump was developed by the Mennonite Central Committee. The pump consists of a 51-inch length of a PVC pipe with a 2-inch internal diameter and set at about 30° to the horizontal with the operator sitting in line with the pump with his feet on a foot rest and his hands on a T-shaped handled on the end of the pump rod. It is a lift pump. The water comes out of the end of the tube directly in front of the operator. It reminds me of an inexpensive bilge pump.

Where the depth to the ground water table exceeds 30 feet the deep-set rower force pump manufactured by the Mirpur Agricultural Workshops and Training School as a pump for obtaining drinking water may be useful (Ref.5). However, the labor required to pump a quantity of water against such a head does not make it practical for irrigation.

The BRRI Diaphragm pump is constructed of steel with the pump diaphragms made from truck tire inner tubes. It is pumped by two men with each man grasping the end of a rocking bar or handle. The basic cost of the pump is Tk.500 to Tk.800 depending upon the type of suction hose.

The Treadle Pump is designed for irrigation in that the water is lifted only to the surface of the ground and the treadle mechanism along with a stationary hand rail takes advantage of a person's strong leg muscles. The treadle framework is made of bamboo. The dual pump cylinder, pistons, and valves are of thin wall steel tubing, steel plate and rubber. The pump has a 10-inch stroke, but the diameter of the pump cylinders are sized for the distance the water must be lifted, in order to match the required pumping force to a man's optimum force

on the treadle. A 3-inch diameter cylinder is used for a 20 ft lift; ~~15-ft~~, 3½-inch cylinder for a 15 ft lift; a 4 3/4-inch cylinder for 8 ft lift; and a 6-inch cylinder for 5-ft lift.

RDRS installed 1800 tubewells with treadle pumps in 1981, 4730 in 1982, and will install about 10,000 in 1983.

With the farmer providing all the bamboo including bamboo for the well casing, a well can be drilled and the pump installed for Tk.170 for a 3-inch diameter pump; Tk.225 for a 3½-inch diameter pump; and Tk.310 for a 4 3/4-inch diameter pump.

Performance characteristics of these manual pumps are given in Table 6. The No.6 hand pump, rower pump, and treadle pump were powered by one person at a time. The BRRI pump utilized two men. Most of the performance tests were one hour in length.

RDRS has been advocating well casing made from bamboo and a strainer made from bamboo and coir rope or plastic sacking to reduce cost. However that portion of the well which is not submerged in water will decay - the treadle pump is estimated to have a life of 4 to 8 years (Ref. 18). In order to alleviate the deteriation of the non-submerged bamboo well casing, RDRS has begun to treat that portion of the casing with a solution of borax, sodium bichromate, copper sulphate, ammonium phosphate and acetic acid.

Of the above manual irrigation pumps I believe the treadle pump is to be preferred since it is the most energy efficient, and the least expensive.

Table 6

Manual Pump Characteristics*

Pump	Depth from Water level to discharge (ft)	Discharge		
		Liters/Sec.	Cu.ft./min.	Acre-inch/hr. or Cusec
No.6 or 2-in. Dia Rower pump (Ref.4)	5	0.75	1.6	0.026
	10	0.7	1.5	0.025
	18	0.4	0.8	0.014
Treadle pump	5	1.2	2.5	0.042
	10	0.8	1.7	0.028
	18	0.4	0.8	0.014
BRRI pump	8	4.4	9.4	0.15
Rower Force Pump (Ref. 5)	39	0.28	0.6	0.01

* These pumps can be seen and operated at the Permanent Exhibition For Locally Made Agricultural Implements on the old Airport Road in Dhaka. Telephone: 314096.

It is my recommendation that HTWs with treadle pumps be part of the USAID program. I believe that we should use 1½ inch galvanized steel pipe (1.9 inch O.D.) for casing and strainer as was done in the USAID Small Scale Irrigation Project (SSIP) (Ref.19). The irrigation should not be jeopardized by a well casing where we cannot control the quality as is the case of a bamboo casing.

The treadle pumps should be manufactured by contracts to several shops in the districts where the pumps are to be installed. PVOs should be contracted to oversee the distribution and installation of the pumps. The pumps and casing should be sold on a cash basis since the pump is inexpensive and credit only adds paperwork. The SSIP experience would be helpful in this regard.

The diameter of the pump cylinder fabricated in a sub-district shop would need to be such as to match the depth-to-water in the area.

20,000 HTWs and treadle pump per year would be an achievable goal. By contracting to have the pump built locally, there will be a residue of manufacturing competence when the program ends.

To promote such a program we need to:

(1) obtain more details from the MCC and RDRS about their experience in manufacturing and installing the pumps;

(2) obtain a map and information showing the areas where the water level is within 15 feet of the surface for these are the areas where the manually operational pumps can be used, and

(3) develop a portion of the project to provide information on proper construction of the treadle frame and sinking of the well by the farmer. The information must be designed for illiterates.

3. WHERE WILL THE EQUIPMENT BE OBTAINED?

For Bangladesh to have a sustainable minor irrigation sector it is essential that pumps and small diesel engines be manufactured in Bangladesh. Machines manufactured in-country will be more readily repaired in-country, for a large portion of the parts will be made in Bangladesh. Furthermore, manually powered pumps manufactured in small private shops are more likely to incorporate improvements designed by the farmers.

PUMPS. During the past five years, nearly all centrifugal pumps purchased for STWs and LLPs have been manufactured in Bangladesh. Milnars Pumps Ltd. and Bangladesh Machine Tool Factory also have manufactured DTW pumps. I visited the Milnars K.S.B. pump factory and was favorable impressed with their pump manufacturing capability. As far as manufacturing centrifugal pumps for STWs, sufficient capacity exists. At present there are six major and six minor pump manufacturers (Table 7). Production could be increased if raw materials were available. The projected capacity for 1985 is 72,000 annually. Bangladesh Machine Tool Factory is owned by the Government.

The Rangpur Dinajpur Rehabilitation Service (RDRS) has been promoting treadle pumps and has been manufacturing the metal parts and valves. The treadle pumps should be built in the districts where they will be used in order that small manufacturing shops will be encouraged and to create the situation where local artisans will more likely be responsive to farmers' needs. The RDRS shops should be encouraged but one must guard against producing only for production quotas. Too many

Table 7

Manufacturing Capacity for Centrifugal Pumps In Bangladesh In 1980

KSB	9,600
SECH (Farm Land)	12,000
GEC	6,000
BEC	6,000
Ittefaque	2,400
Bangladesh Machine Tool Factory (BMTF)	9,600
Others	6,000
Total:	51,600

Source: Table 2, Annex 3, Ref.9.

government warehouses (I have seen them in Indonesia, Sri Lanka and Comilla) contain treadle threshers, pumps, seeders and other agricultural tools which were being produced for a quota instead of sales to farmers.

ENGINES. Diesel engines or electric motors are the two options for powering the pumps used on shallow tube wells or for low lift from tanks and rivers. If a dependable supply of electricity were generally available in the countryside for STWs electric motors would be preferred because of operating and maintenance costs - see reference 10. However, electricity is not available at most STW sites so diesel engines of 5 to 10 hp will be required for the STW and low lift pumps. A 10 hp motor is the largest motor which can be used on a single phase line because of standing current limitations. There is no difficulty with STWs which would be three or four hp electric motor. By using "soft start" starting devices a 15 or 25 hp motor can be used on a single phase line, but these devices add additional cost and maintenance problems. The diesel engine is recommended over the gasoline engine, because (1) gasoline is about twice as expensive as diesel in Bangladesh and (2) a small diesel has no electrical system so a source of maintenance problems is avoided. The diesel engines required for STWs are of such a horsepower that they can be hand cranked thus eliminating the need for a storage battery and an electric starter motor.

According to the World Bank report of April 1982 (Ref.9) the following actual or intending manufacturers have been granted investment approval by GOB to manufacture diesel engines:

Bangladesh Diesel	-	Deutz (German)
Bangladesh Machine Tool Factory	-	Mitsubishi (Japanese)
Bangladesh Diesel Engine Co.	-	Yanmar (Japanese)
Bangla Diesel Ltd.	-	Lister (English)
Milnars Engineering	-	Kirloskar (Indian)

The combined initial production capacity would be 51,300 engines per year with a full production capacity of 74,600 units and employing 1221 workers at full capacity (Appendix 1, Annex 3, Ref. 9). I believe this is highly optimistic since as of early 1983 only Deutz of the above companies is actually manufacturing most of an engine in Bangladesh. Note that there are no U.S. diesel engines in the above list. This is because no small horsepower diesel engines are manufactured in the United States.

In investigating the diesel engine situation I met with Mohammed Shazzad Hossain of Bangladesh Agricultural Industries Distribution Co. who imports Yanmar engines, Hans Hadamzyk of Deutz-Bangladesh Ltd. who produce Deutz engines, and Shafiul Islam of Navana Ltd. and Milnars who import Kirloskar engines.

The engines for the STWs are about 6 hp. The Yanmar 105, Deutz FIL 210D and 5 hp Kirloskar (at 1500 rpm) are typical engines.

Deutz has been working at the task of producing engines in Bangladesh for about nine years. At present the Bangladesh Diesel plant (owned by Bangladesh Engine and Ship Building which is a semi-Government Company) is manufacturing the FIL 210D with 73% of the value manufactured in Bangladesh. The only other engine containing some parts made in

Bangladesh is the Mitsubishi which has about 7% of its value manufactured in Bangladesh. Of the five engines I prefer the Deutz and the Kirloskar since they are heavy simple engines which lend themselves to being rebuilt a number of times. The Deutz FIL 210D is single cylinder direct injection, with a displacement of 0.65 liters and 7 hp at 1500 rpm and 9.6 hp at 2000 rpm. On the larger engines such as the 912 series from 2 to 6 cylinder, Deutz uses modules with base and stroke remaining constant while obtaining horsepower (@ 1500 rpm) of 21 to 65 hp. 25 to 30% of the parts of the 912 engine are made in Bangladesh. Most of the engine - pump sets are made by independently mounting both the pump and the engine on a common frame and correcting them with a flexible coupling. Deutz has a new design where the centrifugal pump is bolted directly to the FIL 210D engine block. This would simplify mounting and eliminate coupling failures. However, if one should expect to switch engines between pumps and rice mills for example, the direct coupled pump would be a disadvantage.

Dr. Hamid in his study of shallow tubewells (Ref. 11, pg. 17) primarily in the Northwest started that the Yanmar 105, Kubota and Kirloskar were preferred by the farmers over the Deutz because of a "manufacturing defect". When I posed this statement to Hans Hadamzyk of Deutz-Bangladesh, he stated this occurred because some of the first farmers to use the Deutz failed to watch the lubrication oil level and had engine failure. I believe Hadamzyk. The problem of poor diesel fuel, particularly water in the fuel, plagues all the diesel engine distributors. An educational program about the need of clean fuel for long engine life must be taught by the engine distributors and government programs.

Mr. Islam of Milnars stated that machinery had been ordered to begin the manufacture of some of the Kirloskar engines in Bangladesh. However I have the sense that at present it is more profitable to him to import the engines from India. In any event, to prevent needless duplication of heavy machine tools such as drop forges, it will be necessary for the various companies to have crankshafts forged at one or two forge shops in Bangladesh. Bangladesh Diesel is forging crankshafts for the Deutz 210.

From my conversation with Mr. Hossain of Bangladesh Agricultural Industries Distribution Co. (Yanmar importer) I gained the sense that he knew his main customer (the government) much better than the farmers who would ultimately use the engines.

On July 10 I visited the site at Shalma for the Bangladesh Diesel Engine Co. plant to build Yanmar engines. The site consists of a sod covered field surrounded on three sides with a brick wall. There was no sign of any activity having occurred for a long period.

A constraint on pump and engine production is the unreliable source of raw materials and the duty on raw materials such as coke, steel and OEM (Original Equipment Manufacturers) parts compared to the duty on finished agriculture equipment. In Bangladesh raw materials compose about two-thirds of the direct manufacturing cost but import duties on raw materials range from 60 to 120% while duty on imported spare parts and assembled equipment for agricultural use is only 15%. However, Mr. Islam of Milnars told me that it was his understanding that the government was rectifying this inequity.

4. SPARE PARTS

Spare parts can be considered in two categories - those required for periodic maintenance and those required to replace a broken part of an inoperative engine or pump.

In regards to the HTWs equipped with treadle pumps the periodic maintenance consists of the farmer keeping the bamboo framework rigid and in alignment. Since the framework consists of bamboo and rope there is not a problem with spare parts. The valves and pistons can break or wear, but those too can be repaired from local materials or at the most require welding in a shop. Illustrated posters and leaflets - for illiterate persons - to show the proper maintenance of the tubewell, steel or bamboo are required to provide farmers with knowledge of how to keep the well productive.

For diesel engine STW pump sets the repairs for regular maintenance are:

1. fuel filter
2. lubrication oil filter
3. oil-bath air cleaner (maintenance rather than replacement).

It is important to impart to the pump driver or farmer the need for regular maintenance and at what intervals different maintenance tasks should be carried out. Two aspects of preventive maintenance which should be stressed are (i) the need to insure clean water-free diesel fuel and (ii) the importance of correct positioning of air directing shrouds and cleanliness of engine fans on air cooled engines, the most common type of STW engines.

Parts which must be installed before a broken engine will operate again include: valves, valve seats, valve springs, piston rings, cylinder liners, piston connecting rods, valve guides, main bearings, camshaft bearings and gaskets. When an engine is rebuilt after approximately 10,000 - 12,000 hours injectors and an injector pump will need to be replaced too. Even when eighty percent of the parts (based on cost) of a diesel engine are manufactured in Bangladesh, the piston rings, ball or needle bearings, injectors and injector pumps will need to be imported.

A constraint on the importation of spares is that most private businessmen don't like to tie up their money in spare parts. A better return can usually be made by importing complete engines and pump sets. In fact I have been told that Milnars imports few spare parts for the Kirloskar engines: the engine is manufactured in India and spares reach the marketplace in Bangladesh by private smugglers.

Dr. Hamid in his paper Organization As A Strategic Source In Irrigation Development: Some Field Experience Of Shallow Tubewell Irrigation In Bangladesh (Ref. 11) relates that in the Bogra area the BADC has OEM parts which are better than the parts made in local shops, but the parts are not always available and the parts machined in the local shops are often less expensive. For example an OEM piston costs Tk.760 at BADC while a locally made piston costs Tk.80. An OEM cylinder liner is Tk.1200 at BADC while on the local market is Tk.120. Some of the price differential is probably due to accounting procedures, but the locally made part will probably be machined from metal that does not meet the specifications for the OEM parts.

There have been a lot of complaints about the distribution of spare parts. The CARE evaluation report on selected Deep Tube Wells during Boro paddy cultivation (Ref. 3) provides an insight into pump and engine maintenance. The diesel engines are primarily three and four cylinder rated at 20 to 25 hp. In Baura Thana where DTWs have been used for fifteen years the pumps in the study were run 94 days for an average of 1156 hours per season (12.3 hrs/day). In Dhamrai Thana, 24 miles from Dhaka, the DTWs ran an average of 1356 hours per Boro season with an average breakdown of 3½ days per season. At the Joydebpur Thana 123 miles north of Dhaka, the average well in the CARE study was operated 83.5 days for an average of 1052 hours per season (12.6 hrs/day) and an average of 38 days lost per season due to break down. Most spare parts were not available at the BADC store. Some parts were available on the local market at higher prices. There was a shortage of BADC mechanics and those available wanted tips ("sweet money"). In Parbatipur Thana in the North the average DTW in the study was operated 98 days for a season run of 1222 hrs (12.5 hrs./day). The maximum number of days an unit was idle due to breakdown was 8 days. The report on the Parbatipur Thana spoke well of the BADC and the effort of BADC mechanics to obtain spares and repair the engines.

Because of the CARE project it can be assumed that the DTW's under study were operated better than other DTWs and there was probably a greater impetus to keep the DTWs running.

5. SERVICING OF PUMPS AND ENGINES

Servicing of tubewell equipment has been a problem. BADC has been criticized in many papers about their poor performance in servicing DTWs and STWs. The BADC could improve service by integrating its DTW, LLP, and STW divisions in each District or Region as far as mechanics are concerned. As long as BADC mechanics maintain DTW, LLP or STW division identities an inefficient use of scarce mechanics will continue. Will privatization provide better service than BADC? I believe the private sector will-assuming spare parts are available-in those areas where there is a "critical mass" of engine - powered pumps. For example, Bogra is in the lead with private workshops - as many as thirty contain at least a lathe. There are sufficient tubewells in the area to support this service. As the engines and pumps accumulate hours of operation, breakdown's will become more frequent. Engines and pumps will need to be reconditioned. The U.S. Soil Conservation Service estimates that a diesel engine should have a service life of 28,000 hours or 14-years and a centrifugal pump 32,000 hours or 16 years. I believe the small diesel pump sets as used in Bangladesh will require major overhead at about 10,000 hours or 8 years at 1250 hrs per year. During the next five years many of the pump sets will require major overhaul.

As a sign as how a critical mass of pumps and engines is essential before private companies will invest capital in service facilities, consider that this year Deutz has opened a separate service facility in Bogra (Gohail Road, Kaigori). The facility has three mechanics to cover five districts. Although they travel by company truck to the

thana and thence by rickshaw to the well it means they are spaced very thin. We were unable to determine the extent of the mechanics training. I was taken aback when the mechanic to whom we talked stated that he recommended "resting" the engine at least every six hours. This matter of "resting" engines is an indication of the lack of mechanical knowledge among the citizenry of Bangladesh.

What can be done to improve servicing? Training will be discussed in the next section of this report.

It may be well to consider a portion of this program to loan money in the form of tools to mechanics in order to establish repair centers. Although the primary reason to encourage local repair facilities is to provide an infrastructure to support pump irrigation, we would be foolish if we don't accept the fact that many of these private repair services will be actually engaged in repairing rickshaw, trucks, etc. But this is not undesirable.

A possible means test is that if a mechanic could exhibit a certain level of skill by examination or by a certificate, money in the form of tools would be given him as a loan. A kit of necessary hand tools and in some cases a cylinder borer, electric welder and pipe threading equipment would be appropriate. All of these tools and equipment are available from U.S. sources.

6. TRAINING OF MECHANICS FOR THE PRIVATE SECTOR

Assuring that one serviceman is required for 25 tubewells (Ref. 11) then the 100,000 tube wells currently in Bangladesh will require 4,000 servicemen. Adding this need to the need to service LLPs results in the need of at least 5,000 mechanics who can service the diesel engines and pumps required for irrigation. Some of the pumps are powered by electric motors and will not require as much repairs and service as will the diesel engines. On the other hand, some mechanics trained in a program to keep the engines and pumps operating, will not repair tube well engines but will repair trucks, autos, etc. Until better information is obtained a training program for 5000 will be advocated.

Mechanics in Bangladesh are primarily trained in an apprentice system where a boy changes tires, removes carbon from engine heads, hands tools to the mechanic, etc. and then over the years gradually learns the mechanic trade.

As to formal training of mechanics and machinists, there is the Mirpur Agricultural Workshop and Training School. By my visit to the Mirpur Workshop and School on June 27 I was impressed with the thoroughness of the three-year training but only 16 machinists and 16 agro-mechanics are graduated per year and many of the graduates have taken jobs overseas in Arabic countries. Mirpur AWTS also has a nine month refresher course for pump operators. Twenty men are accepted at a time. An evening course from 5:00 to 9:00 p.m. for under priviledged boys from the slums of Dhaka is also taught. The course lasts six months and teaches the boys bench fitting, engine lathe operations, and electric welding. There is also a one year instructors training course. Mirpur AWTS has experience in teaching machinists and mechanics and should be

consulted when fleshing out this program.

The Bangladesh Agricultural Development Corporation (BADC) in cooperation with the International Labor Organization (ILO) of the U.N. had an Irrigation Pumps Training Program from 1976 to 1981. This program had as its goal to train for BADC 40 instructors, 4000 mechanics, 120 electricians, 96 machinists, 15,000 pump operators (by indirect methods), 600 thana officers (in management of irrigation pump maintenance and repair), training materials to support the teaching activity, and the installation of a computerized spare parts inventory program.

The BADC also has a program, "Workshop Development Program For Private Sector". It is funded by the Ministry of Agriculture and Forests and is to run from 1981 to 1985. It is to establish 320 thana-level Repair workshops in the private sector and train 77,980 mechanics, blacksmiths, and village artisans. I was unable to determine the performance of these BADC programs.

Private companies such as Deutz, Yanmar, and Mitsubishi train their own mechanics and servicemen. With the coming of privatization the private companies should be encouraged to do more training.

Effective training requires reinforcement of concepts and procedures. This means teaching materials. One goal should be that every pump house should contain a plastic treated wall chart which graphically explains diesel engine (or electric motor) and pump preventive maintenance. Another goal is to have engine repair wall charts as well as manuals written for the functional illiterate in repair shops in the villages.

To repair an engine or pump requires the combination of a mechanics knowledge and the proper tools. The program should be devised so that the best mechanics receive a set of tools and the poorer students a few tools. A portion of the program could be to loan or grant money for the purchase of shop equipment such as lathes, cylinder boring machines, welders and shop tools for thana level workshops. The recipients would receive the machine or tools - not money.

Although none of the diesel engines used on STWs or LLPs are manufactured in the U.S. appropriate machine tools and hand tools are made in the United States and could be purchased for this program.

It appears to me that to further a viable repair servide for pump engines and pumps in Bangladesh that this program should include provisions to:

1. Put an engine and pump maintenance wall chart in all STW and DTW pump houses in Bangladesh;
2. train 5000 thana or village level mechanics through PVOs and major equipment vendors;
3. provide engine and pump repair shops with basic machine tools and hand tools to repair engines and pumps.

Recommendations for further investigation:

1. Determine what can be leaned from the ILO and BADC programs to train mechanics and equip repair shops.
2. Check with the USAID Training Officer, M.R. Chatman, for help in putting together a training proposal. On July 17 two full time training experts arrive for at least ten months. They could be of assistance in devizing the program.

SUMMARY

1. STW pumps can be manufactured in Bangladesh in sufficient numbers but the supply of raw materials - coke, pig iron, metallurgical additions - must be made more dependable.

2. With the exception of one 6 hp engine which is 73% local content, diesel engines are not currently manufactured in Bangladesh. Effort should be made to encourage the manufacture of small diesel engines in Bangladesh, but the number of models should be limited so that the repair parts distribution is not chaotic.

3. STWs should be emphasized in the privatization program. Farmers are already moving ahead in this regard.

4. Manually operated treadle pumps on shallow tube wells are feasible and should be part of the program.

5. The aging diesel engine and pump population will demand more mechanics and training material training and furnishing of tools should be an important part of the program.

6. A portion of the program should be to fund private repair shops with shop equipment and tools.

7. A goal of the program should be to have a wall poster about engine and pump maintenance in every pump house in Bangladesh.

8. More information is required on pump performance characteristics if the efficient use of capital and fuel is to be realized. None of the reports I have read have contained any information about pump specifications of performance at various heads or rpm. The heart of the minor irrigation system has been ignored.

9. More information is required as to the depth to water during the dry season for the various areas of the country. To put STWs or HTWs in areas with other than the proper depth to water will be courting disaster.

10. More information is required about the manufacturing capabilities and plans of the five companies which have been given permission to build diesel engines in Bangladesh.

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TI-59 Program For Discharge Equivalents for TI-59 Calculator

Insert Card, side 1, into calculator

If known quantity is:

Cusec,	enter value and depress	A
U.S. gpm,	enter value and depress	B
meter^3/sec,	enter value and depress	C
liters/sec,	enter value and depress	D
acre-inch/hour "	value and depress	E

Then to read the equivalents:

for Cusec	depress	A'
US gpm	depress	B'
meter^3/sec	depress	C'
liters/sec	depress	D'
acre-inch/hour	depress	E'

TI-59 Program For Discharge Equivalents

LAN

000	76	LBL
001	11	A
002	42	STO
003	01	01
004	71	SBR
005	44	SUM
006	43	RCL
007	01	01
008	91	R/S
009	76	LBL
010	12	B
011	42	STO
012	02	02
013	55	÷
014	04	4
015	04	4
016	08	8
017	93	.
018	08	8
019	07	7
020	02	2
021	95	=
022	42	STO
023	01	01
024	71	SBR
025	44	SUM
026	43	RCL
027	02	02
028	91	R/S
029	76	LBL
030	13	C
031	42	STO
032	03	03
033	55	÷
034	93	.
035	00	0
036	02	2
037	08	8
038	03	3
039	02	2
040	95	=
041	42	STO
042	01	01
043	71	SBR
044	44	SUM
045	43	RCL
046	03	03
047	91	R/S
048	76	LBL
049	14	D
050	42	STO
051	04	04
052	75	-
053	02	2
054	08	8
055	93	.
056	03	3
057	02	2
058	95	=
059	42	STO
060	01	01
061	71	SBR
062	44	SUM
063	43	RCL
064	04	04
065	91	R/S
066	76	LBL
067	15	E
068	42	STO
069	05	05
070	55	÷
071	93	.
072	09	9
073	09	9
074	01	1
075	08	8
076	03	3
077	95	=
078	42	STO
079	01	01
080	71	SBR
081	44	SUM
082	43	RCL
083	05	05
084	91	R/S
085	76	LBL
086	44	SUM
087	43	RCL
088	01	01
089	65	×
090	04	4
091	04	4
092	08	8
093	93	.
094	08	8
095	07	7
096	02	2
097	95	=
098	42	STO
099	02	02
100	43	RCL
101	01	01
102	65	×
103	93	.
104	00	0
105	02	2
106	08	8
107	02	2
108	02	2
109	95	=
110	42	STO
111	03	03
112	43	RCL
113	01	01
114	65	×
115	02	2
116	08	8
117	93	.
118	03	3
119	02	2
120	95	=
121	42	STO
122	04	04
123	43	RCL
124	01	01
125	65	×
126	93	.
127	09	9
128	09	9
129	01	1
130	08	8
131	03	3
132	95	=
133	42	STO
134	05	05
135	92	~~INV~~ SBR
136	76	LBL
137	16	A'
138	43	RCL
139	01	01
140	91	R/S
141	76	LBL
142	17	B'
143	43	RCL
144	02	02
145	91	R/S
146	76	LBL
147	18	C'
148	43	RCL
149	03	03
150	91	R/S
151	76	LBL
152	19	D'
153	43	RCL
154	04	04
155	91	R/S
156	76	LBL
157	10	E'
158	43	RCL
159	05	05
160	91	R/S

To Record or
Depress Ke

INV 2nd

1 2nd

Insert bl.
card

J.K. Campt

48

CENTRIFUGAL PUMP Specific Speed & Power

TI-59 Program

INPUT:

	Depress
Pump RPM	A
Discharge in CUSEC	B
OR	
in meter^3/sec	B'
Head in meters	C
OR	
in feet	C'
Efficiency, .XX	E

- OUTPUT -

Depress	
D	for Specific Speed
E'	for Power (hp)

followed by R/S fo: Kw.

IN STORAGE

RCL	ITEM
01	RPM
02	Discharge, Cusec
03	Discharge, m^3/sec
04	Head, meters
05	Head, feet
06	Specific Speed
07	pump efficiency, .xx
08	power, pump Hp
09	power, pump Kw

Ref. Ch.16, "Pumps and Pumping"

TI-59 Program For Specific Speed & Power 148 Steps

000	76	LBL
001	11	A
002	42	STO
003	01	01
004	91	R/S
005	76	LBL
006	12	B
007	42	STO
008	02	02
009	65	×
010	93	.
011	00	0
012	02	2
013	08	8
014	03	3
015	02	2
016	95	=
017	42	STO
018	03	03
019	43	RCL
020	02	02
021	91	R/S
022	76	LBL
023	17	B'
024	42	STO
025	03	03
026	65	×
027	03	3
028	05	5
029	93	.
030	03	3
031	01	1
032	95	=
033	42	STO
034	02	02
035	43	RCL
036	03	03
037	91	R/S
038	76	LBL
039	13	C
040	42	STO
041	04	04
042	65	×
043	03	3
044	93	.
045	02	2
046	08	8
047	01	1
048	95	=
049	42	STO
050	05	05
051	43	RCL
052	04	04
053	91	R/S
054	76	LBL
055	14	D
056	42	STO
057	05	05
058	65	×
059	93	.
060	03	3
061	00	0
062	04	4
063	08	8
064	95	=
065	42	STO
066	04	04
067	43	RCL
068	05	05
069	91	R/S
070	76	LBL
071	14	D
072	53	(
073	53	(
074	43	RCL
075	03	03
076	34	√X
077	54	)
078	65	×
079	43	RCL
080	01	01
081	65	×
082	05	5
083	01	1
084	93	.
085	06	6
086	05	5
087	54	)
088	55	÷
089	53	(
090	43	RCL
091	04	04
092	45	Y^X
093	93	.
094	07	7
095	05	5
096	95	=
097	54	)
098	95	=
099	58	FIX
100	00	00
101	42	STO
102	06	06
103	91	R/S
104	76	LBL
105	15	E
106	42	STO
107	07	07
108	22	INV
109	58	FIX
110	43	RCL
111	07	07
112	91	R/S
113	76	LBL
114	10	E'
115	53	(
116	43	RCL
117	03	03
118	65	×
119	43	RCL
120	04	04
121	65	×
122	01	1
123	07	7
124	93	.
125	06	6
126	04	4
127	54	)
128	55	÷
129	43	RCL
130	07	07
131	95	=
132	42	STO
133	09	09
134	65	×
135	01	1
136	93	.
137	03	3
138	04	4
139	01	1
140	95	=
141	42	STO
142	08	08
143	58	FIX
144	02	02
145	91	R/S
146	43	RCL
147	09	09
148	91	R/S

To Record on Card

Depress keys

INV 2nd Fix

1 2nd Write

Insert Blank Card

Agencies/Persons Involved In Irrigation/Water Management Activities

1. World Bank
   22 New Eskaton Road
   Dacca, Tel: 400003-5, 405031

   Mr. Walter Kock, Sen. Agriculturist

2. BARD/FAO, Bogra
   DTW Command Area Development Project
   P.O. Box 62, Bogra
   Tel: 6511 (office),5696 (House)

   Mr. Nurul Haq, Director
   Dr. Amjad Hossain, Project Coordinator
   Mr. Keith H. Gorey, FAO Team Leader
   Mr. P. Kanoksing, Irrig. Engineer
   Mr. S. Ong Kingoo, Irrig. Agronomist
   Mr. J.J. Hung, Estension Specialist
   Dr. J. Plusje, Irrig. Engineer
   Rene Plusje, Nutritionist

3. CARE
   DTW Irrigation and Credit Program
   House 33-A, Road 9-A,
   Dhanmondi R/A, Tel: 326507

   Dr. Sandra Laumark, Coordinator

4. Mirpur Agricultural Workshop and Training School (MAWTS)
   Mirpur, Section -12, Dacca

   Mr. M. Ikramullah, Project Manager, Tel: 382544

5. Christian Reformed World Relief Committee (CRWRC)
   3/12, Block-B, Lalmatia, Dacca

   Mr. Peter Vanderbenden, Tel: 316921

6. Ford Foundation
   P.O. Box 98, Dacca-2

   Dr. Martin Hanratty
   Tel: 319645

7. Agricultural Development Council (A/D/C)
   C/o: BARC, Farmgate, Dacca

   Dr. G. Gill

8. Mennonite Central Committee (MCC)
Box 785. Dacca-2, Phone: 317065
Dr. Harold Harder Director

9. Rangpur Dinajpur Rehabilitation Services (RDRS)
House 16, Road 16 (New)
Dhanmondi

Mr. Charles I. Fluegel
Program Coordinator,
Tel: 314485 and 310509

10. Bangladesh Rural Advancement Committee (BRAC)
66, Mohakhali Commerical/Area
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Mr. Izzeddin Shami Iman
Staff Anthropologist

11. PROSHIKHA
5/2 Iqbal Road
Mohammadpur, Dhanmondi
Tel: 317021

Mr. Faruque Ahmed

12. Bangladesh Rice Research Institute (BRRI)
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Phone: 313830 (Office), 303515 (House)

Dr. Frank Sheppard, IRRI Representative

Mr. M.A. Ghani
Senior Scientific Officer
BRRI/Joydebpur

13. Northwest Hydraulic Consultants
SE (F) 1, Gulshan Avenue
Gulshan, Tel: 304385

Dr. H.R. Khan
Mr. Herb Weibe
Mr. Joseph Redhead
Mr. Rodman

14. BAU

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15.	Mr. A.Z.M. Obaidullah Khan Minister, Ministry of Agriculture 2nd 9 Storied Building Bangladesh Secretariat	409742 (O) 406183 PS 404314 (O) 404282 (O) 402917 (H)
16.	Mr. Md. Irshadul Haq Joint Secretary, Ministry of Agriculture Room 533, Bangladesh Secretariat	404977 (O) 23000-2533(O) 313557 (H)
17.	Mr. Nurul Momen Khan Joint Secretary, Ministry of Agriculture Flood Control & Water Resource Division New 5 Storied Building, Room 405 Bangladesh Secretariat	408346 (O) 310104 (H)
18.	Mr. A.M. Anisuzzaman Secretary, Ministry of Agriculture 2nd 9 Storied Building Bangladesh Secretariat	404273 (O) 406037 (O) 402917 (H)
19.	Dr. S.H.K. Eusuf Zai Member, Agriculture, Ministry of Finance & Planning, Block 7, Room 7 Sher-e-Bangla Nagar	314942 (O) 318239 (O) 259842 (H)
20.	Mr. M.F.A. Siddiqui Chairman, BWDB WAPDA Building, Motijheel C/A	232194 (O) 602339 (H)
21.	Mr. A.T.M. Aminul Islam Chief Engineer (Planning) BWDB, WAPDA Building, Motijheel C/A	237026 (O)
22.	Mr. Kazi Sajiruddin Ahmed Member (Engineering), BADC Krishi Bhaban, 49-51 Dilkusha C/A	236394 (O) 601562 (H)
23.	Mr. Hashmatullah General Manager (Administration) BKB, 84 Motijheel C/A	259796 (O) 325635 (H)
24.	Mr. Saiful Islam, Director of Field Services, IMP, Sadharan Bima Sadan 24-25 Dilkusha C.A	258073 (O) 259467-9 (O)
25.	Mr. Amjad Hossain Khan Member, Joint River Commission 127 Motijheel C/A (in front of Zahurul Islam building)	251836 (O) 231076 (O) 314136 (H)

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26.	Mr. K.M. Hasan, Honorary Director Mr. Haq, Asst. Director (Admin.) Bangladesh Institute of Law and International Affairs (BILIA) Road No.7, House 22, Dhanmondi R/A	311718 (O) 316452 (O)
27.	Mr. Jakob Rosing UN Chief Technical Adviser, Planning Cell in both MOA (Irrigation, Water Development and Flood Control Division), Ministry of Energy & Mineral Resources (Energy Div.) New Secretariat Building, Room 420	236476 (O) 600833 (H)
28.	Mr. Dubravko F. Jezina Water Resource Engineer, UN, Planning Cell of MOA (Irrigation, Water Development & Flood Control Div.)	
29.	Mr. Ken R. Gibbs, UNICEF, Chief, Water & Environmental Sanitation Section	310183-85 (O) 600750 (H)
30.	Hugh Brammer FAO, 37, Road 8, Dhanmondi Dhaka	404977 (O) 311795 (H)
31.	Mike Hyland UNDP, Road 11A, House 60, Dhanmondi	317181-5 (O) 602-037 (H)

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