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Groundwater Use for Irrigation in Bangladesh: The Prospects and Some Emerging Issues

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SUMMARY

Groundwater represents a vitally important resource for Bangladesh for its irrigation development. Great efforts are now underway to increase irrigated acreage by employing a mix of three major types of tubewell system—deep, shallow, and hand tubewells. This paper attempts to analyse the past trends of development of groundwater irrigation as well as a number of relevant policy issues, such as the gap between the potential and actual use of the capacity of the different tubewell systems, the rate of groundwater withdrawal that can be sustained on a long-term basis, the recently adopted 'privatization' policy of the government, and the choice of scale in the promotion of the different types of tubewell systems. Finally, a number of problem areas are identified, and some immediate actions required to deal with the problems are indicated.

AGRICULTURE AND IRRIGATION

Bangladesh has only 9·4 million hectares of cultivable land for a population of about 90 million.[4] Although food grain production has increased at an average rate of about 2·0% over the past decade, a higher population growth rate of 2·6% has rendered that progress rather inadequate. A food grain import requirement of 0·81 to 2·84 million tonnes per year, depending on the local climate that dominates local production, has been an apparently unavoidable feature for the country during the past 10 years. Highest priority has always been given by planners to increasing food grain production.

Since the scope to expand physical land area for cultivation is almost negligible, additional food grain can only be produced by increasing the productivity of the available land, by increasing either the yield per season, or the cropping intensity, or both. Each of these options basically requires the development of more irrigation facilities because, despite the prevalence of a subtropical monsoon climate with a relatively high total rainfall, the dry *rabi* season (November March) does not produce a significant amount of rainfall in any part of the country the rainfall is certainly not sufficient to support a grain crop. Furthermore, even during the major *aus* and *aman* crop seasons (April July and July November, respectively), the rainfall is often undependable with long dry periods, particularly during the early part of the *aus* and the latter part of the *aman* seasons, so that supplemental irrigation is a necessity to produce stable high yields of rice during these two growing seasons. At the present time, about 16% of all cultivable land has some access to irrigation water.[3] The Government of Bangladesh has therefore placed a high priority on expanding the provision of irrigation water to more areas so as to increase the production of grain crops. The Second Five Year Plan (1981 1985)[4] has an ambitious target to double the irrigated area from its 1978 79 coverage of 1·46 million hectares in order to achieve food grain self-sufficiency by the end of the plan period.

GROUNDWATER IRRIGATION SYSTEMS AND THEIR CHARACTERISTICS

Four types of groundwater irrigation systems are in use: deep tubewells (DTW), shallow tubewells (STW), handpump tubewells (HTW) and dug wells. A DTW is characterized by a depth of penetration into the soil of more than 46 m (but usually less than 91 m), its 0·4 m diameter casings and screens, and a turbine pump driven by a surface mounted 15 kW diesel engine. Its nominal discharge capacity is 56 litres/s (2·0 cfs). The only notable exceptions are the 377 DTWs of the North Bangladesh Tubewell Project which have a higher discharge capacity, between 85 and 141 litres/s. An STW is less than 45 m deep (usually 24 30 m), uses 10·2 cm diameter pipes and a centrifugal pump driven by a 4·5 kW diesel engine. The discharge capacity usually varies between 14 and 21 litres/s. Many of the deep and shallow wells are being connected to the electric power supply, and the diesel engines are being replaced by electric motors.

TABLE 1

Some Characteristics of the Different Types of Groundwater Irrigation in Bangladesh[a]

Item	*Groundwater irrigation types*			
	Dug well	*HTW*	*STW*	*DTW*
Number in operation[b]	20 000–30 000	165 000	78 000	12 000
Power source (Diesel/Electric/Manual)	M	M	D E	D E
Ownership (State/Private)	P	P	P	S P
Discharge capacity (litres/s)	0·28	0·56	16·8	56·0
Capital cost[c] (Tk)				
per unit	n.a.[d]	1 830	30 470	240 550
per litre/s	n.a.	2 562 000	1 421 840	336 000 0
Government Subsidy or Tax as % of capital cost[c]	0	T 25 %	T 21 %	S 75 %
Area irrigated/unit (ha)	0·2	0·2–0·30	4·8	25·2[e]
Pumping height from water table (m)				
0–1·50	×[f]	×	×	×
1·50–4·50	×	×	×	×
4·50–9·00		×	×	×
9+		—	—	×
Construction equipment source (Foreign/Local/Village)	V	V	L	F/L
Maintenance parts source (Foreign/Local/Village)	V	V	F/L	F/L
Dependence on government for:				
Installation		—	×	× ×
Operation and maintenance	—	—	×	× ×
Dependence on cooperation amongst users	—	—	×	× ×
Labour required for pumping (man-days/ha/crop)	80	80	0·4	0·4

[a] Adapted from Biggs *et al.*[11]
[b] As of Dec. 1982.
[c] As of 1976–77.
[d] Not available.
[e] Available for 1981–82 in the dry season.
[f] Crosses indicate relevance.

An HTW is the smallest scale tubewell system; it penetrates 6–12 m into the soil using 5·1 cm diameter galvanized iron pipes, and is fitted with a reciprocating pump which is operated manually. Its average discharge capacity is about 0·56 litres/s.

Relatively very little is known about the dug wells even though they are the oldest form of groundwater-using irrigation equipment in Bangladesh. Dug wells are the least capital intensive of all the methods of groundwater utilization available in the country. As in the case of HTWs, the operation of this type of well is highly labour-intensive. The discharge capacity of a dug well would vary considerably from location to location, but in general would be very low, with an average of about 0·28 litres/s. About 20 000 to 30 000 dug wells are estimated to be in operation, mostly in the Barind tracts in northern Bangladesh.[11]

A matrix of pertinent features of the different types of groundwater irrigation systems is given in Table 1.

The Bangladesh Agricultural Development Corporation (BADC) is the primary agency responsible for the development of DTWs. All drilling and installation works are carried out through BADC appointed contractors and repair and maintenance works are done by the corporation's own mechanics. On a much smaller scale than BADC, the Bangladesh Water Development Board (BWDB) is involved in the DTW sector in the northern part of the country.

BADC and the Bangladesh Krishi (agriculture) Bank along with, more recently, the Bangladesh Bank are the agencies responsible for the sale, installation and servicing of STWs. Unlike in the DTWs, the private sector plays a significant role in the STW programme, from drilling and installation to selling spares and providing maintenance services.

In addition to BADC, the Department of Public Health Engineering and the Rural Development Board (previously known as the Integrated Rural Development Programme) are engaged in the sale of HTWs for irrigation. The private sector also plays a very dominant role in this programme in the manufacture of the pipes and pumps, installation of the tubewells, sale of spares and servicing.

ROLE OF GROUNDWATER IN IRRIGATION: PAST, PRESENT AND THE FUTURE

The history of mechanized groundwater use in Bangladesh dates back about 20 years. But since then groundwater has played an increasingly

TABLE 2

Contribution of the Different Methods of Irrigation to the Total Irrigation Coverage in Bangladesh During 1969–70 to 1979–80

Methods of irrigation	*% of total irrigated area*										
	1969–70	*1970–71*	*1971–72*	*1972–73*	*1973–74*	*1974–75*	*1975–76*	*1976–77*	*1977–78*	*1978–79*	*1979–80*
Groundwater	3·1	4·1	3·2	3·1	4·1	6·6	7·6	7·8	8·7	10·8	11·5
Low-lift pumps	28·4	35·8	32·1	39·0	44·0	40·5	39·4	41·0	38·2	39·2	39·7
BWDB gravity schemes	3·1	2·9	2·2	2·1	2·0	1·8	2·3	3·0	3·3	3·5	6·2
Traditional methods	65·4	57·2	62·5	55·8	49·9	51·1	50·7	48·2	49·8	46·5	42·6
All	100	100	100	100	100	100	100	100	100	100	100
Total area irrigated ('000 hectares)	1 046	1 154	1 035	1 197	1 281	1 424	1 383	1 201	1 433	1 465	1 549

Source: GOB and the World Bank.[16]

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important role in the irrigation of the country. The flat topography and unpredictable effects of flooding in the deltaic plain, which makes up the bulk of Bangladesh, render other forms of irrigation difficult. Groundwater use is an important alternative.

The relative dependence on groundwater for irrigation development in Bangladesh has significantly increased in the past decade. During 1969–70, only about 3·0% of the total of 1·1 million irrigated hectares used groundwater. Ten years later, i.e. in 1979–80, the share of groundwater in the total irrigation had risen to 11·5% when the total irrigated acreage grew to 1·60 million hectares. Table 2 shows how groundwater has been exploited more and more during the period and how this compares with other methods of irrigation. It is interesting to note that the traditional methods such as swing baskets and *doons* still command a very high percentage of the total irrigated area. Even though this percentage has decreased gradually, the total area irrigated has essentially remained unchanged during the past decade.

The use of the groundwater during the dry season for *boro* rice and wheat accounts for, on the average, more than 85% of the total area irrigated during the three-year period, 1978–79 to 1981–82 (Table 3). Use of tubewell water during the *aus* and *aman* seasons is very small. Undoubtedly, a greater benefit from the investment could be achieved if, in addition to *boro* season irrigation, the tubewells were used for

TABLE 3

Area Irrigated by Deep Tubewells in Bangladesh During the Three Growing Seasons of 1979–80 to 1981–82

Year	*Area irrigated (ha)*					
	Aman *rice*	Rabi *season*			Aus *rice*	*Total*
		Boro *rice*	*Wheat*	*Other crops*		
1979–80	21 188 (8·3)	175 740 (69·2)	46 694 (18·4)	n.a.	10 485 (4·1)	254 107 (100)
1980–81	14 139 (5·5)	185 287 (72·2)	41 286 (17·3)	n.a.	12 731 (5·0)	256 443 (100)
1981–82	18 492 (5·8)	274 128 (85·8)	8 876 (2·8)	4 127 (1·3)	13 651 (4·3)	319 274 (100)

[a] Includes other crops.
Source: BADC.

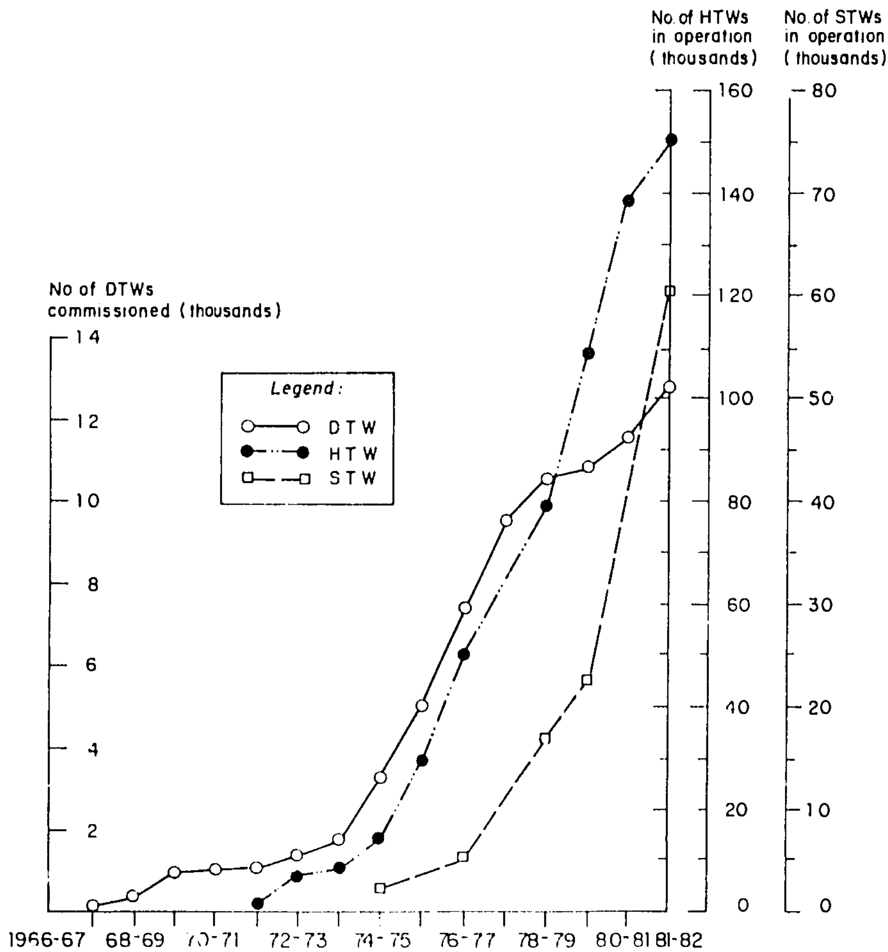

Fig. 1. Growth of DTWs, STWs and HTWs in Bangladesh (source: BADC).

supplemental irrigation during the other seasons, for example during early *aus* and late *aman* seasons when rainfall is often untimely and inadequate. The high benefits achievable from such supplementary irrigation have been well-documented for Bangladesh.[5,23]

The annual growth rate of DTWs increased greatly during the five years beginning 1972–73 compared to the previous five years, but decreased slightly during the following five years (Fig. 1). The average annual rate of growth of DTWs during the 1967–68 to 1971–72 period was only 197 but it increased to 1260 for the period of 1972–73 to 1976–77. The five years since then have seen an average growth rate of 1086 deep tubewells per year (Table 4).

TABLE 4
Cumulative Development and Use of DTWs in Bangladesh

Year	*No. of DTWs commisioned*	*No. of DTWs in operation*	*Area irrigated (ha)*	
			Total	*Per DTW*[a]
1967 68	105	102	1 647	16
1968 69	397	390	6 432	16
1969 70	1 034	980	12 848	13
1970 71	1 069	796	12 828	16
1971 72	1 090	906	11 732	13
1972 73	1 424	1 237	15 110	12
1973 74	1 822	1 343	23 262	17
1974 75	3 324	2 540	46 675	18
1975 76	5 001	3 826	62 774	16
1976 77	7 393	4 471	67 834	15
1977 78	9 484	7 463	141 668	19
1978 79	10 552	9 329	201 736	22
1979 80	10 844	9 795	254 107	26
1980 81	11 532	10 131	256 442	25
1981 82	12 822	11 491	319 274	28

[a] About 90% of this is irrigated in the dry season.
Source: BADC.

The STWs have increased at a very fast rate since 1978 79 (Fig. 1) to reach a total of about 78 400 operating in the country up to December, 1982. In the HTWs sector, the growth rate has been even more spectacular. In 1975, a total of about 30 000 HTWs were estimated to be in operation for irrigation.[18] By the end of 1982, a total of 165 000 HTWs had been installed. Massive HTW expansion programmes supported by external agencies are presently underway.

The Second Five Year Plan of the government,[4] which covers the period 1981 85, envisages a greatly expanded role of groundwater for irrigation. Numerically, HTWs will expand most a total of 500 000 HTWs are to be fielded by 1984 85.[16] The number of STWs will more than double during the period. For example, the Bangladesh Agricultural Development Corporation (BADC), which is one of the agencies having responsibility to field STWs, has a target of 90 000 STWs to have in operation by 1984 85 under its programme. During the same period 25 000 DTWs are planned to be in operation through the BADC programme.[4] It is projected that, by 1984 85, over 50% of the total 2·9 million hectares of the total irrigated area will use groundwater as their water source. To achieve these targets, or even to get close to them, groundwater irrigation systems will have to be developed during the rest of the plan period at a rate unprecedented in the history of Bangladesh.

POTENTIAL AND ACTUAL USE OF TUBEWELLS: THE GAP

Under-utilization of tubewell capacity has been a chronic problem in Bangladesh. The DTWs, because they are capital-intensive and heavily subsidized by the government, have been investigated more than the STWs. In a survey of 64 DTWs located in 12 districts, Biswas *et al.* found that during the 1975–77 period the average area irrigated per DTW was about 18·2 ha.[12] Similar and even lower average coverages by DTWs have been cited by other investigators.[2-10] BADC records indicate that since 1976–77, the irrigated acreage per unit for all DTWs has been consistently increasing and in the dry season of 1981–82, 25 net ha were irrigated per tubewell (Table 4).* Although, on the basis of these figures one can conclude that a major improvement from the average condition reported earlier has been achieved, there exists a wide gap between the potential and current use of DTW capacity.

The potential area that can be irrigated from a 56 litre/s capacity DTW depends on several factors such as the crop grown, soil texture, channel conveyance losses, irrigation and water scheduling methods used, land topography, and hours of pump operation. The field water requirement of rice grown in the dry season is about 2–3 times more than that of wheat grown in the same soil. As a result, the potentially irrigable area from a DTW is much higher for wheat than for rice. There is evidence of achieving more than 52·6 ha irrigated for rice in the dry season from a 56 litre/s capacity DTW (Biswas *et al.*[12]). Unconfirmed reports indicate that a particular DTW group at Fulbaria, Mymensingh district, has irrigated as much as 109·3 ha for *boro* rice by utilizing the pump to a maximum and storing pumped water in specially constructed tanks during night-time operation.[1] However, it has been amply demonstrated that, with good organization and management, a 56 litre/s capacity tubewell can practically irrigate, on the average, more than 40·5 ha of rice

* It is difficult to judge how accurate these records are. The data are collected by the BADC's own staff and there is no good cross-checking mechanism, such as irrigation fee collection, that would prevent inflated reports by field staff.

area in the *boro* season. For wheat cultivation, the practically irrigable area can be 50–100% higher than that for rice. On the basis of field experiments, Sattar estimated that for the sandy soils of the Thakurgaon tubewell project in the Dinajpur district the practically irrigable area for wheat cultivation in the dry season is about 1·1 ha per litre/s (31·6 ha per cfs) of discharge capacity if the tubewells operate 16 hours per day during the peak water-demanding period and if blockwise irrigation is practised.[24]

The wide gap between the current level of DTW capacity utilization and the attainable potential can be narrowed if practically feasible and socially acceptable approaches are applied to solve the problems identified in the field. A number of studies using such an approach have been undertaken in recent years and they have shown very promising results. In one such pilot effort, 20 DTWs were chosen by the field officers of IRDP, BADC and the Department of Extension & Management to have their performance improved. At the end of the year (1979–80) the irrigation coverage per DTW increased from an average of 21·1 ha to 33·2 ha and grain production per acre increased by 57%.[16] In another pilot study, the voluntary agency CARE and the Bangladesh Krishi Bank joined forces with BADC to improve the performance of 10 DTWs.[14] In the first year (1977), they were able to increase the irrigation coverage per tubewell by 55% from the pre-project level and average farmers' yields increased by about 56%. Encouraged by this result, the pilot work was expanded significantly and, in 1982, the project worked with over 215 DTWs in six *thanas* (administrative units of 150–200 villages). In another study in the service area of the Thakurgaon tubewell project, an increase of over 200% in the irrigated area was achieved per DTW in a group of 12 tubewells in the 1982 *aman* rice season compared to the benchmark 1981 *aman* season.[6] There is an urgent need to try to extract the lessons from these different studies and then formulate policies to create conditions favourable to a greater use of DTW capacities. A reasonable degree of improvement in the use of all existing DTWs could make a significant difference in the total area irrigated and in the production benefits achieved by the farmers.

Relative to DTWs, much less information is available on the potential and actual use of the STWs and HTWs. These smaller tubewells have been owned and operated by small farmer groups or individual farmers with no government subsidy. Therefore, the question of their misuse has not been a subject of as much interest as the DTWs. There is a general impression prevailing that the potential of STWs is better utilized than that of DTWs. However, available records indicate otherwise. BADC records show that during the period 1979–82, the average area irrigated per STW has remained constant at about 5 ha. At 14 litres/s capacity this is equivalent to 0·35 ha per litre/s capacity, which is even worse than the present DTW performance. Biswas *et al.*[12] found in their sample of 34 STWs that they irrigated an average of only 0·2 ha per litre/s of discharge capacity during the 1975–78 period. The utilization of STWs should be at least as high as the DTWs per unit of discharge capacity. Indeed, STWs have the comparative advantage of having a smaller service area and consequently a lower loss of water in conveyance and application.

CAN IRRIGATION FROM GROUNDWATER BE SUSTAINED FOR LONG?

It is critically important to know the rate of groundwater utilization that can be sustained on a long-term basis. An accurate evaluation of this question is not possible without adequate field information which is currently lacking, so that only some first approximations are attempted.

If more water is withdrawn in a year from the groundwater than it has received through the annual cycle of recharge, mostly during the wet months from rainfall and streamflows, the water table will decline from its usual level. If this 'water mining' continues for years, the pumping lift and the cost of pumping will continue to increase and a point will be reached when the shallow water lifting devices will become useless. It is therefore vitally important to know what rate of groundwater extraction is safe in the long term. The matter hinges critically on the annual recharge rate in various parts of the country.

For most parts of Bangladesh, the groundwater table shows a natural annual fluctuation from 3 to 6 m; the average is about 3·6 m. As might be expected the water table depth from the soil surface is least during the rainy months and the depth increases with the progress of the dry months.[15] Assuming that the storage coefficient of the soil profiles varies between 10 and 15%, which is a fair estimate of the coefficient for medium to light textured soils, most areas would have a useable water storage of between 0·30 and 0·90 m within the depth of the groundwater table fluctuation.[20] This amount of water therefore becomes a safe amount to be withdrawn from the underground reservoir annually.

TABLE 5
Estimated Potential Annual Groundwater Recharge by Districts

District	*Potential recharge per year*			
	Max. rate		*Min. rate*	
	m	*m × 10⁹*	*m*	*m × 10⁹*
Dinajpur, Rangpur	0·81	13·315	0·42	6 873
Bogra, Pabna	0·51	4·368	0·23	2·024
Rajshahi	0·23	2·197	0·04	0·395
Mymensingh	0·96	15·437	0·53	8·589
Sylhet	2·00	21·842	1·38	15·042
Dacca	0·49	3·628	0·21	1·543
Comilla, Noakhali	0·66	7·009	0·30	3·184
Kushtia	0·25	0·913	0·05	0·197
Jessore	0·42	2·764	0·16	1·111
Faridpur	0·46	3·134	0·19	1·333

Source: IBRD IDA.[20]

Preliminary estimates of annual recharge rates for the different districts indicate that the rate varies substantially between districts (Table 5). These estimates are very rough, but they provide a useful comparison of recharge rates in different geographical areas. Some districts such as Kushtia, Rajshahi, and Jessore have much lower recharge rates than other areas. These districts cannot support full development of agriculture from groundwater alone. On the other hand, Sylhet, Mymensingh, Dinajpur and Rangpur districts have comparatively higher recharge rates and agriculture in these districts could be supported significantly by groundwater.

The recharge rate is affected by a number of factors, including seepage from stagnant as well as flowing water bodies, and by flooding. But it is primarily dependent on the infiltration rate of water through the soil surface, and the rate of percolation in the soil profile. Another source of recharge is the percolation and seepage from irrigated lands and canals. The recharge rate from agricultural lands is increased when farming practices require bunding and storage of water in the field, as is found commonly in rice cultivation. In heavy soils and in areas where the soil is puddled for rice cultivation, the recharge rate is low because of the low infiltration rate of water through the top soil and the low percolation rate because of the hard pan developed by puddling. The groundwater of such an area, however, can be substantially recharged if the aquifer is hydraulically connected to a river bed or its side in a way that allows water movement from the river to the aquifer. For areas where the water table during the wet season rises to very near the ground surface, the groundwater recharge potential becomes limited by nonavailability of soil profile to store water. In that situation, the recharge potential can be increased if the water table is lowered by pumping groundwater out during the dry season.

Since adequate data from actual measurements of recharge rates are not available, some useful assessment of the possibility of the groundwater level decline can be made from the records of water table fluctuations in areas where the present groundwater withdrawal is significant. Investigations by the Bangladesh Water Development Board indicate that in some places in the districts of Kushtia, Pabna, Bogra, Comilla, Chittagong, Tangail, Dhaka and parts of Mymensingh and Rajshahi districts, the groundwater levels have declined by 0·15–0·30 m more during the last 5–7 years compared to earlier records.[8] This additional lowering has been attributed to increased withdrawal of the groundwater by irrigation wells. Further, the study indicates that there is a pronounced effect of an antecedent year's low rainfall, especially the low rainfall of September and October, on the lowest depth of the water table which usually occurs between April and early May. In three of the above-mentioned districts, i.e. Pabna, Bogra and Chittagong, and in the Jamapur district, the groundwater level was found not to be returning to its previous year's level at the end of the rainy season, and to have fallen over the last 2–4 years at a rate of 0·09–0·15 m per year even in the months of August and September, the rainy months.

The current information base is inadequate to assess whether the present rates of groundwater withdrawal can be sustained on a long-term basis. But the available data suggest that the process of gradual lowering of the water table may have already started in some areas. The need for careful and continued monitoring of the behaviour of the water levels throughout the country is therefore of paramount importance.

'PRIVATIZATION'—ITS PROMISES AND PROBLEMS

The STWs and HTWs have always been fully owned by the farmer groups or individual farmers and there has been virtually no government subsidy of the sale price of these types of equipment. On the other hand, for a long time the DTWs have been subsidized for 90–95% of their actual costs. In 1979–80 the government took the bold step of gradually withdrawing the subsidy to DTWs and introducing sale programmes for new DTWs and implementing a programme of 'privatization' of the groundwater sector.

In DTW systems, a farmer group for an existing tubewell is required to pay a yearly rent in exchange for the right to the tubewell's use by them and the repairing and maintenance services of BADC. The cost of spares is to be borne by the farmers. The rental charge remained steady at Tk. 1200 per year from 1974–75 to 1980–81. This rent represented less than 0·5% of the cost of a DTW during most of that period. In 1979–80, in the wake of the privatization policy, new DTWs were sold to farmer groups at a price of Tk. 50 000 each on a cash basis. In 1982, the sale price for a farmer group was raised to Tk. 75 000 cash, or Tk. 85 000 on an instalment plan, for a new DTW which cost BADC Tk. 335 000. For an individual farmer, a DTW bought through BADC would cost the full price.

The rental charge for an old DTW has been raised to Tk. 3500 per year since mid-1982. Further, farmer groups are now encouraged to purchase the old DTWs at an attractive price calculated on the basis of a straight line depreciation between the 1980 price of Tk. 60 000 and the salvage value of Tk. 30 000 after 10 years. The plan is that the yearly rental charge would be increased further to discourage renting and encourage the farmer groups to purchase the equipment. Conditions for farmers wishing to obtain bank credits to purchase any kind of tubewell have been greatly relaxed and official formalities liberalized. Over 4100 DTWs had been sold up to March 1983 under the privatization scheme.[3]

Major benefits can be obtained from proper implementation of the privatization policy. Most of all, the government can get relief from a heavy burden of subsidy in the DTW sector, which amounted to about Tk. 130 million in 1975–76 but ran several times higher per year in more recent years.[10] The subsidy was mainly helping the relatively affluent farmers who are influential in society and able to arrange installation and operation of DTWs under their control.[19,21] The ownership system should help to counter the problems associated with the low use of a tubewell's potential capacity and with its care and maintenance. For new DTWs, an economic rationale should dominate any undesirable social and political influence in the decision to locate a tubewell. Another major benefit accruable from a proper implementation of the privatization policy is the development of the private sector for equipment and spares manufacture, sale and servicing facilities.

There are a number of areas in which caution must be exercised and sound plans formulated and implemented to avoid likely suffering of the small farmers from the privatization policy. There is a fear that a quick implementation of the policy may create more 'water lords' than there are now. If a DTW is purchased by a wealthy individual or a small group of relatively well-off farmers, the owner(s) could use the water source for excessive profiteering by selling the water at a high price to a captive group of neighbours who would not have a chance to use the groundwater by any other means such as an STW or an HTW. The purchased ownership of the water source could be used by the owners against those neighbours for any purpose suitable to them. This could also happen to some extent in the case of STWs. The social problems created through such developments could be worse than when the DTWs were a government-owned property and all members had at least an equal theoretical right to the use of the water. Possible exploitation of small farmers by the affluent ones through ownership of tubewells can be minimized through appropriate government policy and legislation. BADC should sell an existing or a new DTW only to genuinely registered farmer cooperatives. The water charges that can be realized from interested non-members of the cooperatives should be limited by appropriate legislation. Socio-economic studies are needed to support such government action.

The privatization policy supported by a multi-agency involvement in the sale of the different types of tubewell systems to individual farmers or farmer groups may create overcrowding of tubewells in some areas, affecting the availability of water to some farmers. There is an urgent need to try to prevent such a development.

THE CHOICE OF SCALE

The three main types of tubewells found in use in Bangladesh, i.e. the DTW, STW and HTW, appeared on the irrigation development scene in an order inverse to their scale. The DTWs were first promoted by the government. Large-scale development was started by BADC in 1967–68 and since then, on the average, more than 1000 DTWs have been installed by the agency every year. The STW programme started in 1974–75 but developed very quickly into a programme of nearly 100 000 units by 1982–83. Although an HTW programme was initiated at about the same time as the STW programme, a major government initiative to popularize their use did not occur until a few years later. The last 4 5 years have seen a phenomenal growth of HTWs for irrigation.

Clearly, there has been a shift in the government's emphasis in recent years on the type of groundwater systems to be developed. DTW development has been de-emphasized in favour of the STW and HTW types. Although DTWs will still remain on the development scene, it is likely that the Second Five Year Plan's target of operating 25 000 DTWs by the end of 1984 85 will be revised to a smaller number. The recent policy of privatization and sale of DTWs has introduced new economic considerations, which the farmer groups must consider seriously before they decide to invest in the DTWs. The number of DTW units sold during the first nine months of the year 1982 83 is about 1500 against a target of 2300. On the other hand, the yearly targets for the sale of STWs and HTWs are being adjusted toward a higher figure. BADC has a target to bring into operation a total of 90 000 STWs by 1984 85. In all probability, this target will be achieved. Similarly, the present rate of development suggests that the target of 500 000 HTWs by the end of 1984 85 will be exceeded.

The DTW scheme was originally conceived with the assumption that farmers would form cohesive groups to use properly the water-lifting equipment made available to them virtually free of cost. The condition for them to have a tubewell was to show that a sufficient number of farmers had formed a cooperative group to use the irrigation water. The low utilization of DTW capacity is indicative of the fact that this assumption did not work satisfactorily. However, records indicate that substantial improvements have been achieved during the past 5 6 years in the use of the DTWs.

The reasons for the low utilization of DTW capacity have been investigated by a number of researchers.[9,11,12,24] The primary reasons for low utilization are rooted in technical problems of sub-optimal siting of the wells, inadequate maintenance and repair of the equipment, defective water conveyance and distribution systems, organizational and management problems of the tubewell committee with a relatively large number of members having small and fragmented land holdings, and social problems of interference and exploitation by the powerful members in the rural community.

The STW technology, which requires a lower investment, is less demanding of cooperation from a large group of farmers and serves a

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smaller area per tubewell, seemed an attractive alternative to the DTWs. STWs are either individually or cooperatively owned and operated. The lack of need for government subsidy to popularize the use of these tubewells was a welcome contrast to the DTW sector which, toward the middle of the 1970s, became a very questionable investment for the future development of groundwater for the small farmers of Bangladesh.

HTWs, on the other hand, represented the smallest and most truly individual form of groundwater development and use for irrigation. Such a scale of development is imaginable only in an agrarian background as in Bangladesh where the land holdings are very small — 80% of farms are less than 2·02 ha in size — and where pressure to produce from the land is very high. The economic attractiveness of the technology and its accessibility to the very-small-scale farmers have made HTWs the most quickly spread means of groundwater irrigation in the country.

An important question is: what type of tubewell technology is the most relevant and appropriate for Bangladesh today? This question can be looked at from various viewpoints. In terms of technology, all the different options, i.e. DTWs, STWs, HTWs and dug wells, are relevant. In areas where shallow aquifers are not available, deep wells are a relevant technological option. Since the cost per unit of water is substantially higher in deep tubewells than other forms of wells (Table 6), this technology could become an appropriate option only when the benefits from it outweigh the costs. The past DTW development plan of the government seems to have been excessively influenced by the false promise of quick irrigation development, which may have contributed toward their overlooking the need for better judgement on implementation strategies; namely proper siting, social equity, and development of effective water conveyance and distribution systems for all the users. Thomas argued that the choice of deep tubewell technology in Bangladesh was determined by the organizational requirements of the implementing agencies, including the aid donors.[25] He further argued that in the actual decision-making, such factors as risk avoidance, appearance of modernity, established procedures and familiar techniques, and control outweighed development policy objectives. However, it is clear that at the root of many of the problems was the very high subsidy given to DTWs.

The STWs represent a scale that fits the needs of individual large farmers or groups of small farmers tapping shallow groundwater. For geohydrologically suitable areas, an STW is about 50% cheaper than a

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TABLE 6

Costs of Irrigation Water by Different Types of Groundwater System Based on 1976–77 Prices

Item	*DTW*		*STW*		*HTW*	
	With duty	*Without duty*	*With duty*	*Without duty*	*With duty*	*Without duty*
Capital cost (Tk.)	240 550	223 000	30 446	24 100	1 835	1 380
Capital cost per ha metre of water (Tk.)	824·01	753·31	353·15	282·45	517·88	388·49
Operation and maintenance cost per ha metre of water (Tk.)	659·27	659·27	647·60	647·60	470·86	470·86
Total cost per ha metre of water (Tk.)	1 483·28	1 412·58	1 000·75	930·05	988·74	859·35

Source: GOB and the World Bank.[16]

DTW in making a unit volume of groundwater available for irrigation (Table 6). Since STWs have been privately owned and no government subsidies are involved in their acquisition or operation, such wells are being used only by motivated farmers. Because of its small service area, the degree of farmer cooperation required for successful operation of an STW is much less than that required for a DTW. The existence of a cooperative environment is an economic necessity for investment in an STW by a farmer group. The appropriateness of the STW technology is proven by its great popularity.

HTWs are at the lowest level in the technology scale. They require minimum investment, minimum skill to instal and operate, and the working life is short. HTWs are individual-farmer oriented, require no cooperation from neighbours, and they represent an option that is not permanent in nature, i.e. a farmer-user does not have to subscribe to it for a long time, if he finds it unsuitable for some reason. The cost of water per unit volume in an HTW is comparable to the cost of water from an STW (Table 6). HTWs are the most labour-generating type of groundwater irrigation device. They generate labour both for installation and for operation. About 80 man-days of labour are required to pump water for 1 ha for one crop with an HTW compared to about 0·4 man-days in a mechanized tubewell system (Table 1).

HTW development has been criticized because it requires arduous labour.[22] The criticism is correct, but the important point is that this technology provides an option to the small farmer who may not have access to other means of irrigating the land. It is quite likely that, as many more new HTWs are installed in the near future, some of the old ones will cease to function because of problems associated with the availability and cost of labour, or because they have found access to an STW. (This transformation is reportedly happening now in some areas such as Tangail, Tamapur and Bogra.[13]) Such a transformation of status is desirable in the sense that these farmers have, in all probability, gained a good appreciation of the value of irrigation water and some knowledge of water management. Such a change of status, which should generally mean progress for the farmers, is almost ideal when we consider the problems that have been encountered in the DTW sector in the attempt to transform a group of rainfed farmers into efficient users of deep tubewell water. However, one can reasonably argue that the total impact of HTWs on the irrigation scene in Bangladesh will remain limited compared to mechanized means of irrigation.

The entire need for groundwater irrigation development in Bangladesh cannot be met by use of only one or two of the different scales or types of tubewell technology that are available. The geohydrologic background will prohibit the development of the full potential of groundwater by use of any one of the types. Socio-economically speaking, each type of tubewell requires a specific set of conditions for optimal use of the investment. The deep tubewells, because of their high investment and large discharge capacity, are the most demanding in that regard. However, there are many examples of deep tubewells which have been using their discharge capacities at optimal or nearly optimal levels to the benefit of a large number of small farmers, indicating that this technology has a suitable place in the society of Bangladesh.

The recent policy decision of the government to privatize deep tubewells seems logical and sound. The shift of emphasis from deep tubewells to shallower ones for extensive groundwater development is also a logical step toward achieving the much-desired goal of helping the small farmers, including those in the remote areas, to produce more food and earn more income. If backed up properly with the necessary policies concerning the siting of the different scales of tubewells in the various parts of the country, the deep, shallow and hand tubewells should find their appropriate places in the total groundwater utilization programme. Lessons of the past should be kept in mind while formulating these policies and their implementation strategies, and at the same time, the long-term future, rather than just quick immediate gains, should be uppermost in the decision-making process.

NATIONAL-LEVEL PLANNING AND COORDINATION: ACTIONS NEEDED

Bangladesh needs an up-to-date master plan for the development, use and management of its water resources, including groundwater. The rate of groundwater development presently underway in the country is such that the short-term plans guiding development can at the best be approximately consistent with the long-term national needs, but at the worst they can give rise to major future problems. Fortunately, the total groundwater resource available in the country is much more than will be exploited during the next few years, but it must be recognized that the groundwater resource is finite and it is closely interrelated with surface

TABLE 7
Number of DTWs Sunk, Commissioned and Operated in North Bengal

Year	*No. sunk*	*No. commissioned*	*No. operated*	*% of commissioned DTWs in operation*
1967 68	27	23	24	100
1968 69	156	155	138	89
1969 70	450	428	405	95
1970 71	450	430	319	74
1971 72	450	430	331	77
1972 73	450	442	397	90
1973 74	639	464	383	83
1974 75	2262	603	442	73
1975 76	3037	736	418	57

Source: Hamid *et al.*

has traditionally not been considered challenging or rewarding by the technical professionals. Because of this and the heavy orientation towards new construction, procurement of materials and equipment for new tubewell installation has always found preference, in these agencies, over the procurement of spares for repair and maintenance work. Government action is needed to find a better balance between the emphasis on new installation and that on services to promote optimal use and maintenance of the installed equipment.

In this respect, the privatization policy, if implemented properly, should help alleviate the problem. With the involvement of several government agencies in the sale of different types of tubewell, there is a greater degree of competition among the agencies, particularly among those concerned with the sale of STWs and HTWs. This competition is putting pressures on the agencies to reach the farmers even in the relatively remote areas where servicing facilities are yet to be developed. At the same time, the farmers are demanding a better service for their purchased equipment. The development of the private sector which is supposed to take care of most of the needs for the spares and maintenance services of the equipment has been very slow in most areas. Many newspaper reports and complaints against non-existent or inadequate services of STW dealers in various parts of the country have been published during the current year's dry season. There is an immediate need for the government to take appropriate steps to encourage the water hydrology. A comprehensive (but regularly revised) master plan for the development, use and management of all water resources—surface water and groundwater—will help to formulate short-term plans and policies consistent with the national goals and resources available. It will also help to avoid conflicts and interference among subsectoral schemes in the same basin. There are already reports of cases of interference between surface water drainage schemes and deep tubewell schemes in the same area.

A recent review by an expert team recognized that considerable data are available on both surface and groundwater resources, collected primarily by two agencies—Bangladesh Water Development Board (BWDB) and Bangladesh Agricultural Development Corporation (BADC).[16] However, they concluded that they are not adequate in quantity or quality for optimal planning for the future. The review particularly mentioned the inadequacy in the capacity of the agencies for data processing and management that is required to make the data readily accessible in easy-to-use form. Recognizing the critical importance of the finite water resource in the national economy in the future, there is an urgent need to establish appropriate institutions and networks with trained manpower systematically to collect data on the availability, use, quality and behaviour of groundwater in the country. Computerized data processing systems should be established for ready use of such data.

At the present time a good number of government agencies are directly responsible for making groundwater irrigation systems available to the farmers. These are: BADC and BWDB for deep tubewells; BADC, Bangladesh Krishi (agricultural) Bank, and Bangladesh Bank for shallow tubewells; and BADC, The Department of Public Health Engineering, and the Rural Development Board for hand tubewells. In addition, the private sector is involved in providing the goods and services required for the tubewell development programmes, particularly the STW and HTW programmes. The major emphasis of all these agencies is to meet the targets of new tubewell installation or sale imposed on them by the planners. What happens to the equipment after it is sold or installed is a question that receives inadequate attention. For example, in the DTW sector, the number of units which actually operated in any given year was always significantly less than the installed number because, among other reasons, the repair and maintenance given to the installed units has been inadequate. Hamid cites perhaps an extreme example of this situation for DTWs in North Bengal (Table 7).[17] Operation and maintenance work

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