MINOR IRRIGATION DEVELOPMENT IN BANGLADESH

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CHAPTER I

BACKGROUND AND INTRODUCTION

Agriculture plays a critical role in Bangladesh's economy. It employs seven out of every ten people, produces 56 percent of the nation's Gross Domestic Product and accounts for 90 percent of export earnings. Sector performance has been satisfactory over the past decade. Rapid population growth, however, has absorbed modest increases in foodgrain production and per capita food intake and nutrition, already at critically low levels, have stagnated or possibly declined. Shortfalls in foodgrain production have been met by imports. Averaging 1.7 million tons annually since 1972, they now account for one quarter of the nation's import bill and absorb one half of average annual foreign exchange earnings.

With a limited agricultural land base of approximately 22 million acres and a deteriorating man-land ratio, government efforts to accelerate agricultural growth have focused on intensive rather extensive development strategies. Central to government efforts are improvements in irrigation and water control to increase the area under cultivation, and improving long term productivity and employment. The rapid expansion of irrigated acreage is seen as a precondition to the introduction of HYV seeds, increased fertilizer demand and the application of higher management and labor inputs.

Investments in irrigation and water control have been substantial, averaging 15 percent of government annual revenues since 1975 (IBRD 1981 pp 114, 116). In the past they have focused on the development of large government owned irrigation and flood control projects, the introduction of smaller tubewell and portable pump schemes, and the spread of manually operated water lifting devices managed by individual farmers. Largely conceived and managed by engineers, results have been mixed.

A small number of large irrigation schemes while expanding winter season cultivation have had problems. Poor management, the absence of effective institutions which encourage farmer participation, limited understanding of water management principles, and system design problems have resulted in command areas smaller than anticipated and have raised doubts about the cost effectiveness of the schemes. Preliminary evidence suggests that flood control projects also have had difficulties -- ineffective maintenance, poor design and deleterious effects on soil fertility (Hanratty 1979).

As problems with large scale systems have emerged, greater reliance on small-scale, mechanical and manually operated irrigation technologies has developed. Recently, emphasis on manual irrigation has begun to decline as policy makers realize that the area where these schemes are appropriate is relatively small, their impact limited and the energy efficiency associated with the technology suspect[1]. While activities in this area will continue at a reduced level, mechanically operated shallow and deep tubewells and low lift pump technologies will be heavily relied on in the medium term to expand irrigated acreage. Over the last ten years, the acreage irrigated by these schemes has expanded rapidly and now constitutes over half the area irrigated (Wennergren, 1983, Table 3.18). Government plans, while optimistic, suggest a two fold increase in area irrigated by these technologies by 1985 (PC 1980, p.XII-80).

Irrigation development has and will continue to be heavily dependent on foreign aid. To date USAID has played a limited role, focusing largely on improving deep tubewell command area performance, expanding the use of manual tubewells and supporting irrigation research. Given the importance of irrigation in Bangladesh's agriculture future, the Dhaka Mission is exploring the need for expanded support in this area.

The purpose of this paper is to provide a background review of Bangladesh's irrigation policy for this exploration. More specifically, the paper assesses the role of irrigation in national development in Asia and attempts to determine if government investments in irrigation vis-a-vis alternative policies are sound. This leads to a historical evaluation of Bangladesh's irrigation policy focusing on the technological choices made in implementing past policies. A third section compares the financial and economic costs and returns associated with preferred technologies low lift pumps and shallow and deep tubewells. And a concluding section summarizes research results and suggest areas for potential AID support.

CHAPTER II

THE ROLE OF IRRIGATION IN DEVELOPMENT

The public allocation of scarce resources is an important function of government in developing economics. Low levels of private savings and investment, new and imperfectly functioning capital markets and divergent private and social rates of return on investments argue convincingly for active government intervention. The focus and level of intervention has been hotly contested. Some investment strategies favor industrial growth, others agriculture. Within sectors, debate focuses on the efficiency and merits of relative investment options including price supports, input subsidies and infrastructure investments.

Evidence gathered over the past three decades, implies that agriculture plays a critical role in national development. It provides the food, raw materials and labor required for industrial growth while providing a growing market place for consumer goods, modern agricultural inputs and the skills produced by industry. During the early stages of development, agricultural growth ranging from 3 to 5 percent is required to support modest industrial growth of 5 percent. Over the long term, growth of 2 percent is needed for industrial growth rates of 8 to 10 percent. (Krishna 1982, p. 8). This general rule is substantiated by the evidence. For example, long-term industrial growth rates in developed economies, the U.S., U.K. and France, have ranged from 3 to 6 times agricultural growth rates (Klein and Okhawa 1968). In Japan during its major development period, 1876 to 1938, a 3:8 ratio prevailed (Klein and Okhawa 1968, p. 74). Modeling efforts in relatively closed developing economies with low trade to GDP ratios, substantiate historical evidence exists. In Pakistan and India, agricultural growth in the order of 2 to 5 percent was necessary to balance industrial expansion ranging from 6 to 10 percent. (Rudra 1972; PPD 1964; Eckaus and Parekh 1967; Leiftinck 1969).

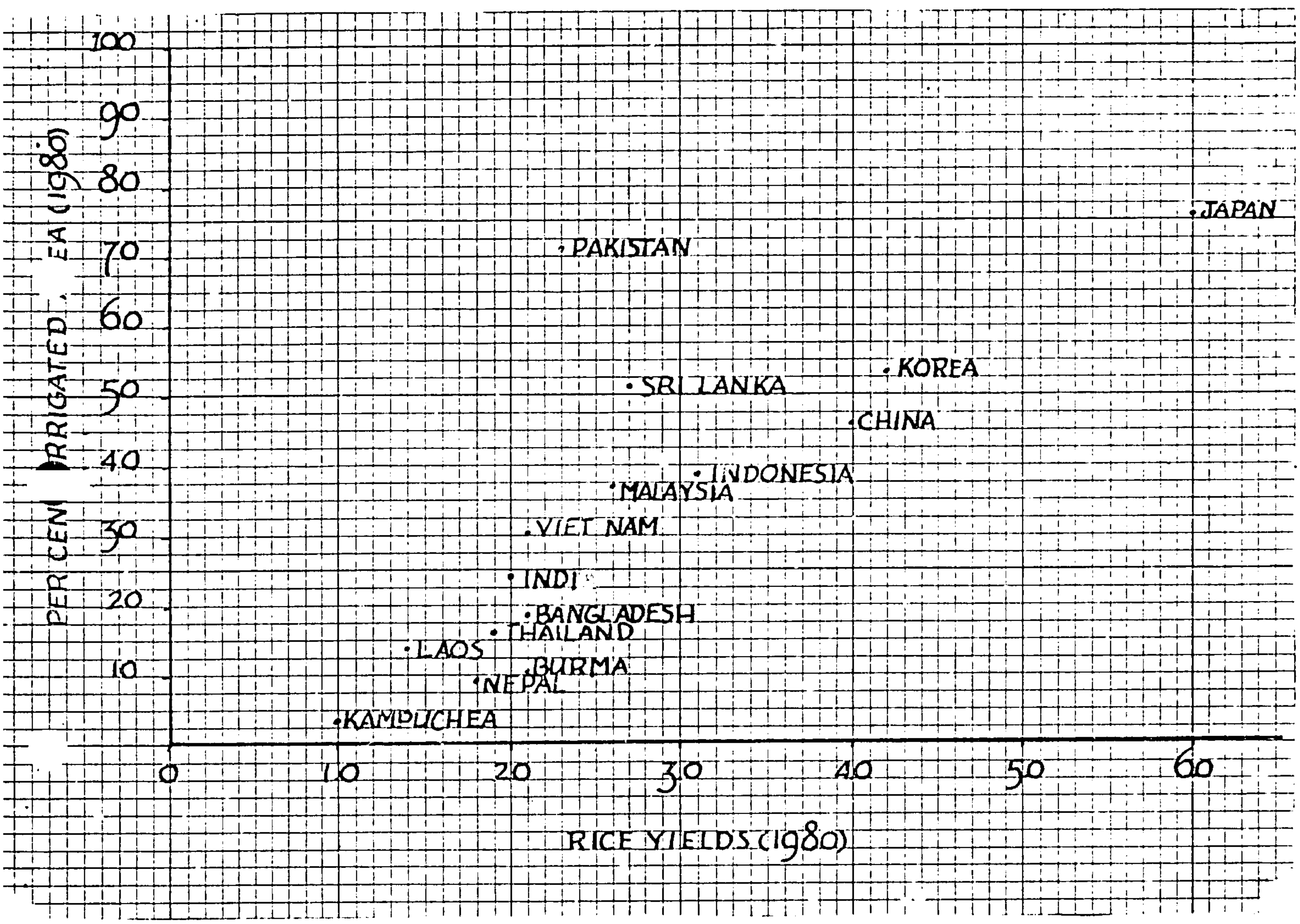
During the last two decades agricultural growth in the poorest developing countries has not kept pace with population increases.[1] In many cases sluggish performance is associated with underestimating the importance of capital investment during the early stages of development. Assuming that agriculture exhibits low incremental capital-output ratios (ICORs), the amount of investment required to produce an additional unit of agricultural output, national planners consistently have underinvested in agriculture.[2] Recent empirical evidence, indicating ICOR's substantially higher than previous estimated, has challenged this assumption. Kuznet's analysis of capital investment levels in several developed economies over the last century suggests agricultural ICORs ranging from 1.1 to 3.3 times higher than those in mining and manufacturing (Kuznets 1961, p.46). Scattered research results from the developing world agree with these findings. For example, a UN report covering twelve developing countries in the late 60s, reported ICORs of 3.2 in agriculture, 2.8 manufacturing and 3.0 for the whole economy (UN 1971, p. 80-81). In India, Kelhar reports ICORs in agricultural rising to 1.9 in the early 50s to 2.7 in the early 70s (Kelhar 1980). More recent Indian ratios, ranging from 2.45 in the 50s to 2.99 in the 70s, suggest that investments in agriculture, all things being equal, increase output more than investments in other sectors (Abbie et. al. 1982, p. 7).

Evidence of the high capital investment costs associated with agricultural development is provided by Hayami. In his historical appraisal of agricultural growth in Japan and Taiwan, he found different ICORs associated with different stages in agricultural growth. In Japan the ratios rose rapidly from a low of .4 in 1876-1904 to 2.2 in the pre-World War I period (1904-1918); declined steadily to 1.4 in the post-World War II period 1947-1957); and again rose to record levels of 8.9 in the 1960s (Hayami et. al. 1979). This suggests that during agricultural growth, ICORs rise in early periods when basic investments in irrigation, drainage and land development are made, and later when mechanization becomes necessary. In the interim, they decline as productivity increases primarily as a result of bio-chemical input growth (Ishikawa 1978).

The importance of increased investments in Asian agriculture, especially those focused on irrigation, are highlighted in a number of recent reports. The Trilateral Commission, in their review of Asian rice production and consumption, conclude that water control is the most fundamental constraint to increasing Asian food production. Sighting the high correlation between irrigated area and rice yields (Figure 1), the report recommends substantial irrigation infrastructure investments, totaling $52.6 billion over a 15 year period[3] (Colombo et. al- 1978). The Commission report concludes that foodgrain production could be doubled by 1990, at current levels of technology, by a six-fold annual increase in irrigation investment from US $ 700 million to US $ 4.5 billion. The International Food Policy Research Institute concurs with the Commission's findings (Oram et. al. 1979). In their assessment of investment levels required to meet 1990 food needs in the world's 36 poorest nations, they recommend investments of US $ 78.3 billion, with 84 percent or US $ 78.3 billion committed to irrigation development (Table 2.1). A substantial portion of these investments, approximately US $46.0 billion, would be made to improve Asian irrigation.

Recommendations for rapid increases in Asian irrigation investments, suggest a strong preference for irrigation over other forms of agricultural sector investments. Research in the Philippines supports this preference (Barker and Hayami 1976; Hayami, Barker and Bennagin 1977). In an assessment of the relative efficiency of various agricultural development policies researchers found that government investments in fertilizer price subsidies were more efficient than equivalent amounts invested in rice support programs. Both investments were, however inferior to irrigation investments.

FIGURE 1. RELATIONSHIP BETWEEN IRRIGATION AND RICE YIELDS IN ASIA, 1980



Source: USDA 1980, FAO 1981.

TABLE 2.1 : CAPITAL INVESTMENT COST TO MEET 1990 FOOD REQUIREMENTS IN THE WORLD'S 36 POOREST COUNTRIES 1/

(IN U.S. $ MILLION)

	Irrigation 2/	Fertilizer	Seed	Machinery 3/	Pesticides	Storage	Research/ Extension 4/	Regional Totals
Asia	45970.5	7116.8	248.0	3959.9	907.5	3080.7	4656.9	65940.3
Africa/Middle East	6061.4	1976.8	62.8	1182.7	177.4	1266.5	1558.3	12248.0
North Africa and Middle East	(4281.0)	(547.3)	(35.3)	(438.0)	(47.4)	(247.2)	(336.7)	(5932.9)
West Africa	(940.9)	(832.0)	(12.6)	(387.0)	(74.7)	(578.1)	(560.7)	(3386.0)
East Africa	(570.5)	(554.4)	(14.3)	(315.6)	(50.3)	(415.9)	(565.7)	(2666.7)
Latin America	89.0	43.1	.6	42.1	5.0	25.3	95.2	262.4
Total:	52031.9	9116.8	310.8	5142.6	1084.9	4349.1	6215.2	78251.3

Source: Oram et. al. 1979.

Notes : 1/ Includes eight countries in Asia, three in North Africa/Middle East, thirteen in West Africa, ten in East Africa and two in Latin America.

2/ Excludes cost of training new manpower to operate new systems.

3/ Includes both animal-powered and fossil fuel powered machines.

4/ Cost of training research and extension staff.

A more comprehensive follow-up study exploring the relative costs and benefits of these three policy options in the context of Philippines rice self-sufficiency, substantiated earlier findings (Baker, Bennagin and Hayami 1978). This later study concluded that although price and fertilizer policies resulted in higher producer benefits, irrigation investments constantly outperformed both policies in achieving self-sufficiency. Estimated benefit-cost ratios associated with irrigation developments ranged from 1.6 to 6.6, with internal rates of return ranging from 21 to 36 percent.

Although returns to irrigation are positive, they are not high in developing economies. Research findings, presented in Table 2.2, suggests gross marginal returns, expressed in wheat equivalents per cubic meter of irrigation water, ranging from .05 to .50 kilograms. Net marginal returns, calculated by deducting the marginal costs associated with irrigated production, ranged from .06 to .45 kg. Valued in 1982 wheat prices, gross and net returns were not high, averaging only 0.036 and 0.032 1982 US dollars, respectively.[4]

Low economic returns are not necessarily characteristic of worldwide irrigation investments. Comparing developed versus developing countries, there is an important difference. Gross and net returns in developed countries average 9.7 and 10.4 times developing country estimates. The difference in returns suggest that further investments to improve existing Asian irrigation systems would be very profitable. The Trilateral Commission believes that upgrading existing irrigated acreage is the cheapest course for improving Asian rice production (Colombo, et. al. 1978).[5] Capital development costs associated with producing an additional ton of rice on this acreage is estimated at US $ 200 per ton, while costs of converting rainfed to fully irrigated acreage, the cheapest alternative, are US $ 300 per ton.

High returns to irrigation in developed countries imply a high complementarity between irrigation and other inputs. This relationship is consistent with experience in developing countries. For example, Gotsch in his work in Pakistan found an inverse relationship between the demand of irrigation water and price, indicating a positive marginal value product for water (Gotsch 1971). His most striking finding was the impact of irrigation development on labor demand and its marginal productivity. He estimated that an intensive groundwater resources development program would increase labor use by over 50 percent, 35 percent being new hired labor.

Research conducted by the International Fertilizer Development Center, in Bangladesh supports these findings (Sidhu et. al. 1982). Baseline data collected during the study suggest a high complementarity between irrigation, fertilizer use and rice yields. Researchers found application rates associated with irrigated local and high yielding varieties to be 1.9 and 1.4 times greater than those of their rainfed counterparts (Table 2.3). Fertilizer when combined with irrigation and improved seeds significantly enhanced productivity, with irrigated HYV varieties outproducing local rainfed varieties by almost two to one.

TABLE 2.2 : RETURNS[1/] TO IRRIGATION

Country	Crop	Gross Marginal Returns	Net Marginal Returns
Developing Countries			
Bangladesh	Rice (unmilled)	.45	
	General: Senapur		.25
	Orissa		.24
	Bihar		.45
	Bombay		.3-.5
Iran	Wheat	.05	
Iraq	Wheat	.12	
Jordan	Wheat	.47	
Pakistan	Cotton (unginned)	.24	
	Cotton (ginned)		.07
	Millet		.06
	Rice (milled)		.12
	Sugar cane		.13
	Sorghum		.08
Developed Countries			
Australia	Rice	.17	
	Sorghum		.21
	Wheat		.94
France	Potato	11.54	
	Wheat	1.07	
Israil	Cotton (unginned)	.41	
	Groundnut (unshelled)	.99	
	Sorghum	1.10	
Italy	Maize	.56	
	Potato	5.20	.82
	Wheat	.26	
United States	Cotton (ginned)	2.31	
	Maize	1.84	
	Potato	9.50	6.55
	Sorghum	1.03	
	Sugar cane	.06	

Source: Carruthers 1982, pp. 174-183.

Notes : 1/ Returns in kilograms of wheat equivalent per cubic meter of water supplied with and without additional costs of production.

The research concluded that increases in irrigation would significantly alter the demand for other inputs. For example, a one percent increase in the use of irrigation would result in .10 and .21 percent increases in fertilizer and HYV seed demand. In addition, irrigation development would increase the demand for labor. If government efforts to double irrigated acreage were realized, this could lead to a 10.3 percent increase in labor required per acre. Assuming a 20 percent increase in cropped area as a result of irrigation, the study concluded that employment of farm labor could be increased by as much a 30.3 percent. These estimates reflect only the direct impact of improved irrigation. Secondary and tertiary demand for labor to process, transport and market increased production would significantly enhance direct employment efforts.

The above review suggests that irrigation has an important role to play in national development. The role of agriculture in the development process, the importance of capital investments in the early stages of agricultural growth, the superior efficiency of irrigation over other agricultural policy options and the high pay off associated with irrigation investments indicates substantial investments. Investment levels ranging from 46.0 to 52.6 billion 1975 US dollars have been suggested for Asia. Farm level data from Bangladesh complement these findings and suggest that irrigation growth could have a significant role to play in increasing production, improving yields and solving growing problems of rural unemployment.

TABLE 2.3 : COMPLEMENTARY BETWEEN IRRIGATION AND FERTILIZER USE IN BANGLADESH - 1979/80 1/

	Fertilizer Inputs (lb/acre)	Rice Yields (lb/acre)
Irrigated areas		
Local rice varieties	166	5033
High Yielding Varieties (HYV)	765	9366
Rainfed areas		
Local rice varieties	86	4756
High Yielding Varieties (HYV)	535	7837

Source: Sidhu et. al. 1982, Tables V.21 and VI.3

Note : 1/ Includes data from three growing seasons: 1979/80 Boro (dry season), 1980 Aus (early rainy season) and 1980 Aman (rainy season).

CHAPTER III

IRRIGATION POLICY IN BANGLADESH

Over time irrigation policy in Bangladesh has undergone substantial changes. During British rule it suffered from benign neglect. By 1947 declining per capita foodgrain supplies led to interest in investments in large scale surface irrigation systems. Growing foodgrain requirements and delays in implementing large scale systems, resulted in a growing reliance on smaller scale surface irrigation complimented by use of ground water aquafers in the 1960s. During the 1970s, problems with these technologies led to the increased use of smaller tubewell pumps and engines, owned by private individuals rather than public agencies.

At each step in this evolutionary process decisions taken in response to prevailing conditions have led to technical choices which continue to shape policy options today. The identification of past choices and their link with present policy options is the focus of this brief historical review.

Irrigation Policy in British India

Irrigation development in British India was limited to the growth of large gravity canal systems in areas of high potential. Irrigation policy suffered from three constraints; a strong focus on the development of railways rather than irrigation to deal with food shortages, the absence of an effective mechanism to finance irrigation development and lack of support for small scale irrigation. (Bhatia 1963. p. 123-26). After a century of British rule, only 11 percent of India's 197 million cultivated acres were serviced by irrigation.

During the 19th century, civil disorder and influential business and trade interests biased investments toward transportation rather than irrigation.[1/] Proponents of an expanded Indian rail system believed it a sufficient first-line defense against famine.[2/] Viewing famine simply as a supply problem, they argued that a modern rail system would provide transportation facilities required to meet local shortfalls.

The Famine Commission of 1898 attacked this assumption arguing that famine was a demand rather than supply related problem, which could only be solved by increased investments to stabilize and increase food production (IFPRI 898, Ch 2 para 52). Their conclusion, which remains valid today, was that in most instances adequate food was available in famine affected areas to forstall death. Death resulted from a sharp rise in unemployment, subsequent declines in laborers' incomes, and their growing inability to purchase food.

While the Commission report argued strongly for increased irrigation investments, especially in unstable production and employment areas, public investments continued to favor transportation. In part this was due to government's inability to develop adequate financial mechanisms to support irrigation developments. Declines in the exchange value of the rupee and growing foreign exchange constraints made it increasingly difficult to raise foreign funds to support irrigation developments. Unfortunately early efforts to involve private investors in canal projects in Madras (1860) and Orissa (1862) proved to be costly failures, and led to the exclusion of private involvement in future irrigation developments.[3]

The increasing incidence of famine in the late 19th century and the inability of transportation policies to control the problem, argued strongly for increased investment in irrigation. Following strict financial criteria adopted in the 1880s, new projects were typically located in high payoff areas such as the Punjab.[4] Bangladesh, then part of the Province of Bengal, received little attention. The country's flat deltic topography and the instability of its major rivers made large, canal-based, irrigation systems costly. Adequate rainfall during most years assured at least one rice crop each year. At the turn of the century, Bengal was self sufficient in rice, annually exporting one to three million tons to other parts of India (Bhatia 1963, p. 277). Also, the provincial tax structure, which froze tax revenues at ten elevenths of land rents paid in 1793, made it difficult to raise funds for irrigation development.[5]

During the early twentieth century conditions in Bengal changed. The province's favorable foodgrain position ended. Increasing population, limited expansion of cultivated area and adverse weather led to declining per capita availabilities. Average exports during the five year period from 1928 to 1933, dropped to 128 thousand tons. During the next ten years (1933-42), production did not keep pace with consumption, and annual imports averaging 51 thousand tons during the first five years rose to 159 thousand tons during the last half of the period (IFIC 1976, p. 207).

The tragic 1943 Bengal famine, which claimed 1.5 million lives, sharply focused the need for increased food production. At the time, only 7 percent of the province's rice acreage, approximately 1.8 million acres, was irrigated. Much of this, located in the western section, was outside present day Bangladesh.

Post-Partition Policy

The post-partition era marked the beginning of major water resource investments in Bangladesh. Like earlier Indian efforts, planning focused on large-scale, public undertakings to stabilize water regimes associated with rainy season rice production. Investments took two forms; improvement in flood control and drainage and the development of supplementary irrigation during the monsoon season. Emphasis was on flood control and drainage to increase agricultural productivity not irrigation.

There were a number of reasons for this. Seismatic activity in Assam in mid-1950 resulted in mammoth land slides which blocked the river for a time, major watershed damage, increased surface erosion, and a rise in sediment loads in the Brahmaputra. The rapid increase in river bed elevation led one observer to conclude that "although floods on the Brahmaputra have always occurred; the earthquake seriously aggravated them.[6/] They may be expected annually for an unpredictable number of years." (Kingdon-Ward 1955, p. 303). Tragic floods in Bangladesh in 1954 and 1955, lent credibility to this projection and led to the belief, as late as 1963, "that the Brahmaputra may yet be overburdened with sediment as a result of the great seismic disturbances" (Hardin 1963, p.10).

It is not surprising that international observers visiting Bangladesh in the late 1950s and 1960s, focused attention on the country's unique flood problems and consistently recommended water resources investment strategies which relied heavily on the construction of embankments and channel improvements (PC 1973, p. 142).[7/] This approach was institutionalized in 1959 with the creation of the East Pakistan Water and Power Development Authority (now the Water Development Board) and the development of the nation's first Water Resources Master Plan in 1964. The plan recommended implementation of 50 major projects which would empolder large areas of the country, provide flood protection and drainage to 12.1 million acres and supply irrigation facilities to another 7.9 million acres by 1985.[8/] Irrigation services were to be provided by gravity canals, with secondary pumping only in areas not serviceable by the gravity system. The Plan assumed groundwater development to be costly and largely ignored pumps and wells, except in small areas in Dinajpur, Mymensingh, and Comilla Districts. Unfortunately, it glossed over or remained silent on important issues such as the use of minor irrigation equipment and the role of private ownership, appropriate modes of command area organization, ground water exploration, changes in irrigation water demands associated with the changing agricultural technology and techniques for project funding and loan repayment. A major review of the Plan, requested by government and implemented by the World Bank in 1966, questioned the Plan's basic assumptions and concluded that smaller pump based surface and subsurface systems, if introduced with the high yielding input package developed at the International Rice Research Institute, could produce the rice needed to feed the country's growing population by 1985.

Although never accepted by government, highly criticized by donors and subsequently modified to include only 20 "core projects", the Plan had a significant impact on water resource policy decisions in Bangladesh.[9/] The Water Board adopted it as its major operating document and organized its staff and support activities in anticipation of full implementation. The original project portfolio served as the basis for the water resources investment strategies outlined in the 1965-70, 1970-75 and 1973-78 national plans. Long after large scale projects had proven to be of dubious merit, the Water Board continued to annually commit scarce human and financial resources to each of these projects.

A number of factors, some present today, reinforced this preference for large scale projects. Trained in the west, Water Board engineers believed their professional advancement was linked to a proven command over modern technology. Also, the continued selection of high technology choices reinforced existing relationships with consultants and donors, improved the probability of acceptance by the Planning Commission which had little technical expertise to question involved plans and avoided risky and expensive changes in the institutional and administrative structure of the Board. Finally, the agency believed that continued support of high-cost, high-technology development alternatives would maintain their control over a substantial portion of the nation's development budget, amounting to 19 percent of all development funds in the 1960's and continued their political control over the nation's water resources (Dearden 1979, p. 29-30).

Although major emphasis fell on flood control projects, smaller scale surface and subsurface systems were experimented with throughout the 1950's and 60s (See Table 3.1). For example, two cusec low lift pumps, using surface water, were introduced through the Mechanized Cultivation and Power Pump Irrigation Program (MCPPI) beginning in 1956. A total of 3,990 pumps were fielded (EPADC 1968, p. 17), first under the auspices of the Water Board, and then the East Pakistan Agricultural Development Corporation (ADC), a semi-autonomous government agency established in 1962 to improve the distribution of agricultural inputs. The program never reached full potential primarily because ADC was unable to establish an effective means of organizing farmers to share water from a single pump or to ensure the delivery of water at critical times for crop production (Thomas 1972, p.5).

Shortcomings led to the replacement of the MCPPI scheme in 1968 by the Thana Irrigation Program (TPI), a joint venture of the ADC; the Integrated Rural Development Program (IRDP), Ministry of Local Government, Rural Development and Cooperatives, and the Directorate of Extension and Management (DEM), Ministry of Agriculture. Unlike its predecessor, the TIP placed emphasis on organizing farmers to share and utilize water before a pump was provided. To receive a pump a farm group having contiguous plots in a 50 acre area had to be formed, agreement reached on the payment of a pump rental fee and operating costs, and an election held to select a group chairman, a pump driver to be trained, and a model farmer to undergo instruction in HYV rice production. The scheme proved exceptionally successful and by 1969-70, 18,000 pumps irrigating 700,000 acres, were in operation. Although constrained by problems of water losses, poor maintenance and timely pump distribution, the major constraint facing this program was the availability of surface water.

While experiments with minor surface irrigation were underway, early pilot programs to tap underground water were also commencing. In 1961, the German Government in cooperation with the Water Board installed 380 four cusec electrically powered wells in the northwest part of Bangladesh.

TABLE 3.1: MINOR IRRIGATION DEVELOPMENT IN BANGLADESH 1960 to 1982

	Low Lift Pumps[1/]			Deep Tubewells[2/]			Shallow Tubewells[3/]		
		Irrigated Area			Irrigated Area			Irrigated Area	
	Number	Total	Per Pump	Number	Total	Per Pump	Number	Total[4/]	Per Pump
1960/61	1,367	67,142	44.5						
1961/62	1,555	73,922	47.5						
1962/63	2,024	133,043	65.7						
1963/64	2,477	156,751	63.3						
1964/65	2,239	131,360	58.7						
1965/66	3,420	173,360	50.7						
1966/67	3,999	224,105	56.0						
1967/68	6,558	317,903	48.5	102	4,117	40.4			
1968/69	10,852	430,052	39.6	380	16,080	42.3			
1969/70	17,846	642,752	36.0	980	32,070	32.7			
1970/71	24,483	889,809	36.3	796	32,070	40.3			
1971/72	24,243	883,941	36.5	906	29,330	32.4	685		
1972/73	32,917	1,218,766	37.0	1,237	37,776	30.5	1,324		
1973/74	35,343	1,330,81[illegible]	37.7	1,494	61,456	41.1	1,252		
1974/75	35,534	1,300,507	36.6	2,699	117,854	43.7	4,029	35,052	8.7
1975/76	36,382	1,312,577	36.1	3,828	153,747	40.2	5,179	31,074	6.0
1976/77	28,224	1,034,323	36.6	4,461	164,198	36.8	5,402	31,332	5.8
1977/78	36,730	1,300,00[illegible]	35.4	7,453	338,474	45.4	12,325	112,158	9.1
1978/79	35,895	1,436,212	40.0	9,329	504,340	54.1	17,036	180,582	10.6
1979/80	37,389	1,496,802	40.0	9,795	582,298	59.5	23,061	279,038	12.1
1980/81	36,730	1,370,421	38.0	10,131	560,000	63.0	26,735	321,497	12.0

Sources: 1960/61 to 1976/77 IBRD 1979, p.63; 1977/78 to 1979/80 IBRD 1982,pp 91,93-94; 1980/81 IBRD 1982, p.3.

Notes: 1/ Consists of diesel and electric powered centrifugal pump sets, ranging from one to five cusecs in capacity, used to pump surface water.

2/ Consists of a submersible turbine pump, engine, right angle gear and pump house over a six to eight inch diameter wells over 190 ft. deep with a capacity between 1.5 and 2.5 cusecs.

3/ Consists of a diesel powered centrifugal suction pump, attached to 4 inch diameter well with an average depth of 110 to 150 ft.

4/ Estimates of the area serviced by STW's only known for those sold by BADC. To arrive at an estimate of the total area serviced by STS, the average area serviced by a BADC pump was multiplied by the total pumps sold by BADC and the Bangladesh Krishi Bank.

From the outset the project had problems. Although engineering and installation work was completed in two years, construction of an electrical generating plant and transmission system delayed operation until 1965. Costs were prohibitive, averaging Rs.260,000 per well,[10/] approximately half for electrical generation and transmission facilities. Coverage per well was limited because of high seepage losses, [11/] and provisions to train farmers in the techniques of irrigated agriculture were not developed. Subsequent training of farmers and the formation of cooperatives led to some improvements, but by 1970 three fourths of the irrigable area of 71,000 acres remained unused (EPWAPDA 1969, Appendix A, pp i-v).

A second pilot project, implemented by the Kotwali Thana Central Cooperative Association (KTTCA) in east-central Bangladesh, made extensive use of low-cost, manual drilling techniques, installed 211 two cusec diesel powered wells between 1962 and 1970. Using simple hand operated drilling machinery which relied heavily on unskilled local labor, the wells were relatively inexpensive averaging Rs.27,000 per well or Rs.18,000 per cusec.[12/] With command areas managed by established cooperatives, irrigation coverage, still less than potential, averaged 29 acres per cusec, 60 percent more than wells in Thakurgaon.

Although a high rate of return to tubewell and low-lift pump irrigation was demonstrated, it did not spread rapidly for a variety of reasons.[13/] The government's heavy bias toward flood control, and its lack of financial and political commitment to alternatives discouraged expansion. Also, credit and pricing policies did not foster private involvement. Credit to cover substantial start up costs was not available and poor farmers couldn't accumulate the required capital. Public rental policy made private ownership uneconomical. For example, the 1970 cost of an installed well to a private individual or group in the Comilla area was Rs.32,500. On the other hand the ADC provided the well at no cost through the KTTCA and rented pump and engine to irrigation group on a sliding scale beginning at Rs.300 for the first year and reaching Rs.1,400 in the fourth year. These subsides made it uneconomical for individuals or groups to invest in wells when they could obtain use of one in a year or two at a significantly reduced cost. Finally, the limited expansion of well technology was frequently justified by the absence of comprehensive knowledge about groundwater resources. Information about the latter began to expand in the late 1960's and initial investigations indicated that groundwater existed in substantial quantities, was recharged annually by monsoon rains and was sufficient to support a program of further exploration (CPS 1969, Section IIa, pp. IIa 1-10 and IIc, 1-14: McDonald 1969, p. 10: IBRD 1969).

The questionable depth and focus of the Master Plan, early success with surface and subsurface minor irrigation, and the introduction of a new seed technology highly adapted to dry season irrigation led to a reevaluation of the nation's water resource development policy in 1970. Under the auspices of the World Bank, an action program focusing on food production, not flood protection, was presented. Implementation, which placed heavy emphasis on small, quick-yielding schemes, was forced to wait until after the War of Independence in 1972. (IBRD 1970; IBRD 1972).

Post-Liberation Policy

Assisted by soil and land capability data from a UNDP/FAO soil survey, flood records accumulated and cross checked by the Water Board, limited but promising groundwater data [15] and ten years experience with minor irrigation, World Bank studies completed in 1970 and 1972 emphasized small quick-yielding irrigation schemes. The studies projected foodgrain self sufficiency by 1983 (18.8 million tons) through the implementation of a multifaceted program including: high yielding seeds production and distribution; use of input packages comprising seeds, fertilizer, plant protection and improved draft animal power; greater availability of low-lift pumps and small drainage improvements; completion of minor to medium size drainage works; and the rapid expansion of tubewell irrigation.

Components in the Bank's study became the basic building blocks of the First Five Year Plan. In part paralleling the study, the Plan recognized "the tremendous potential that could be realized with small and intermediate scale irrigation and drainage projects, low-lift pumps and tubewell development." (PC 1973, p.147). It suggested investments totaling Tk. 598 crores (1.26 billion 1971 US dollars) to irrigate an additional 2.8 million acres by 1975.[16] However, the involvement of the Water Board in drafting the plan assured a strong continued bias to larger scale projects. Consequently, 54 percent of the total water resources budget and 46 percent of its foreign exchange requirements were earmarked for large scale projects. Secondary emphasis was placed on deep tubewell development, which consumed an additional 30 percent of budgeted funds.

Investment biases in the Plan were not found in alternative strategies commissioned or developed directly by the major donors (see Table 3.2). More consistent with economic realities, these strategies suggested modest increases in large gravity projects, rapid growth in tubewell development and constrained development of low-lift pumps. Growth of the latter continues to be limited by the supply of dry season surface water. FAO hydrologists estimate that over one-half of the average dry season flow is required to maintain an ecological balance in the system; prevent disruptions in inland water transportation, warm-water fisheries, domestic and commercial water use; and limit saltwater intrusion from the Bay of Bengal.[17] A World Bank team has suggested that low-lift pump potential will be exhausted at about 55,000 units (110,000 cusecs), less if pumps are used more efficiently. (FAO 1973, Vol. II, p.225; IBRD 1979, Annex 3, p. 13). These limits continue to guide planners today.

Emphasis on the expansion of tubewells was well founded. With less than 1000 wells in 1970, the potential was obvious. Economic returns, which were presumed to begin immediately after installation, were favorable with installation costs ranging from 5,300 to 15,800 1971 US dollars and annual net returns averaging $8,000 per well. Also, the divisibility of the technology allowed for a number of different technologies to be tested simultaneously and those proving most suitable subsequently utilized.

TABLE 3.2 : ALTERNATIVE IRRIGATION STRATEGIES FOR BANGLADESH

(000 ACRES)

	1975/76 Actual		1984/85 Projections MOA		IBRD Report		IBRD Macro Model		Harvard Study		META Systems	
	Acres	% %	Acres[1/]	% %	Acres	% %	Acres	%	Acres	%	Acres	%
Gravity	110	4.0	1660	29	425	9	350	9			439	9.5
Low Lift Pumps	1431	52.0	1700	30	2034	44	1600	43	656	11	1841	42.0
Deep Tubewells	152	6.0	940	16	512	11	660	18	1636	27	79	2.0
Shallow Tubewells	8	.3	440	8	512	11	290	8	2941	49	1012	23.0
Hand Pumps	20	.7	170	3	200	4	30	1			20	.5
Traditional Means	1000	37.0	800	14	1000[2/]	21	800	21	759[4/]		1000	23.0
Total:	2721	100.0	5710	100	4683	100	3730	100	5992	100	4392	100.0

Source : IBRD 1979, Annex 3, Table 2.13 & 2.14 and FAO/UNDP 1977, p. 121.

Notes : 1/ Projections reported for 1985/86 in FAO/UNDP 1977.

2/ The report gives no estimate for traditional irrigation. Assumed equal to the MOA estimate.

3/ The macro model does not provide acreage estimates. Estimates were calculated by IBRD assuming the following equipment and acreage estimates : 16,500 DTW @ 40A/well; 53,333 LLP @ 30A/pump; 35,000 STW @ 8.3A/well; 90,000 HP @ .33A/pump; 350,000 A gravity and 800 A traditional (IBRD 1979, pp.86 & 90).

4/ Includes estimated acreage under traditional, gravity and hand pump irrigation.

Finally, wells could be geographically disbursed thus distributing benefits more equitable than large scale projects, making better use of location specific soil and water characteristics and targeting irrigation to those areas where farmer demand was high. The latter was an important factor in improving command area performance.

Agreement on the importance of tubewells was unanimous. Differing assumptions regarding technical and financial constraints, however, led to different mixes of tubewell technologies. World Bank strategies emphasized high-cost deep and shallow tubewells, the former installed by foreign contractors. Although expensive and not economically optimal[18], Bank advisors believed the approach had advantages. It was reliable - machine power drilling, fiberglass screens, high speed engines and turbine pumps represented a known and trusted technology. It was acceptable to the parties involved - the Water Board and ADC both had strong preferences for modern technologies - and it fit existing Bank and government routines and procedures. Finally, installation by foreign contractors meant greater centralization, assured Bank control over implementation and less reliance on limited local management capabilities.

Alternative strategies rejected these arguments and promoted the decentralized implementation of simplier, cheaper technologies which relied more on local rather than imported skills. A Harvard strategy, modeled after the Comilla experience, suggested installation of low-cost deep and shallow tubewells. Drilled manually using jet or percussion methods, the wells used locally produced brass strainers, low-speed diesel engines produced regionally and surface mounted centrifugal pumps. Deep tubewells sunk in this manner cost 1/3 the alternative implemented by the World Bank.[19]

Underlying this debate was the basic question of control. The original concept of a tubewell irrigation system centered on the organization of a user group around a two cusec pump. As the number of wells proliferated, problems with this concept emerged. Organizing groups large enough to effectively support a two cusec pump was difficult. With relatively small land parcels, the number of farmers required to make up an irrigation group was large and organization costs in both time and effort were substantial.[20] Also, with limited knowledge of the technical and organizational requirements associated with high-input, irrigated agriculture, problems of equitable water distribution, excessive water losses, high on-farm application rates and group management and accountability arose.

Government agencies were ill equipped to respond. Responsibilities for training farmers were scattered. The Bangladesh Agricultural Development Corporation (ADC), having control over tubewell and low-lift pump distribution, believed its mandate limited to the installation and commissioning of equipment, not command area development. The Integrated Rural Development Program (IRDP), while effective in organizing farm groups, had limited technical expertise. The Water Development Board and the Directorate of Extension and Management, Ministry of Agriculture (DEM), were extremely short of extension agents properly trained in irrigation and on farm water management. The absence of a national organization specifically responsible for conducting irrigation management training was sighted by a 1979 joint World Bank and Government of Bangladesh team as a major factor contributing to low efficiency of irrigation water use and poor water management within pump groups and on the farm (IBRD 1979, p. 29). But limited knowledge of irrigation is not the only problem. When new but poorly organized irrigation groups cut across old, established village power groups, patterns of dominance emerge with small farmers often participating at the pleasure of larger better informed farmers. As per acre investments increase with irrigation and the probability of group conflict rose, dominant members tend to reduce group size in an effort to improve their control of irrigation supply, reduce conflicts and lessen the risk of individual financial loss (Thomas 1976, pp 8-9).

Government pricing policies supported rather than discouraged this process. In 1978, irrigation subsidies ranged from 100 percent on gravity systems, 70 percent on deep tubewells, 50 percent on low lift pumps and 10 to 25 percent on shallow tubewells (IBRD 1978, p. 10). With annual rental rates far below actual operating costs, there was little incentive for farmers to expand irrigated area. In 1976 the Water Development Board attempted to address this problem by implementing a 1963 Irrigation (Imposition of Water Rates) Ordinance in areas under its control. Unfortunately, complex procedures adopted to determine water rates and the lack of instructions for collecting water levies, doomed this well meaning attempt from the very beginning (IBRD 1978, p. 5).[21] An adequate law which encourages improved command area management remains to be drafted.

The continued poor performance of large tubewells, strong farmer demand for smaller, simplier equipment and the growing burden irrigation subsidies were placing on government budgets, helped initiate further policy change in the late 70s and early 80s. Policy choices coalesced around three major factors: (1) the need to dramatically increase the rate of minor irrigation while simultaneously increasing the efficiency and equity of resource use; (2) the importance of private sector ownership of equipment and their involvement in the supply of equipment, spares, and repair and maintenance services and; (3) the encouragement of domestic irrigation equipment manufacture. (IBRD 1982, p. 10).

<u>The Second Five Year Plan</u> (1981-85) places heavy emphasis on technically simple, divisible, quick-to-plan and quick-to-implement projects. Stronger focus on minor irrigation is anticipated (see Table 3.3), with five fold increases in investments over the <u>First Five Year Plan</u>. Use of shallow tubewells is to be emphasized, while deep tubewell installation will be limited to areas where shallow tubewells are not appropriate. Again, the use of low lift pumps is constrained with investments focusing on the fielding of new pumps to bring the number fielded to 50,000 (close to the estimated limited of surface water supplies) and the purchase of replacement units. For the first time, improving command area performance became a major objective and the private sale of shallow and hand tubewells, set at 30 and 200 thousand units respectively, was officially encouraged.

TABLE 3.3 : PLANNED INVESTMENT IN MINOR IRRIGATION
FIRST AND SECOND FIVE YEAR PLANS
(CRORE TAKA)

	First Five Year Plan		Second Five Year Plan	
	Total Investment	%	Investment	%
Bangladesh Agricultural Development Corporation				
Low lift pumps	74.0 (45,000)1/	28.8	128.0	10.5 (50,000)2/
Shallow tubewells	9.1 (15,000)	3.5	243.0	19.9 (90,000)
Deep tubewells	174.0 (19,000)	67.7	439.0	36.0 (25,000)
Hand tubewells	-		45.0	3.7 (3,000)
Command area development	-		300.0	24.6
Bangladesh Krishi Bank				
Shallow tubewells	-		53.0	4.3 (30,000)
Integrated Rural Development Program				
Hand tubewells	-		12.0	1.0 (200,000)
Total:	257.1	100.0	1220.0	100.0

Source : PC 1973, p. 153; PC 1980, Section XII, p. 86.

Notes : 1/ Number of pumps in parenthesis.

2/ Includes 45,500 2 cusec and 4,500 1 cusec units, slightly less than the 110,000 cusec limit previously set.

Finally, the Plan recommended a reduction in government subsidies on water through the gradual increase in low lift pump and deep tubewell rental and shallow and hand tubewell sale prices. Sale of low lift pumps and deep tubewells was also to begin.

Although policy changes were significant, they did not reduce subsidies enough to meet the stringent budget constraints faced by government. Plan implementation required subsidies of approximately Taka 2.4 million on the rental program and Taka 2.7 million on the sales program (see Table 3.4). While 80 percent of the subsidy was for deep tubewells and the remainder for low-lift pumps, these technologies were only expected to contribute 20 and 28 percent respectively to the total irrigated area of 7.2 million acres anticipated by the end of the Plan (IBRD 1972, Annex 2, pp. 1-2).

Subsidies were substantially higher than deemed prudent and a number of alterations in the Plan have been suggested. For example, the government in consultation with the World Bank, has altered the sale and rental prices of minor irrigation equipment. Under the new system, all equipment prices will be based on a shallow tubewell equivalent formula. The formula states that equipment prices will be set in a manner than will equate costs per unit of water discharged with those of a shallow tubewell. Shallow tubewells in turn will be sold at full current replacement costs. As Table 3.5 suggests government estimates of the cost per acre inch of water from different technologies range from Tk.16 for low lift pumps, Taka 30 for shallow and hand tubewells and Taka 46 for deep tubewells. This suggests that low lift pump prices be increased by 40 percent, and deep tubewells, if priced at their shallow tubewell equivalent, continue to receive a subsidy of Tk.123,000 or 57 percent of actual cost less duties (IBRD 1972, pp 33-34). This policy continues the long standing bias in favor of deep tubewells. Equivalent pricing could effect equipment demand so that shallow and deep tubewells are competitive in all areas. This would lead to deep tubewell installations in areas where shallow tubewells have a comparative advantage, continue the growth of conflicts between shallow and deep tubewell owners and result in substantial government subsidies at a time of budget austerity. To establish parity between rental and sales programs, government has been urged to substantially increase deep and low lift pump rental rates and to set-up used equipment sales. Sales preference should be given to groups or co-operatives and moderate prices set to encourage sales.22/ Finally, to reduce subsidies further it has been recommended that deep tubewell development be further curtailed, dropping from 25,000 to 20,500 units in 1985, and that shallow tubewells be developed in their place. This would result in the development of an additional 100 to 150 thousand shallow tubewells by 1985 (Harma 1972, p. 7). Rough estimates in Table 3.4 indicate these adjustments would result in a 43 percent reduction in minor irrigation subsidies, equivalent to a Tk.2.2 billion saving.

TABLE 3.4 : SUBSIDIES FOR MINOR IRRIGATION UNDER THE SECOND FIVE YEAR PLAN WITH AND WITHOUT PROPOSED ADJUSTMENTS
(ALL HEADINGS IN TAKA, TOTALS IN MILLION TAKA)

	BADC Costs		Without Adjustments			With Adjustments		
	Total	Net Duties/Taxes	Cost Recovery	Subsidy Per Unit	Total Subsidy 2/	Cost Recovery	Subsidy Per Unit	Total Subsidy 4/
Rental Program								
Deep tubewells	33,500 1/	33,500	1,200	32,300	1,615	1,200	32,300	1,421
Low lift pumps	5,800 1/	5,800	1,500	4,300	880	1,500	4,300	688
Total rental subsidy					2,475			
Sales Program								
Deep tubewells – new	240,000	223,000	50,000	173,000	2,595	95,000	128,000	1,216
used						45,000 3/	(45,000)	198 5/
Shallow tubewells	30,000	24,100	23,100	300	30	24,100	–	
Hand tubewells	1,835	1,320	1,320	–	–	1,320	–	
Low lift pumps – new	23,500	21,600	16,500	5,100	61	23,500	–	
used						11,880 3/	(11,800)	190 5/
					2,686			828
					5,161			2,937

Source : IBRD 1972 and author's estimates.

Notes : 1/ Represent annual costs taken from ADC's FY 76 accounts, the latest available. They are likely underestimates.

2/ Assumes rental of 10,000 DTW and 40,000 LLP; sale of 15,000 DTW, 100,000 STW and 12,000 LLP.

3/ Recovery cost of DTW and LLP are calculated assuming 10 percent of 1981 stocks are sold annually. Sale prices were determined as follows: for LLP-salvage value (10% of net cost) plus the annual straight line depreciated value for five years; for DTW 1980 government sales prices less salvage value (50% of sale price) plus the annual straight line depreciated value for five years. Depreciation calculations assumes equipment life of 10 years.

4/ Assumes rentals decline 10 percent per year from 1981 reaching 6,600 DTW and 24,000 LLP by 1985 and sales of 9,500 new DTW, 4,400 used DTW, 250,000 STW, 12,000 new LLP and 16,000 used LLP.

5/ Cash inflows from equipment sales which offset subsidies.

Table 3.5 1981 PRICE OF MINOR IRRIGATION EQUIPMENT EXPRESSED IN SHALLOW TUBEWELL EQUIPMENTS (In Taka)

	STW		DTW		LLP (2 Cusec)		LLP (1 Cusec)	
	With duties	Without duties	With duties	Without duties	With duties	Without duties	With duties	Without duties
Capital costs (Tk)	30,466	24,100	240,550	223,000	39,950	36,450	23,500	21,625
Capital costs per acre in. of water	10.9	8.7	23.9	21.7	4.7	4.4	5.5	4.7
O & M costs per acre in. of water	20.0	20.0	20.3	20.3	11.6	11.6	11.3	11.3
Total costs per acre in. of water	30.9	28.7	44.2	42.0	16.3	16.0	16.7	16.0

Source: IBRD, 1982 Annex 2 page 5.

Actions by government and others are beginning to encourage private sector development. For the first time, in late 1980 government permitted the private importation of spares on open general licenses. Also the World Bank has suggested that as the ADC's rental program declines, it should begin seeking out local parts dealers and sell as much of their stocks to them at full cost plus overhead prices. To encourage private fabrication of diesel engines, government has licensed five private sector manufacturing ventures. Planned investments of Tk.1.36 billion are expected to result in output of 74,600 units and 1,221 new jobs annually. Still to be resolved are problems of over production, effective levels and forms of import protection, and steps to increase domestic value added and labor inputs.[24/] Finally, Government and foreign donors are beginning to discuss ways of rapidly expanding private sector repair facilities. Credit resources and training needed to set up new facilities are being discussed with the World Bank, the Asian Development Bank, and ILO.

While command area organization and management have long been neglected, steps to improve equipment utilization are finally being considered. In the past underutilization has been linked to unreliable equipment, poor user group organization and management, and technical deficiencies in water distribution, cropping patterns and input supply. (Biswas et. al. 1978; Biswas et. al 1982); Biggs et. al. 1977; Khan and Mirjahan 1979; Alam 1975). Pilot efforts mounted by CARE, the Bangladesh Krishi Bank and IRDP in conjunction with the ADC and DEM have overcome many of these problems. As Table 4.9 suggests substantial returns to command area development programs are possible. What is needed is to expand the lessons learned in these pilot projects and apply them at the national level. Training will be required. One major step has been taken with Government and UNDP agreeing on a program to train

BADC, DEM, and IRDP staff in command area development techniques and to support research on water management, distribution system improvements and alternative methods for establishing command areas. The task is large and other programs of this type are required. More important will be the development of follow-up programs which support trainees when they return to the field. Although critical such programs are still to be developed. Finally, national command area development strategies will continue to be constrained as long as an effective institutional coordinating mechanism, which link BADC, DEM and IRDP efforts, is lacking. What form this mechanism is to take, possibly a lead agency or a coordinating committee model, is yet to be decided.

Past and Present - A Summary

Over the past century, irrigation policy has shifted from a state of benign neglect to one where it now comprises one of the core components in Bangladesh's development policy. Declines in per capita foodgrain production in the 1930s and 40s, a major famine in 1944 and radical changes in river structure, linked to the 1950 Assam earthquake, encouraged the development of large, complex flood control and drainage projects to increase monsoon rice production. Highly compatible with the interests of engineers and the institutions controlling water investments, focus on these projects continued well beyond the point where the changing environment dictated major policy adjustments. Delays in implementing large projects, increased use of new HYV rice varieties and the importance of dry season irrigation, improved understanding of Bangladesh's ground and surface water resources and ten years of experience from working with small scale irrigation pilot projects pointed to the increased use of minor irrigation.

TABLE 3.6 EFFECT OF COMMAND AREA DEVELOPMENT PROGRAMS ON SELECTED PERFORMANCE CRITERIA

	CARE/BKB			IRDP-IMPP Program		
	Before	After	%Change	Before	After	% Change
Coverage (acres)	35	62	77	52	94	82
Yield per acre (md. paddy per acre)	35	68	94	37	58	56
Participants (per pump)	45	82	82	83	135	63
Short term credit (Tk. 000 per pump)	-	84	-	11.4	30.3	16.6
Operating costs (Tk. per acre)			-	404	283	-30

Source: IBRD 1972, p. 16 and 31,

Focusing first on publicly owned two cusec low-lift pumps and deep tubewells, policies have gradually changed to encourage the use of privately owned .5 to .75 cusec shallow tubewells. Growth in the use of low-lift pumps continues to be limited to approximately 110,000 cusec per year by dry season surface water availability. Deep tubewells have proven expensive and government subsidies difficult to support. Owning relatively small parcels of land farmers have found it difficult and expensive to organize irrigation groups large enough to effectively use two cusec pumps. Large groups have been unstable and dominant factions have seen it in their interest to reduce the size of an individual group to increase the probability of water supply and limit risk. Government pricing policies, which recovered approximately one-fifth of actual government costs, encouraged rather than discouraged these trends. Finally, as the size and complexity of government's minor irrigation program grew, it became increasingly evident that public sector agencies were unable to provide the mushrooming maintenance and repair services required.

The development of a private market for irrigation, including equipment sales, servicing and manufacturing, is in its infancy. After two hundred years of public irrigation development in South Asia, many in government remain skeptical and the initiative for major policy changes continues to fall outside government.

Significant policy changes have occurred however. Government has begun to sanction the private importation of spare parts and has licensed five firms to begin diesel engine production. But, major challenges remain. Credit to establish new repair shops and training is needed. The command area development program established by FAO with government support needs to be expanded, duplicate efforts started elsewhere and complimentary field support programs developed. Programs to train farmers, who purchase new equipment, are also important to assure maximum production per unit of energy consumed in irrigation. Also, more efficient models of government cooperation, which link and give direction to the efforts of ADC, IRDP and DEM, need to be forged before the substantial gains to command area development can be realized. Finally, a continuous process of appraising new technological options is required to assure compatibility between new technological choices and Bangladesh's diverse social and physical environment.

CHAPTER IV

ECONOMIC RETURNS TO INVESTMENTS IN IRRIGATION

Introduction

Positive returns to minor irrigation investments have led to increased use of equipment. The reliable and timely supply of water enables farmers to increase yields on existing crops using higher levels of complimentary inputs, encourage shifts to higher value more productive crops and increase cropping intensities by allowing farmers to grow two or more crops on the same land each year. These changes occur under far less uncertainty because of irrigation.

Benefits to the nation have also been substantial. Increasing production has helped moderate price rises, forestalled major reductions in nutrition levels and limited the growth of imports and saved scarce foreign exchange. Idle labor has been employed in the intensive production systems which follow the introduction of irrigation. Also, new jobs have been created to produce and distribute the increased volume of required inputs and to process, store and market increased outputs.

These benefits have not been without costs. New irrigation pumps, engines, and accessories have had to be imported, distributed and installed. Investments to strengthen markets for complimentary inputs - diesel, oil and lubricants, fertilizer, seed, pesticides and credit - continue to be required. Also investments in training programs to educate farmers about irrigated agriculture, forms of group organization and effective management are needed.

The changes associated with the rapid expansion of irrigated agriculture are far-reaching. The effect irrigation is likely to have on Bangladeshi farmers, their cropping patterns, production and income are explored below. Four irrigation technologies, one and two cusec low lift pumps and two and .75 cusec tubewells, are compared. Focus is on the comparative efficiency of these technologies, and the basic analytical unit is the acre, not the command area. Analytical results serve as reasonable estimates of the overall impact irrigation will have on Bangladesh's complex cropping systems and the relative, not absolute, productivity of different irrigation technologies.

Changing Cropping Patterns

Assessing the impact of irrigation is difficult because of the complexity of Bangladesh's agro-ecosystems. Largely based on rice, cropping patterns vary by agroclimatic zone, soil type and annual flood levels. Thirteen major land classifications, each with its own cropping patterns, have been identified (See Annex Table A2.0). For purposes of simplicity, the analysis consolidates land classes into four models - high flood plain soils, medium elevated soils, low-land soils and low flood plain soils. In a more detailed analysis further disaggregation would likely improve analytical results. This is especially true in low-land soils where mixed permeable and impermeable soils are found.

The availability of an assured water supply is expected to change farmer's attitudes toward risk and encourage changes in present cropping patterns. For example, irrigation would encourage him to intensify production by cultivating land previously fallow or adopting higher-input, higher-output crops. Rice would remain his dominant crop. Less dependent on rainfall, he would use more fertilizer and pesticides and shift from low to higher yielding rice varieties. Supplemental irrigation at the beginning and end of the rains would increase the probability of favorable yields. With water for dry season nursery production, he would sow and transplant rice earlier, thus allowing him to explore the greater yield potential of HYV boro rice. Finally, access to irrigation would allow for increased cultivation of valuable rabi season crops like wheat, chillies, oilseeds and vegetables.

As Table 4.1 indicates, not all changes would occur in each model area. For example, in the higher elevations (Model I and II) broadcast local varieties of aus and aman rice would be replaced by more productive transplanted local and HYV varieties. High soil premeability would limit boro rice cultivation, but cultivation of wheat and other highly profitable rabi crops would expand, partially at the expense of pulse production. Previously dry season fallow land would be brought into cultivation, and cropping intensities would increase from 1.3 to 1.7 and 1.4 to 1.9 high flood-plain soils and medium elevated soils respectively.

Table 4.1 Changes in Cropping Patterns With the Introduction of Irrigation

Crop	MODEL I	MODEL II	MODEL III	MODEL IV
Rice				
Boro rice - Local	0	0	-	0
Boro rice - HYV	0	0	+	+
Broadcast aus rice - Local	-	-	-	0
Transplanted aus rice - HYV	+	+	+	0
Broadcast aman rice - Local	-	-	0	0
Transplanted aman rice - Local	-	-	0	0
Transplanted aman rice - HYV	+	+	0	0
Other Crops				
Wheat	+	+	+	0
Potatoes	+	0	0	0
Chillies	+	+	+	0
Pulses	-	0	-	0
Oilseeds	+	+	+	+
Jute	0	0	0	0
Vegetables	0	+	+	+

Sources: Annex Table A.3

Notes: - = decrease; + = increase; 0 = no change; blanks indicate crop not grown in cropping pattern.

In lower areas susceptable to annual flooding, mixed broadcast aus and aman and broadcast aman varieties would remain the dominent rainy season crops. On slightly higher elevations, where flooding is less likely, limited introduction of transplanted HYV aman would be possible. Irrigation would encourage the introduction of HYV boro cultivation, as well as the growth of other highly profitable rabi season varieties. On better drained low land soils wheat production would expand, again at the expense of pulses; and oilseed, chilli and vegetable production would increase. On lower flood plain soils (Model IV), the potential for rabi season crops would be less. Cropping intensities associated with both models would increase from 1.5 to 2.0 on low land soils and from 1.0 to 1.6 on low flood plain soils.

Change in Yields and Production

With the increased use of HYV's, fertilizers and pesticides, expanded cultivation of high rather than low yielding rice varieties, and the availability of irrigation to overcome drought periods, yields per acre would substantially increase.

Table 4.2 Yield Changes With Irrigation
(In Maunds/Acre)

		FUTURE		
	Present	Without Irrigation	With Irrigation	Incremental Change
Boro rice	22	22	38	16
Aus rice	16	16	30	14
Aman rice	19	25	30	5
Wheat	18	18	28	10
Potatoes	-	-	98	98
Chillies	5	5	9	4
Pulses1/	9	9	13	4
Oilseeds	-	-	10	10
Jute2/	15	15	23	8
Vegetables	35	35	50	15

Notes: 1/ Pulse production assumed to shift from black gram (mashkolai), garden pea (matar) and grass pea (khesari) cultivation to higher value mungbean (mung), lental (masur) and chick pea (chola).

2/ Vegetable production assumed to shift from sweet pumpkin and spinach (brinjal) to turnip, cabbage and cauliflower.

As Table 4.2 indicates local boro rice, now grown in low lying areas with traditional irrigation, would be replaced by HYV boro and yields would almost double (from 22 to 38 maunds/acre). Similarly, the change to HYV aus varieties with fertilizer and pest protection would increase aus yields from 16 to 30 maunds/acre. Wheat yields, which are low because of a reliance on rainfall, would increase with an assured water supply from 16 to 28 maunds/acre. The addition of potato, oilseed and chillies production, not otherwise grown because of a lack of reliable water, would add to total production. The availability of supplemental irrigation would increase jute yields by over 50 percent by allowing earlier sowing and greater use of inputs. Finally, dry season irrigation would encourage the more intensive cultivation of vegetables and pulses, and replacement of lower quality traditional varieties with higher-quality lines.

Changes in Input Requirements

Annual incremental input requirements are provided in Table 4.3. The introduction of irrigation would increase annual fertilizer use by 58 seers or 54 kg per acre (53 percent urea, 31 percent TSP and 16 percent potash). This would be in addition to respective increases in manure and pesticide application rates of 40 maunds and 7 seers per acre. Also, irrigated cropping patterns would require significant increase in animal and human labor inputs. For example, an addition 13 team days/acre and 53 man days/acre (60% family and 40% hired) would be required. With estimated rural employment and under-employment averaging 32 percent, increased demands for human labor are not likely to be a problem, except during peak demand periods. Increased use of animal power and green manure could be a problem, especially in areas where herds are small.

Table 4.3 Incremental Increase in Use of Production Inputs Associated With the Introduction of Irrigation

Input	Unit	Incremental Increase: High Flood Plain	Medium Elevation	Low Elevation	Low Flood Plain	Average Per Acre	2/ 3/ Projected
Fertilizer							
Urea	Seer	26	38	33	28	31	79.9
TSP	Seer	11	24	18	20	18	46.4
MP	Seer	5	10	10	12	9	23.2
Manure	Maund	36	44	44	35	40	4122.4
Pesticides	Seer	0.2	0.1	0.7	0.7	0.43	1.1
Animal Power	Pairday	9	14	12	17	13	35.9
Labor							
Family	Manday	22	37	27	41	32	88.4
Hired	Manday	5	32	25	22	21	58.0
Diesel 1/	Gal/Cusec	9.3	14.1	15.3	15.2	13.5	20.4

Source: Tables A 3.0, A 4.0 and 4.4

Notes: 1/ Diesel at .05 gal/hp/hr. Calculated using Medium Term Food Production Plan estimates of pumps to be fielded by 1985 as weights.

2/ Estimated using 1985 irrigation projections in Medium Term Food Production Plan.

3/ Fertilizer, manure and pesticides in thousand metric tons; animal power and labor in million pair and man days and diesel in million gallons.

Projecting 1985 requirements for these inputs using targets appearing in the GOB's Medium Term Food Production Plan suggests that an additional 35.9 million pair days of animal power and 4.1 million metric tons of manure will be needed. The introduction of machine cultivation has been suggested by some as a partial solution to the draft power constraint. The evidence, however has not been encouraging. Field research to assess the impact of mechanical cultivation has found it to be labor displacing and often leads to the expansion of large farm holdings, at the expense of smaller marginal farmers (Gill 1979, p.129). Also, the greater dependence on machines would increase the nation's reliance on expensive diesel imports, already projected to grow 20.4 million gallons (454 thousand barrels) annually. A potentially more cost effective approach might focus on the labor inputs during planting, and the introduction of simple manually powered harvesting equipment. Research and development investments in this area would seem appropriate at this time. Also, field studies to identify areas where power will be a pontential constraint would be useful to focus future extension efforts and credit to encourage local machine production.

Complementing other input changes, per acre water requirements would increase. Requirements would vary because by crop, soil type, cropping pattern, annual levels of precipitation and water losses rates. Composit per acre estimates for each land type are presented in Table 4.4.

Table A 4.4 Annual Per Acre Water Requirements For Each Model Land Type (In Acre Inches)

	Requirement Per Acre	Requirement Per Composit Acre[1/]			
		High (Flood Plain)	Medium	Low	Low (Flood Plain)
Paddy					
Boro	40.4			12.1	16.2
T. Aus	19.0	3.8	3.8	1.9	
T. Aman	12.1	6.1	7.1		
Wheat	15.3	1.5	3.1	4.6	
Potato	15.3		1.5		
Chillies	10.1		1.0	1.0	
Pulses/Oilseeds	21.2	2.1	4.2	4.2	6.4
Jute	10.2	2.0	2.0		1.0
Vegetables (two crops)	17.9		1.8	1.8	1.8
Irrigation requirements		15.5	23.5	25.6	25.4
Pumping House[2/] [3/]					
DTW		9.76	14.81	16.10	16.10
STW		26.05	39.49	43.02	42.68
LLP (1 cusec)		17.37	26.32	28.68	28.46
LLP (2 cusec)		8.69	13.16	14.34	14.23

Source: Adapted from IBRD, 1981a; Annex 2, Tables 3 and 4 and Table A3.0 in appendix.

Notes : 1/ Assumes only improved rice varieties and rabi crops receive full irrigation requirements. Traditional varieties are not irrigated.

2/ Assumes distribution efficiency of 60% for rabi and 70% for rice crops.

3/ Actual vs. installed capacity assumed to be as follows: DTW 80%, STW 90% and LLP 90%.

Estimated requirements of 15.5 acre inches on flood plain soil, 23.5 inches on medium elevation soils, 25.6 inches on low land soils and 25.4 inches on low flood plain soils are indicated. Assuming various pumping characteristics, pump hours required to supply these requirements are identified for each technology and land type.

Input/Output Prices

Input/output prices used in the analysis are summarized in Table 4.5. Output prices in the financial analysis represent 1981 average annual wholesale prices collected bi-monthly by the Directorate of Marketing, Ministry of Agriculture from 71 domestic wholesale market centers. Use of wholesale rather than farm gate price, which are not presently collected, overstates the value of farm production. The margin of error is believed to be relatively minor given the large number of markets surveyed, the proximity to producers to these markets and the small marketing margins present in the Bangladeshi systems.[1/] Prices for production inputs, other than labor, are those specified by Government (Urea, TSP and MP), or paid by farmers and reported in various local surveys for 1981 (manure, pesticides and animal power). Given the high incidence of unemployment in rural Bangladesh, family labor is not valued in the financial analysis. Wages for hired labor represent national average 1981 wages paid to unskilled labor plus an estimate for inkind payments (meals and tobacco).

Input/output prices used in the economic analysis are adjusted to remove distortions caused by imperfections in local markets, transfer payments from one group in the society to another (taxes, tarriffs, subsidies etc.) and an overvalued taka to dollars exchange rate. Prices of non-traded inputs and outputs are estimated by adjusting 1981 market prices to reflect distortions in the value of the taka vis-a-vis other international currencies. Recent World Bank appraisals suggest the taka is overvalued by 20 percent. Bank procedures to account for this distortion, the deflating of domestic prices by a standard conversion factor equal to the reciprocal of the percentage distortion (1/120% = .83), have been adopted in the economic analysis. Prices of internationally traded commodities are computed using projected annual international market prices adjusted for transport and handling costs, quality differences and processing losses (See Annex Table A 8.2 for details). Finally, estimates for both family and hired labor wages are used in the economic analysis. Estimates of wages used in the economic analysis are those prevailing in a full employment economy. Bangladesh is far from this, with rural unemployment estimated at 32 percent by the World Bank (IBRD 1982a, p.32). To account for unemployment, 1981 average market wages in cash and kind paid to agricultural laborers were first multiplied by .68 to approximate wages paid under full employment and then by the standard conversion factor.

Irrigation equipment prices and operation and maintenance costs play a significant role in determining per acre irrigation charges (see Annex Tables 7.1 and A 7.4 for details). Prices for equipment used in the financial analysis with the exception of DTW reflect recent Government

Table 4.5: Prices Used in the Financial and Economic Analysis

	Financial		Economic	
	Seeds (Tk./Seer)	Crops (Tk./md)	Seeds (Tk./seer)	Crops (Tk./md)
A. Crops and Seeds				
Aman rice	3.0	121	4.3	173
Aus rice	2.7	106	3.9	157
Boro rice (local)	2.7	108	3.9	157
Boro rice (HYV)	4	107	3.9	157
Wheat	3	114	3.5	140
Potatoes	2.4	95	2.0	79
Chillies	16.6	665	13.8	552
Pulses1/	4.4/6.8	177/270	3.7/5.6	147/224
Oilseeds2/	7.5	300	10	400
Jute	3.0	120	4.6	182
Vegetables3/	1.8/2.8	70/110	1.5/2.3	58/91
B. Fertilizers and Pesticides				
Urea	3.3		4.8	
TSP	2.8		6.3	
MP	2.3		4.9	
Manure (Tk/md)	2.7		2.2	
Pesticides	270		270	
C. Animal Power and Wages				
Animal power (pair/day)		22		18.3
Hired labor (man day)4/		20		11.3

Sources: Price Prospects for Major Primary Commodities, Vols. I, II and III. The World Bank, July 1982 and "Sholesale Prices of Agricultural and Animal Products in Bangladesh", Directorate of Agricultural Marketing, Ministry of Agriculture.

Notes :
1/ Farmers typically shift from low to high priced oilseeds when irrigation is introduced. Prices presented represent annual average price for lower quality pulses (mash, matar, khesari and arhar) and higher quality pulses (masur, mung and gram).
2/ Mustard seed price.
3/ Lower price for traditional vegetables (sweet pumpkin and bringal), higher price for irrigated vegetables (turnip, cabbage, chollowflower).
4/ Average 1981 daily wage plus allowance for meals taken at 68% of financial price and adjusted by the SCF = .83.
5/ Prices for internationally traded commodities are from Table A8.2 and A8.3, prices for non traded commodities are estimated by adjusting financial prices by the SCF = .83.

policy decisions to sell irrigation equipment at open market prices or their shallow tubewell equivalent price (see p.32). Shallow tubewell prices are average 1981 market price (Tk. 23,825) charged by the ADC. One and two cusec low-lift pumps were not sold during that year, but rented. Equivalent open market sales prices (equipment costs plus ADC overhead) are estimated at Tk. 23,500 and Tk. 39,950 respectively. As indicated earlier (p.33), the continued high subsidization of DTWs distorts demand, leads to growing conflicts between shallow and deep tubewell owners and increases government subsidies. These factors suggest that there will be continued pressure on government to reduce DTW subsidies further. To reflect this long term trend and to account for donor and government support of an open market sales program, DTW subsidies have been reduced from 57 to 20 percent and a price of Tk.190,000 used in the calculations.

Converting financial prices to economic counterparts requires the deletion of all taxes and subsidies, the diversion of the remainder into corresponding foreign and domestic cost components and the deflating of domestic costs by the standard conversion factor. These steps result in 1981 economic prices for deep tubewells of Tk. 204,980, shallow tubewells - Tk. 22,097, one cusec low-lift pumps - Tk. 19,097 and two cusec low-lift pumps - Tk. 33,518. Finally, variable irrigation costs reflect both operating and maintenance costs associated with each technology (see Table A5.0 to A5.3). Rates do not include monopoly rents reported to be extracted by some equipment owners.

Changes in Farm Income

Analytical estimates of net farm income substantiate earlier studies which show positive and often substantial returns to irrigation. As Table 4.6 suggests returns measured as the net present value of incremental income resulting from irrigation investments[3] vary over a wide range across land type models and technologies.

Table 4.6 Net Present Value of Incremental Farm Income Farm Irrigation[1]
(Taka/Acre)

	Land Types			
	High Flood Plain	Medium	Low	Low Flood Plain
Deep Tubewells	1072[2]	-1886	-2165	182
	(23)[3]	-	-	(14)
Shallow Tubewells	2877	239	1043	1851
	(84)	(17)	(40)	(66)
Low-Lift Pumps (1 cusec)	5055	3183	2954	3708
	(149)	(93)	(94)	(111)
Low-Lift Pumps (2 cusec)	5848	3157	2872	3676
	(149)	(87)	(97)	(129)

Source : Appendix Tables A9.0 and A9.1

Notes: 1/ Assumes command areas as follows: DTW - 40 acres; STW - 10 acres; LLP (1 cusec) - 20 acres and LLP (2 cusec) - 40 acres.

2/ Net present values calculated using a 12% discount rate.

3/ Financial rates of return in parenthesis.

Net returns are highest on high flood plain soils where irrigation encourages more intensive cultivation of transplanted aus and aman varieties, the rapid expansion of HYV wheat and the introduction and intensification of other rabi season crops, especially potato and chillie. On these soils, irrigation is supplemental and costs relatively low. Reduced risk associated with irrigation, encourages crop diversification and intensification and leads to high per acre returns ranging from Tk. 1,072 with deep tubewell irrigation to Tk.5,848 with a two cusec low lift pump.

Returns to irrigation on low flood plain soils are less, ranging from Tk.182 per acre with deep tubewell irrigation to Tk.3,708 with one cusec low-lift pumps. Because of annual flooding, broadcast aman rice remains the dominent rainy season variety. Irrigation encourages the introduction of HYV boro rice, a highly profitable crop, expansion of wheat cultivation and the adoption of intensive oilseed production. Higher water requirements and irrigation costs associated with this cropping system, especially boro rice, drive returns below those associated with high flood plain soils.

Finally, returns associated with medium and low elevation soils are roughly comparable, ranging from a negative Tk.2,165 for deep tubewell irrigation on low land soils to Tk.3,183 for one cusec low-lift pumps on medium elevation soils. In both cases, high water requirements and irrigation costs limit net returns.

The financial analysis suggests a strong preference for low-lift versus tubewell irrigation and smaller versus larger technologies. For example, the financial rates of return associated with one and two cusec low-lift pumps are consistently more favorable than those from deep and shallow tubewell investments. This is not surprising. Use of surface water precludes costly investments in well construction and allows for the use of smaller horsepower pumps which consume less fuel per irrigated acre. This results in per acre returns two to three times higher than those associated with tubewell technologies. Unfortunately, limited surface water supplies will constrain the increased use of these technologies in the future.

In areas where surface water is a problem, tubewell irrigation will be the only option. Higher initial per acre investments and annual operating costs associated with these technologies, significantly limit returns. In the case of deep tubewells, even at subsidized prices (Tk.190,000), financial viability is questionable. Net returns are positive only on high flood plain soils, becoming marginal on low flood plain soils and negative on medium and low elevation soils. Conversely, returns to shallow tubewell investment are positive across all land types, ranging from Tk.239 on medium elevation soils to Tk.2,877 on high flood plain soils. This suggests a clear preference for shallow versus deep tubewell irrigation, a trend now underway in rural Bangladesh.

Although net returns are important, a farmer's cash flow position is critical to adoption. High investment costs and the negative cash flows which result as cropping patterns adjust to irrigation can limit adoption and restrict sales to more affluent farmers. Although the present data has limited use in making inferences in this area, it does suggest some insights (See Table 4.8).

Table 4.7 Cash Flow Per Irrigated Acre With and Without Financing For The Purchase of Irrigation Equipment 1/
(Taka/Acre)

	Farmer Financed			Bank Financed 2/		
	Annual Net Returns Without Irrigation 3/	Negative Cash Flows With Irrigation	Percent	Annual Net Returns Without Irrigation 3/	Negative Cash Flows With Irrigation	Percent
Deep Tubewells	1374	- 5617	407	1374	- 1474	107
Shallow Tubewells	1374	- 3300	240	1374	- 419	30
Low-Lift Pumps (1 cusec)	1374	- 1841	134	1374	- 421	31
Low-Lift Pumps (2 cusec)	1374	- 1828	133	1374	- 409	29

Source: Tables A 9.0 to 9.7.

Notes : 1/ Estimates of negative cash flows are calculated by discounting negative flows associated with each land type and technology using a 12 percent discount rate and then averaging across land types.

2/ Bank financing includes medium term loans at 14 percent p.a., one year grace, ten year term for 90 percent of equipment purchases and short term loans at 16 percent p.a. for one year.

3/ Net returns without irrigation are averaged across land types.

Table 4.8 assumes net returns per acre without irrigation are a reasonable proxy for ability to absorb the initial negative cash flows associated with irrigation investments. When purchases are completely financed by farmers, demands on farm savings could be substantial. Negative cash flows resulting from purchases range from 403 to 133 percent per acre net returns before irrigation. This strongly suggests the need for effective financing if open market sales are to be promoted. Financing spreads user liability over the life of the equipment and reduces cash flow constraints. Loans for 90 percent of the cost of equipment over a ten year period at 14 percent significantly decrease negative cash flows associated with all types of equipment purchases, except deep tubewells. Here alternative arrangements would be required to reduce cash flow constraints further if open market sales are to be encouraged.

The Economic Impact of Irrigation

Complimenting the financial evaluation, an economic analysis of each irrigation technology was undertaken. Returns are presented in Table 4.8.

Table 4.8 Net Present Economic Value and Rates of Per Acre Returns to Irrigation 1/

	LAND TYPE			
	High Flood Plain	Medium	Low	Low Flood Plain
Deep Tubewells	3483 (20)	1261 (11)	-398 (9)	2173 (17)
Shallow Tubewells	6628 (41)	2261 (21)	3041 (25)	5627 (34)
Low-Lift Pumps (1 cusec)	9658 (75)	5590 (48)	6954 (60)	9612 (73)
Low-Lift Pumps (2 cusecs)	9859 (81)	5802 (52)	7079 (62)	9824 (76)

Notes: 1/ Uses economic prices (Table 3.4) and a 12 percent discount rate.
2/ IRR in parenthesis.

Overall results substantiate the high profitability of irrigation investments. Returns to low-lift pump irrigation remain superior to those associated with tubewells and range from a high of 81 percent for two cusec equipment on high flood plain soils to 48 percent for one cusec pumps on medium elevation soils. Of the tubewell technologies, shallow tubewells consistently are better investments than deep tubewells. Internal rates of return associated with the former are two times those the latter and range from 41 percent on high flood plain soils to 21 percent on medium elevation soils. Results strongly question the economic viability of deep tubewells and suggest the technology be used only in areas where shallow tubewell and low-lift pump technologies are inappropriate.

Economic Returns to Improvements in Irrigation Coverage

Consistent with conditions in rural Bangladesh, the preceding analysis assumes command areas per pump to be relatively low. Based on existing command area data, it was assumed that one cusec could provide adequate water for 20 acres. This is far below the physical limits of the technologies examined, and suggests that substantial increases in command areas are possible. Earlier efforts associated with the Kotwali Thana Central Cooperative Association (p. 15) and more recent pilot programs conducted by CARE and IRDP (p. 23) suggest that increases can be achieved. The impact of increasing command area size on net present economic value per acre is presented in Table 4.9.

Table 4.9 Effects of Increasing Command Area Size on Per Acre Net Present Economic Values (NPEV) Associated With Selected Irrigation Technologies[1/]

(In Taka and Percent)

	NPEV With			Change			
	Low[2/] Coverage	Medium[3/] Coverage	High Coverage	Low to Medium Absolute	Low to Medium Percent	Medium to High Absolute	Medium to High Percent
Deep Tubewells	2306	3909	4616	1630	71	707	18
Shallow Tube-Wells	4389	6049	6916	1660	38	867	14
Low-Lift Pumps (1 cusec)	7954	8870	9273	916	12	403	5
Low-Lift Pumps (2 cusec)	8141	8960	9335	819	10	375	4

Source: Tables A9.0 to A9.7.

Notes : 1/ Average net present economic value across land types.

2/ Low, medium and high coverage varies by technology: with DTWs = 40, 60 and 80A; with STWs =.10, 15 and 20A; with LLP (1 cusec) = 20, 30 and 40A, and; with LLP (2 cusec) = 40, 60 and 80A.

3/ Separate NPEV were developed for each technology and land type assuming medium and high coverage. Worksheets are available upon request.

The data suggest that there are substantial per acre returns to be captured. The largest absolute increases are associated with shallow tubewells, followed closely by deep tubewells. Because of the higher per acre investment costs associated with these technologies, improvements in tubewell command areas result in returns double those associated with low-lift pumps technologies.

Positive returns while necessary are not sufficient to guarantee improvements in irrigation coverage. Typically, costs for expanding coverage are borne by pump owners or management groups, while returns are distributed across all farmers in the command area. Unless mechanisms are developed which facilitate the transfer of a portion of the benefits to those who bear the costs, little change is likely to occur. Various approaches warrant further examination. For example, training of pump owners prior to pump installation could partially focus on the impact which changes in command area have on profitability. Training would encourage owners to establish rules early in the development of command area to facilitate later transfer payments. These might include the adoption of a graduated salary structure for pump managers based on command area size, increased water rates or the use of entrance fees payable by new farmers joining the command area. Where these options are not possible, government intervention might be justified. Use of government field staff to promote expanded coverage, would absorb the costs normally born by pump owners or management groups. Such services would constitute a financial subsidy to the irrigation group. If per acre costs of services were less than consequent increases in net present value, investments would be justified and positive economic returns would result.

CHAPTER V

MINOR IRRIGATION INVESTMENT OPTIONS

Introduction

This analysis has explored the political economy of minor irrigation policy in Bangladesh. It was conducted to provide USAID Bangladesh with basic background information to reassess its role in irrigation development and identify promising new areas of investment. The analysis has not attempted to assess AID's comparative advantage in supporting irrigation nor the detailed activities of other donors, areas which need to be explored before programming decisions are taken.

The Past

A brief review of available Asian literature, suggests that irrigation has an important place in national development. The key role of agriculture in the development process, the need for substantial capital investments during the early stages of development, the superior efficiency of irrigation over other policy options and the high potential pay off to minor irrigation combine to make it a leading investment choice. Based on the evidence, both the Trilateral Commission and the International Food Research Institute have suggested strong Asian irrigation investment programs, ranging from 3.0 to 4.5 million U.S. dollars annually.

Returns to irrigation investments in Bangladesh are positive. Earlier evaluations of deep tubewell developments in east central Bangladesh, suggested returns ranging from 27 to 43 percent. More recent field work conducted by the International Fertilizer Research Institute indicates strong positive returns to irrigation and a clear complimentarity between it and other inputs. The study concludes that a doubling in irrigated acreage, envisioned in the Second Five Year Plan (1981-85), would increase fertilizer demand by 32 percent and labor use by 30.3 percent.

Although positive returns are associated with irrigation, use of machine irrigation is a relatively new phenomenon in Bangladesh. Prior to the 1930s, production was sufficient to meet local foodgrain needs and provide an export surplus. Deficits in the late 1930s and early 40s, spurred new interest in water resource investments. [illegible] in the 50s and a focus on monsoon rice production, led to investment strategies heavily biased toward large flood control and drainage projects. Investment strategies outlined in the first National Water Resources Plan, which had significantly influenced investments from the early 1960s to mid 70s, rejected sub-surface irrigation as too costly and placed only minor emphasis on surface irrigation due to limited dry season water flows.

Through the 1960s and 70s, a debate over the optimal mix of irrigation technologies unfolded. The trend was away from larger publicly implemented and managed flood control projects to small-scale privately owned surface and sub-surface irrigation. The transition has not always been smooth. Delays on implementing large flood control schemes, questions regarding their economic and technical viability as new HYV rice varieties spread, and favorable reaction to small pump irrigation projects led to growing support for quick-to-install, quick-return minor irrigation. However, the irrigation establishment was reluctant to change. Engineers saw the larger, more technically complex schemes more compatible with their professional image and promotion trajectory. Also, the Water Development Board was comfortable with the earlier strategy which formed the basis of its administrative and salary structures. By supporting large scale developments it had been able to maintain its control over a large portion of the development budget and assure its political leadership among government agencies involved in water resource development.

It was only when the evidence became overpowering in support of minor irrigation that policies began to change. Surface irrigation which grew slowly was constrained in the long term by the lack of water in the dry season while interest in sub-surface irrigation focused on the installation of technically complex and expensive two cusec deep tubewells. With small land parcels, irrigation groups tended to be large and the time and effort spent in organizing groups was substantial. Groups often cut across traditional village lines, rekindling old disputes or creating new ones. More influential villagers dominated and as production costs and the probability of conflict rose, they tried to reduce group size to improve their control over irrigation supply, reduce conflict and lessen risk for personal financial loss.

Emphasis on two cusec deep tubewells and low lift pumps received both donor and domestic support. The World Bank favored the deep tubewell program, though it was not economically optimal, because it represented a well known and proven technology, fit existing bank and local procurement policies, placed minimal demand on scarce local managerial capacity and allowed for continued bank involvement through bank consultants. Use of two cusec low-lift pumps also fit ADCs interests to establish itself in a leadership role in irrigation development. In addition, national subsidy policies and strong focus on equipment procurement and installation, not improved command area management, fostered continued under-utilization. In 1978 subsidies ranged from 100 percent on gravity systems to 10 to 25 percent on shallow tubewells with average coverage per cusec 26 acres, 50 percent of potential.

The continued poor performance of minor irrigation, the growth in irrigation subsidies and stringent budget constraints led to substantial changes in policy in the early 1980s. Decisions were taken to eliminate irrigation subsidies on all equipment except deep tubewells, establish an open market sales program for new and used equipment, and for government to withdraw from pump rentals as soon as possible. If fully implemented these changes could generate savings of Tk. 2.9 billion during the Second Five Year Plan period. Also, credit programs to facilitate purchase of new and used equipment have been initiated with preference given to established irrigation groups. Program performance is still a question. In addition,

- the importance of command area development has been recognized and efforts to train government field staff, through a FAO program at the Bogra Rural Development Academy has begun. Duplicate efforts in other parts of Bangladesh which expand the present initiative and provide followup services for trainees in the field are being discussed. Which agency will take a lead role in this area is yet to be decided. Finally, policies to encourage local manufacture of pumps and engines and the growth of a private irrigation parts and service sector are underway.

Results of the economic and financial analysis substantiate many of these policy choices. For example, emphasis on the use of low-lift pumps is economically optimal. In the analysis, this technology proved superior to tubewells with internal rates of return ranging from 67 to 149 percent, two to three times those from tubewell investments. Unfortunately, increased use of this technology is limited by dry season flows. But, there is scope for the expansion of smaller one cusec pumps in areas of limited supply such as coastal zones where sweet water is limited to set periods during the day.

The physical constraints placed on low-lift pump irrigation suggest a heavy reliance of tubewell irrigation in the future. Recent suggestions to limit deep tubewell expansion in favor of shallow tubewell are well founded. The analysis indicates that shallow tubewells consistently outperform deep tubewell technologies, with internal rates of return of 21 to 41 percent. Low rates of return to deep tubewell investments suggest that plans to increase installation to 20,500 units by 1985 be carefully reviewed, new wells be limited to areas where shallow tubewells cannot be used and wells be installed only in command areas large enough to support the high investment costs associated with the technology.

The financial analysis points to the importance of credit financing to support private equipment purchases. Per acre investment costs for tubewell irrigation is substantial and results in negative net returns per acre during early pump life. Negative cash flows resulting from investments were found to be one to four times pre-irrigation net returns, placing irrigation beyond the means of many smaller farmers. With credit financing to cover 90 percent of equipment costs and 50 percent of incremental production expenditures, negative cash flows from shallow tubewell and low-lift pump investments were reduced to 30 percent of net non-irrigated income, well within the reach of most farmers. Unfortunately, negative returns associated with deep tubewells remained relative high, suggesting that special credit programs to encourage small farmer participation may be required and focused in areas where other irrigation technologies cannot be used.

Finally, the analysis indicated substantial returns to improvements in command area management. Returns associated with the expansion of tubewell command areas ranged from Tk. 1,660 to 707 per acre and suggest a highly focused development initiative, possibly similar to those undertaken by IRDP and CARE, be considered.

Future Options

The analysis suggests various options for USAID/Dhaka consideration. Economic, historic and financial analysis unanimously agree that irrigation investments make sense in the context of Bangladeshi development. The Mission's future role however, is less clear. Decisions regarding future program components must await a complete assessment of AID's comparative advantage vis-a-vis other donors, the compatibility of potential programming options with longer term Mission objectives, and government interest. What is provided below is an array of possible program options which may or may not be incorporated into an expanded assistance program.

Irrigation Technologies

Although economically superior, low-lift pumps will not play a critical role in future irrigation growth. Focus in the medium term will be on shallow tubewells. Rural demand is strong and consideration is already being given to doubling planned installation levels. A program focusing on the rapid expansion of shallow tubewells, especially as replacements for less economical deep tubewells, seems justifiable and might benefit from AID support. The development of credit facilities, possibly in cooperation with Bangladesh Bank, focused on private equipment wholesalers is an attractive option. Easy access to foreign exchange and local lines of credit would encourage the increased participation of entrepreneurs and relieve delays in credit availability likely to occur in a dynamically growing market.

The economic analysis suggests that government interest in deep tubewells be significantly curtailed. Efforts in this area need to be focused on identifying areas uniquely suited to deep tubewells and exploring alternative for reducing per acre costs. A number of options, some already underway, are available. Electrification can reduce investment and operating costs, but reliability has been a problem. Brown outs and power failures during critical irrigation periods could be overcomed by organizing pump operations during periods of low electrical demand. Extensive water losses, which result in excessive pumping, remain a problem, and cheap effective remedies need to be tested. Finding an acceptable technology will not be a problem, organizing farmers to adopt and pay for a proven solution, will. Finally, less expensive equipment and installation methods need to be explored. The Harvard approach which relied on manually drilled wells using rigs fabricated in Bangladesh, locally produced brass strainers, simple surface mounted pumps and low speed diesel engines needs to be re-evaluated. In light of increasing rural unemployment and landlessness, heavy reliance placed on the use of local labor make the approach a promising option.

Training in Water Management

High economic returns associated with increasing command area size, one component in an improved management program, suggest a strong investment program to strengthen capacity within Bangladesh institutions charged with expanding irrigation services. At present a number of agencies including the Water Board, Agricultural Development Corporation, Integrated Rural

Development Program, the Directorate of Extension and Management and the Bangladesh Agricultural Research Council have interest in training and supporting field services. Little interagency coordination exists and it is not clear which agency has a comparative advantage in either area. The situation suggests a number of investment options. For example, a lead agency could be identified and strengthened to provide the needed services. Problems associated with selecting the correct agency and the political implications of the choice mare this option. Conversely, assistance could be provided to strengthen capacity within any agency committed to improving water management services. This "1000 flower" approach implicitly assumes that agencies, as their technical competence increases, will see it in their own interest to encourage cooperation with others with complimentary interests. A more formal varient to this latter approach would involve the development of an interagency coordinating committee, possibly under the new National Water Resources Council. If action is to be taken, a statement clearly identifying possible institutional options and their impacts would be timely.

In addition, there is a vast unfilled need for water management training which will remain unmet in the future. Present efforts of the FAO are promising, but they need to be expanded rapidly and linked with an effective field support program. AIDs involvement could be important in setting the substantive tenor of future training and focusing it on specific interests not presently represented. For example, the development of a strong problem solving approach which relies heavily on the social and physical sciences is need to compliment the strong engineering bias already present. Training should be developed around three basic components; instruction on procedures for identifying and solving practical field management problems; applied field research which identifies new problems, tests promising solutions and updates classroom and field instruction; and follow-up field support to assist trainees in applying what they have learned and to identify constraints in training methods. Although foreign expertise may be required initially, the long term goal must be to replace expatriate staff with local professionals. Institutional arrangements which attract and retain highly qualified local staff, and provide them with an atmosphere condusive to multidisciplinary training and research are needed. Serious consideration should be given to developing a separate irrigation institute to organize continuous training programs, conduct multidisciplinary field research and serve as a forum for professional debate on the various aspects of irrigation development in Bangladesh. The development of new institutions, is not in vogue today. However, given the importance of water to Bangladesh's future, the "ad hoc" nature of present research, and the narrow engineering focus being taken in solving water management problems the development of a stronger semi-independent institute focusing of the physical, social and legal aspects of irrigation is a viable alternative, worthy of serious consideration. Finally, with the rapid development of a private market for irrigation equipment a new system of water management instruction, tied to pump purchases, is needed. In the future field specialists are likely to be called on for assistance only after a pump has been installed, decision taken on physical layout and organization and management problems have developed. Training of shallow tubewell owners and operators in preventive maintenance, command area layout and construction, irrigation scheduling and group management processes at the time of equipment purchase could be an important step in resolving many of these issues. The development of simple yet detailed written instructions supplied with each pump, would reinforce other training and hasten the spread of improved management ideas. In deep tubewell areas, the development of an irrigation group and their training prior to discussions concerning well placement, command area layout and financing could reduce future problems and improve coverage. A pilot program which tests alternative methods for organizing command areas prior to well installation needs to be tested.

Support for Private Market Developments

Government pricing policy will play a critical role in establishing a private market for irrigation pumps, engines and spares. Recent policies which realigned shallow tubewell prices with costs and set the prices of other equipment at par, is a major step in private market development. Complimentary development of an irrigation service sector remains. Rural workshops to repair equipment are required, new mechanics trained in a variety of different skills and a spare parts production and distribution system established. The reliable flow of credit to underwrite the purchase of machines, materials and spare parts and access to import permits will be essential to encourage growth in this small scale rural industry. Initially, ADC should be encouraged to maintain small stocks of critical parts as insurance against market shortage. The Corporation should be encouraged to sell excess stocks to private dealers and the latter should be allowed to import spares in the future. Also, major international pump manufacturers, wishing to conduct business in Bangladesh, need to be required to establish both sale and service centers in areas where pumps are concentrated. Finally, a training system, possibly established by major equipment vendors with government assistance, is needed to provide skilled manpower to service irrigation equipment. Three levels of manpower are required. Machinists will be needed to staff larger workshops which carry out major overhauls and produce replacement parts. Retention of skilled machinists will be a problem given demands in the Middle East. A well developed local placement program which links training with initial job placement might prove successful. Also, a large number of less highly skilled mechanics, located in rural hats and bazars with a minimum of equipment will also be needed. Finally, a cadre of semi-skilled artisians attached to rural workshops are required to service pumps in the field, carry out minor repairs and be on call when pumps break down. While the bulk of the training should be focused on upgrading rural artisians, special interest needs to be placed on involving the landless. Being largely illiterate, training materials which rely more on visual and spoken instruction than the written word, will be required.

Institutional Development

As irrigation development progresses increased demands will be placed on the nations limited water resources and conflicts between users are inevitable. For example, as low-lift pump use has expanded, disputes between the upper and lower riparians have increased. Conflicts between shallow tubewell owners and homeowners over disruptions in domestic water supplies have become common place.

New methods to arbitrate disputes are needed and steps must be taken, over the next decade to resolve potential problems. A national water resources code which clearly identify the rights of the state vis-a-vis those of the individual in surface and subsurface water, the priority of various water uses (agricultural, navigation, fisheries, industry etc.) in national development plans and the role of the various government agencies involved in regulating use is needed. The National Water Resources Council, recently established could provide a nonpartisan platform for developing such an overall code. Technical assistance in this area would be productive.

New institutions which regulate the supply of irrigation water are required. Existing water rights need to be recorded, a legal system which assures continued use created, and methods of arbitrating conflicting claims and awarding damages developed. Important issues such as methods for determining low-lift pump placement, shallow and deep tubewell spacing, ground water use and development and efficient methods of determining just compensation need attention. The local specific nature of many water related issues argues strongly for the development of local institutions, possible in upgraded thanas, that would deal specifically with water related problems. Finally, a set of guidelines which could be adopted by an irrigation group is outlining how water will be managed within irrigation commands, is needed. Procedures for establishing group and individual rights and responsibilities, determining the distribution of water within the command, procedures for contracting irrigation fees and regulating group operation and accountability would be included.

The possible options for AID involvement in irrigation development are numerous. Returns to investments are positive and likely to be substantial. What configuration AID policies will take is yet unclear. Past performance would suggest the Mission has interest and a possible comparative advantage in supporting programs focusing on training, research, credit supply and open market development. Opportunities for expanding these interests, as well as entering into new ones such as water law, national resource planning and irrigation field support services are possible and need to be considered. Given the present level of donor activities and Bangladesh's needs for the future, AID could play a significant role in irrigation institutional development.

APPENDIX TABLES

Table A 1.0

Water Balance Assessment for Bangladesh
(Period: December to March)
(In Million Acre Ft.)

Water Resources	Average Winter Season
Locally Available	
Precipitation average annual dry season 1/	+ 24
Local channel precipitation	+ 3
Local dry season runoff	- 45
Surface water storage 2/	+ 150
Ground water storage 2/	+ 44
Total evaporation	- 35
Total available locally	141
Imported Availability 3/	
Ganges River	18
Brahmaputra River	32
Meghna River and others	5
Total imported water	55
Total Available Water Resources	196
Water Demand 4/ 5/	
Irrigation	
Large scale surface irrigation	21
Small scale irrigation	
Low-lift pumps	8
Tubewells	7
Domestic uses	8
Livestock	6
Industrial uses	4
Ecological systems ~~management~~ 6/	98
Total Water Demands	152
Water Balance	
Average year	44
Drought year 7/	(15)

Source: FAO 1973 Water Resource Development Volumn II, Appendix 10 Table 2 and the authors own calculations.

Notes:
1/ 10% of annual average national levels.
2/ Storage between 5 to 30 ft. of surface water and ground aquafer Later assumed to be 30% water of which 20% is accessable.
3/ Based on average minimum flows.
4/ Estimates based on Second Five Year Plan targets for 1985.
5/ Irrigation requirements based on estimates of irrigated area in Second Five Year Plan.
6/ To maintain water levels in rivers, tanks and ponds so fishing, navigation and domestic uses are not disrupted and to control salt water intrusion, 50% available water is required.
7/ Assumes 30% reduction in total available water resources.

Table A 2.0

Relationship Between Model Land Types and Standard Bangladeshi Land Type Classifications

	Land Type	Land Elevation	Soil Permeability	Monsoon Flood Characteristics	Present Cropping Patterns: Spring	Summer/Fall	Winter
	1 1/	High	High	Free	Aus or millet, fallow	Fallow or karif vegetables	Rabi or fallow Rabi or fallow
Model 1	2	High, flood plain	Low	Free	Aus or jute	Fallow	Rabi
Model 1	3	High, Barend Tract	Low	Water poundable by bunding	Fallow or aus	T. Aman	Fallow
	4 1/	Medium	High	Water poundable by bunding	Aus or jute	T. Aman	Rabi or fallow
Model 2	5	Medium	Low	Very shallow flooding	Aus or jute	T. Aman	Rabi or fallow
Model 2	6	Medium	Low	Flooding upto 3 feet	Aus or jute	T. Aman	Rabi or fallow
Model 2	7	Medium	Low	With flood hazard	Aus	T. Aman	Fallow
	8 1/	Low	High/Low	Deep but not hazardous.	Mixed aus and B. Aman and Jute	Broadcast aman (continue)	Fallow
	9 1/	Low	High/Low	Deep and hazardous flooding	B. aman Fallow,	B. aman (continue) Fallow	Fallow Boro
Model 3	10	Low, Char Land	High/Low	Flood hazard	Fallow aus, millet or B.aman	Fallow Fallor or B. aman (continue)	Fallow Rabi or fallow
Model 3	11	Low, Char Land	High/Low	Flood hazard	Fallow, B. aman	Fallow B. aman (Continue)	Fallow Fallow
Model 4	12	Low, flood plain ridges outside	High/Low	Flood hazard	Aus, jute or millet	Fallow	Rabi or fallow
Model 4	13	Low, flood plain depression outside embankment	High/Low	Flood hazard	Mixed aus and B. aman or jute	B. aman (Continue) Fallow	Fallow Fallow

Source: Compiled from data in (1) East Pakistan Soil Survey Reports, Bogra District and (2) Report on the Potential for Rainfed HYV Rice Cultivation in Bangladesh by H. Bremer, 1974.

Note: 1/ Existing models are assumed to represent these land types. In a more detailed analysis, these land types should be modeled separately to account for differences in soil permeability.

Table A 3.0

Cropping Systems by Land Type With and Without Irrigation

	Model One High (Flood Plain)			Model Two Medium			Model Three Low			Model Four Low (Flood Plain)		
	P	$\bar{W}$	W	P	$\bar{W}$	W	P	$\bar{W}$	W	P	$\bar{W}$	W
Paddy												
Boro (Local)							10	10		10	10	10
Boro HYV									20			40
B. Aus (Local)	30	30	20	40	40	30	50	50	40			
T. Aus HYV			10			10			10			
B. Aman (Local)	10	10		10	10		50	50	50	70	70	70
T. Aman (Local)	40	20	10	40	30	10						
T. Aman HYV	10	30	50	10	20	50						
Wheat			20	10	10	30	10	10	30			
Potatoes			10									
Chillies			10			10			10			
Pulses	10	10		10	10	10	30	30	10	20	20	20
Oilseeds			10			10			10			10
Jute	20	20	20	20	20	20						
Vegetables	10	10	10			10			10			10
Cropping Intensity %	1.3	1.3	1.7	1.4	1.4	1.9	1.5	1.5	2.0	1.0	1.0	1.6

Source: IBRD 1980, Annex 2, Tables 1 and 6.

Table A 4.0 **Crop Inputs and Yields Per Acre**

	Unit	Local Boro1/	Boro (HYV)	B.Aus (Local)	T.Aus (HYV)	B.Aman (Local)	T.Aman (Local)	T.Aman (HYV)		Wheat		Potatoe	Chillies		Pulses		Jute		Vegetables		Oil Seeds
		PW2/	W	PW	W			PW	W	PW	W	W	PW	W	PW	W	PW	W	PW	W5/	W
Seed	seer	15	15	35	15	30	16	15	15	40	45	40	2	2	12	12	4	4	5 4/	10 4/	4
Fertilizer																					
Urea	seer	30	50	20	42	10	20	30	40	25	50	60	10	30	–	–	15	25	15	60	20
TSP	seer	15	30	15	24	10	10	15	25	15	25	20	4	10	–	20	7	5	10	30	10
MP	seer	10	15	10	11	–	10	10	10	10	10	20	2	10	–	10	5	5	5	30	10
Manure	maund	30	50	20	30	–	–	21	28	25	50	80	50	80	–	–	20	40	50	150	50
Pesticides	seer	0.5	1.0	0.5	1.0	0.5	0.5	–	1.0	–	0.5	–	–	–	–	0.5	–	0.5	0.8	2.0	0.5
Animal Power	pair day	20	23	20	23	16	22	20	23	16	19	21	22	22	10	15	17	18	16	28	15
Labor																					
Family	man day	50	58	27	42	28	46	46	57	33		65	47 3/	51	21	36	47	61	96 3/	105	25
Hired	man day	32	38	18	28	18	30	30	38	20		44	43	50	14	24	31	41	79	70	17
Yield	maund	22	38	16	30	16	21	19	30	18	28	98	5	9	9	13	15	23	35	50	10

Source: IBRD, 1981 b; Appendix 2 Table 10.

Notes :
1/ Grown only on low flood plain soils.
2/ PW = present without irrigation; W = future with irrigation.
3/ Includes 15 man days traditional irrigation per month as indicated in Table A 4.1.
4/ Harvest equivalent.
5/ Two consecutive crops of vegetables grow per dry season with irrigation.

Table A 4.1

Labor Requirements Per Acre
(Man Days)

Crop	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Boro (Local	12	27	5	5	11	17						6
Boro HYV	14	29	7	7	13	20						6
B. Aus (Local)			7	13	2	2	12	9				
T. Aus HYV			9	19	4	4	20	13				
B. Aman (Local)			7	13	2	1	1			6	14	6
T. Aman (Local)						7	15	21	3	4	16	10
T. Aman HYV						7	15	21	5	4	25	18
Wheat P$\overline{W}$ 1/	2	2	18	4							12	15
W	4	4	21	6							15	20
Potatoes P$\overline{W}$W		25	19	10	25							30
Chillies P$\overline{W}$			40	50	30	6						
W			25	40								
Pulses P$\overline{W}$	3	2	20								3	7
W 2/	5	5	30								8	12
Oilseeds W		8	7	3	24							
Jute P$\overline{W}$			23	6	5	3	36	5				
W			25	10	5	3	50	9				
Vegetables P$\overline{W}$	25	35	30							20 4/	35 4/	30 4/
W3/	10	25	30	25	3					15	25	15

Source: IBRD 1980 Annex 2 Table 8.

Notes:
1/ P = present; $\overline{W}$ = future without irrigation; W = future with irrigation.
2/ Oilseeds follow-on from pulses on the same land with irrigation for both.
3/ Two crops of vegetables with irrigation.
4/ Includes 15 man days per month for traditional irrigation of vegetables and chillies.

Table A5.0 Operating and Maintenance Costs for a 22 HP Deep Tubewell (2 cusec) by Model Land Type and Command Area Size
(In Taka)

	Model 1 - High Flood Plain			Model 2 - Medium			Model 3 - Low			Model 4 - Low Flood Plain		
	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres
Operating hours 1/	390	590	780	600	890	1180	640	970	1290	640	960	1280
Managers salary 2/	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Operators salary 2/	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Diesel 3/	11150	16870	22310	17160	25450	33750	18300	27740	36890	18300	27460	36610
Oil 4/	940	1430	1890	1450	2150	2860	1550	2350	3120	1550	2320	3100
Maintenance and spares 5/	1810	2740	3620	2790	4130	5480	2970	4510	5990	2970	4460	5950
Channel maintenance 6/	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Miscellaneous expenses 7/	450	590	720	600	800	1010	620	860	1090	620	850	1080
Total	22750	30030	36940	30400	40930	51500	31840	43860	55490	31840	43490	55140
Financial cost/acre	570	500	460	760	680	640	800	730	690	800	720	690
Economic cost/acre	630	560	520	850	770	730	890	810	760	890	810	760

Sources: Adopted from IBRD, 1982, Annex 2 Table 6.

Notes:
1/ From Table 4.4 in the text.
2/ Assume 1.5 full irrigation seasons to account for supplemental irrigation during monsoon season.
3/ Diesel at .05 gal/hp/hr at Tk. 26 gallon.
4/ Oil consumption 0.02 percent diesel consumption at Tk. 110 gallon.
5/ .5 percent of the capital and pump costs (inclusive of taxes and duties) per 100 hrs. of operation.
6/ Includes salary for ditch rider.
7/ Two percent of other costs.

Table A5.1 Operating and Maintenance Costs of a 6 HP Shallow Tubewell (.75 cusec) by Model Land Type and Command Area Size
(In Taka)

	Model 1 - High Flood Plain			Model 2 - Medium			Model 3 - Low			Model 4 - Low Flood Plain		
	10 Acres	15 Acres	20 Acres	10 Acres	15 Acres	20 Acres	10 Acres	15 Acres	20 Acres	10 Acres	15 Acres	20 Acres
Operating hours 1/	261	392	522	395	590	790	430	645	860	430	645	860
Operators salary 2/	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Diesel 3/	2030	3070	4080	3080	4620	6160	3350	5040	6710	3350	5040	6710
Oil 4/	60	100	130	100	150	200	110	160	210	110	160	110
Maintenance and spares 5/	300	450	610	460	690	920	500	750	1000	500	750	1000
Channel maintenance 6/	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Miscellaneous expenses 7/	120	150	170	150	180	220	150	190	230	150	190	230
Total	6160	7420	8640	7440	9290	11150	7760	9790	11700	7760	9790	11700
Financial cost/acre	620	500	430	740	620	560	780	650	590	780	650	590
Economic cost/acre	660	540	470	800	680	620	850	720	660	850	720	660

Source: Adopted from IBRD, 1982; Annex 2 Table 6.

Notes: See Table A5.0

Table A 5.2 Operating and Maintenance Costs of a 6 Hp Low Lift Pump (1 cusec) by Model Land Type and Command Area Size

(In Taka)

	Model 1 - High Flood Plain			Model 2 - Medium			Model 3 - Low			Model 4 - Low Flood Plain		
	20 Acres	30 Acres	40 Acres	20 Acres	30 Acres	40 Acres	20 Acres	30 Acres	40 Acres	20 Acres	30 Acres	40 Acres
Operating hours	350	520	700	525	790	1050	575	860	1150	570	855	1140
Operators salary[2/]	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Diesel[3/]	2730	4060	5460	5000	6160	8190	4490	6710	8970	4450	6670	8890
Oil[4/]	90	130	170	130	200	260	140	210	290	140	210	280
Maintenance and spares[5/]	410	610	820	610	920	1230	670	1010	1350	670	1000	1330
Channels maintenance[6/]	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Miscellaneous expenses[7/]	140	170	200	200	220	270	180	230	290	180	230	290
Total	7120	8620	10300	9580	11150	13600	9130	11810	14550	9090	11760	14440
Financial costs/acre	360	290	260	480	370	340	460	390	370	450	390	360
Economic costs/acre	390	320	290	530	420	390	500	430	410	490	440	400

Source: Adapted from IBRD, 1982; Annex 2, Table 6.

Notes: See Table A5.0.

Table A 5.3 Operating and Maintenance Costs of a 12 Hp Low-Lift Pump (2 cusec) by Model Land Type and Command Area Size

(In Taka)

	Model 1 - High Flood Plain			Model 2 - Medium			Model 3 - Low			Model 4 - Low Flood Plain		
	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres	40 Acres	60 Acres	80 Acres
Operating hours 1/	350	520	700	525	790	1050	575	860	1150	570	855	1140
Managers salary 2/	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Operators salary 2/	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Diesel 3/	5460	8120	10920	10000	12320	16380	8980	13420	17940	8900	13340	17780
Oil 4/	180	260	340	260	400	260	140	210	580	240	420	560
Maintenance and spares 5/	850	1270	1710	1280	1930	2560	1400	2100	2810	1390	2090	2780
Channel maintenance 6/	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Miscellaneous expenses 7/	280	340	410	380	440	530	360	460	570	360	470	570
Total	14170	17390	20780	19320	22490	27130	18280	23590	29300	18290	23720	29090
Financial costs/acre	350	290	260	480	370	340	460	390	370	460	400	360
Economic costs/acre	380	320	390	530	420	390	500	430	410	500	440	400

Source: Adapted from IBRD, 1982, Annex 2, Table 6.

Notes : See notes Table A5.0.

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Table A 6.0

Equipment Cost of Shallow and Deep Tubewells
As of March, 1981

(In Taka)

	Shallow Tubewells 1/				Deep Tubewells 1/			
	Foreign Cost	Local Cost	Duties Taxes	Total	Foreign Cost	Local Cost	Duties Taxes	Total
Engine 1/	6500		980	7400	48000		7200	58200
Pump 1/		4200	2/	4200	30000		4500	34700
Materials and accessories	5620		5386	11006 3/ (5620)	39000	23500	5850	68350
Drilling and installation		1600		1600		75000		75000
Overhead and handling 3/		4180		2925		7500		7500
Total	12320	11780	6366	30466	117000	106000	17550	240550 5/

Source: IBRD 1972, Annex 2, Tables 1 and 2.

Notes: 1/ STWs average 110 ft. deep with 4" diameter risers, surface mounted centrifugal pumps, 6 hp diesel engines and rated discharges averaging 0.75 cusecs. DTWs average 260 ft. deep, have submergible turbine pumps, 22 hp diesel engines and rated discharges averaging 2.0 cusecs.

2/ Duty of 35 percent charged on 4" pipes and 125 percent on brass strainers used in STW is absorbed by BADC and not passed on to farmers. Duty of 15 percent is charged on imported DTW engines and blind pipe.

3/ BADC currently charges an overhead of 14 percent which is considered low. Actual cost is closer to 20 percent, the margin likely required by the private sector to cover profit and interest on working capital.

Table A 6.1

Equipment Cost of One And Two Cusec Low Lift Pumps
As Of March, 1981
(In Taka)

	One Cusec Pumps				Two Cusec Pumps			
	Foreign Costs	Local Costs	Duties/ Taxes	Total	Foreign Costs	Local Costs	Duties/ Taxes	Total
Engine 1/	6500		975	7475	16000		2400	18400
Pump, trolly and coupling		4200		4200		6000		6000
Accessories	2500	4500	900	6900	3200	4800	1100	9100
Handling (20%) 2/		3925		3925		6400		6400
Total	9000	12625	1875	23500	19200	17250	3500	39950

Source: IBRD 1972; Annex 2, Tables 3 and 4.

Notes: 1/ The engine for a one cusec pump is 6 hp, for a two cusec pump 12 hp.
2/ BADC overhead or private sector margin .
3/ Imported LLP accessories are charged duty at 35 percent; engines at 15 percent.

Table A7.0 **Financial Value of Farm Production Per Acre**

(Taka/Acre)

Production Cost	High Flood Plain W̄	High Flood Plain W 1/	Model 2 - Medium W̄	Model 2 - Medium W	Model 3 - Low W̄	Model 3 - Low W	Model 4 - Low Flood Plain W̄	Model 4 - Low Flood Plain W
Seed	69	197	90	120	125	157	78	113
Fertilizer								
Urea	78	199	86	203	68	176	33	125
TSP	39	113	43	124	43	95	24	146
MP	25	46	25	46	16	39	2	30
Manure	93	195	61	192	42	159	8	103
Pesticides	130	272	135	313	149	324	108	311
Animal Power	532	694	581	861	541	811	334	653
Hired Labor	548	1124	502	1123	230	738	204	640
Irrigation	-	570	-	620	-	360	-	550
Total Costs	1514	3410	1523	3602	1214	2859	791	2371
Farm Production	2883	6048	2963	5906	2782	5535	1912	4771
Net Return (without irrigation cost)	1369	2638	1440	2304	1568	2676	1121	2400

Source: Tables 4.5 and A3.0

Note : 1/ W̄ = future without irrigation; W = future with irrigation.
2/ Include variable cost of irrigation. Capital costs and debt servicing are calculated separately. (Tables A7.1, and A7.2) and combined in Tables A9.0 to A9.7.

A7.1 <u>Financial Operating Cost for Deep Tubewells (2 cusec), Shallow Tubewells (.75 cusec) and Low-Lift Pumps (1 and 2 cusec)</u>

(Taka/Acre)

	High Flood Plain	Medium	Low	Low Flood Plain
Deep Tubewell				
40 acres	570	760	800	800
60 acres	500	680	730	720
80 acres	460	640	690	690
Shallow Tubewell				
10 acres	620	740	780	780
15 acres	500	620	650	650
20 acres	430	560	590	720
Low-Lift Pump				
20 acres	360	480	460	450
30 acres	290	370	390	390
40 acres	260	340	370	360
Low-Lift Pump				
40 acres	350	480	460	460
60 acres	290	370	390	400
80 acres	260	340	370	360

Source: Table A5.0, A5.1, A5.2 and A5.3.

A 7.2 Financial Purchase Price of Equipment and Salvage Value Per Acre[1/]

	Purchase Price Total	Purchase Price Acre	Salvage Value Total	Salvage Value Acre
Deep tubewells with a command area of				
40 acres	190000	4750	24055	601
60 acres		3167		401
80 acres		2375		301
Shallow tubewell with a command area of				
10 acres	23825	2383	2383	238
15 acres		1588		159
20 acres		1191		119
Low-lift pump (1 cusec) with a command area of				
20 acres	23500	1175	2350	118
30 acres		783		78
40 acres		588		59
Low-lift pump (2 cusec) with a command area of				
40 acres	39950	999	3995	100
60 acres		666		67
80 acres		499		50

Source: Calculated from data in Table A6.0 and A6.1.

Notes : 1/ Per acre estimates are developed for inclusion in the financial analysis Tables A9.0 to A9.7.

Table A 8.0 <u>Derivation of Prices Used in Economic Analysis (1981 Constant Prices)</u>

Item	Rice AMAN	Rice AUS/BORO	WHEAT	OILSEEDS	JUTE	Fertilizer UREA	Fertilizer TSP	Fertilizer MP
Projected Average World Market Price 1982-95 (US $/MT) 1/	395	395	183	539	401	236	209 2/	132 2/
Freight to Bangladesh Port (US $/MT)	32	32	65	44	-	+ 20 3/	65	65
CIF Chittagong (US $/MT)	427	427	248	583	401	256	274	197
CIF Chittagong (Tk/Md) 4/	311	311	180	424	292	186	199	143
Adjustment for Quality Differential 5/	.7	.65	.9	1.0	1.0	1.0	1.0	1.0
Adjusted CIF Price (Tk/Md)	218	202	162	424	292	186	199	143
Local Costs Between Port and Market/ District Store (Tk/Md)	18	18	20	18	-23	-24	24	24
Market Price (Tk/Md)	236	220	182	442	269	162	223	167
Local Costs Between Market/District Store and Farmgate (Tk/Md) 6/	-63	-63	-42	-42	-42	+30	+30	+30
Farmgate Price (Tk/Md)	173	157	140	400	182 7/	192	253	197

Source: IBRD 1982 <u>Price Projections for Major Primary Commodities</u> Vol. I, II, III.

Notes: 1/ Price basis;
- Rice - Thai 5% broken, FOB Bangkok
- Wheat - Canadian No. 1 Western Red Spring in store, Thunderbay
- Oilseeds - Groundnut, CIF Rotterdam
- Jute - Bangladesh BWD, FOB Chittagong/Chalna
- Urea - bagged, FOB N.W. Europe
- TSP - bulk, FOB Florida
- MP - bulk, FOB Vancouver

2/ Price includes bagging costs US $30 MT.
3/ Assumes Bangladesh will be an exporter with a regional comparative advantage over European competitors.
4/ Official exchange rate 19.5 = US $ 1.00 and 26.8 Md. per MT.
5/ Quality difference in rice for higher % broken (25-35% overall with aus/boro higher than aman); in wheat for varietal differences.
6/ Estimates provided by GOB adjusted by SCF = .83.
7/ Includes process loss of 20%.

Table A8.1 Economic Costs of Production Per Acre

(Taka/Acre)

	High Flood Plain		Medium		Low		Low Flood Plain	
	$\overline{W}$	W	$\overline{W}$	W	$\overline{W}$	W	$\overline{W}$	W
Production Costs								
Seed	92	205	112	114	166	200	105	140
Fertilizer								
Urea	113	289	125	125	125	125	125	182
TSP	88	254	97	279	67	214	54	104
MP	53	98	53	98	34	83	4	64
Manure	77	162	51	159	35	132	7	85
Pesticides	130	272	135	313	149	324	108	311
Animal Power	442	576	485	715	449	673	277	542
Labor								
Family	728	1010	744	1089	655	961	424	876
Hired	307	629	281	629	129	413	114	358
Total Costs	2030	3495	2083	3691	1809	3256	1218	2662
Farm Production	3937	7472	4167	7409	3634	6872	2548	6160
Net Returns	1907	3977	2084	3718	1825	3616	1330	3498

Source: Tables 4.5, A3.0 and A4.0.

Notes : 1/ Excludes fixed and variable costs of irrigation which are calculated in Tables A8.2 and A8.3.
2/ $\overline{W}$ = future without irrigation; W = future with irrigation.

Table A8.2 Per Acre Economic Costs of Irrigation Equipment Assuming Different Command Area Sizes 1/

(Taka/Acre)

	YEARS 1	10 2/	11 2/	21
Deep tubewell with a command area of				
40 acres	5125	(195) 3/	1950	(513)
60 acres	3416	(130)	1300	(342)
80 acres	2562	(98)	975	(256)
Shallow tubewell with a command area of				
10 acres	2210	(100)	999	(221)
15 acres	1473	(67)	666	(147)
20 acres	1105	(50)	499	(111)
Low-lift pump (one cusec) with a command area of				
20 acres	974	(50)	499	(97)
30 acres	649	(33)	330	(65)
40 acres	487	(25)	250	(49)
Low-lift pump (two cusec) with a command area of				
40 acres	838	52	525	(84)
60 acres	559	35	350	(56)
80 acres	419	26	262	(42)

Note: 1/ Assume engine life 10 years, pump life 10 years, accessory life 20 years and 10% salvage value for all equipment.

2/ Represent salvage value received at the end of the 10 irrigation seasons and costs of replacing engine and pump prior to the 11 irrigation season.

3/ Cash inflows in brackets.

Table A8.3 Per Acre Economic Variable Cost of Irrigation Assuming Different Command Area Sizes

(Taka/Acre)

	High Flood Plain	Medium	Low	Low Flood Plain
Deep Tubewell				
40 acre	630	850	890	890
60 acre	560	770	810	810
80 acre	520	730	760	760
Shallow Tubewell				
10 acre	660	800	850	850
15 acre	540	680	720	720
20 acre	470	620	660	660
Low-Lift Pump (1 cusec)				
20 acre	390	530	500	490
30 acre	320	420	430	440
40 acre	290	390	410	400
Low-Lift Pump (2 cusec)				
40 acre	380	530	500	500
60 acre	320	420	430	440
80 acre	290	390	410	400

Source: Table A6.0, A6.1, A6.2 and A6.3.

Table A9.0 Financial Budgets For A Hypothetical Acre With Deep Tubewell Irrigation[1]

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12[3]
Model I High Flood Plain Soils								
Inflows - Farm Income[2]	2833	2883	4466	5406	6048	6048	6048	6048
Outflows Production Costs[4]	1514	1514	2465	3032	3410	3410	3410	3410
Investment Costs[5]		5100						(601)[6]
Incremental Working Capital[7]		476	284	189				(949)
Net Benefits Before Financing - Total	1369	(4207)	1717	2185	2638	2638	2638	5391
- Incremental		(5576)	348	816	1269	1269	1269	4022
Financing - Loan Receipts[8]		4751	760	949	949	949	949	
Debt Servicing			1626	1889	1885	1708	1011	1011
Net Financing		4751	(866)	(940)	(936)	(759)	(62)	(1011)
Net Benefits After Financing - Total	1369	544	851	1245	1702	1879	2576	4380
Incremental		(825)	(518)	(124)	333	510	1207	3011
Model II Medium Elevated Soils								
Inflows - Farm Income[2]	2963	2963	4485	5317	5906	5906	5906	5906
Outflows - Production Costs[4]	1523	1523	2633	3298	3742	3742	3742	3742
Investment Costs[5]		5100						(601)[6]
Incremental Working Capital[7]		556	332	222				(949)
Net Benefits Before Financing - Total	1440	(4216)	1470	1791	2164	2164	2164	3714
Incremental		(5656)	30	351	724	724	724	2274
Financing - Loan Receipts[8]		4831	888	1110	1110	1110	1110	
Debt Servicing			1719	2032	2162	1985	1288	1288
Net Financing		4831	(831)	(927)	(1052)	(875)	(178)	(1288)
Net Benefits After Financing - Total	1440	615	639	864	1112	1289	1986	2426
Incremental		(825)	(801)	(576)	(328)	(151)	546	986

Notes: 1/ For the financial rate of return calculation, all benefits and costs except investment costs are laged one year and an incremental working capital stream introduced. These adjustments are made to allow for time lags occuring between incremental costs and benefits in different farming systems.

2/ Full irrigation is achieved in year four. In year one no changed (see #1), year two .5 coverage, year three .8 coverage.

3/ Included for discounting purposes only.

4/ Includes irrigation costs assuming 40A commands for deep tubewells and 2 cusec low-lift pumps, 20A for 1 cusec low-lift pumps and 10A for shallow tubewells.

5/ Includes per acre equipment costs and command area organizational costs as follows: DTW - Tk. 4750 and 350 respectively; STW - Tk.2383 and Tk.150; LLP - (1 cusec) Tk. 2350 and 250; and LLP - (2 cusec) Tk. 3995 and 350.

6/ Salvage value based on full cost of equipment.

7/ Assuming two cropping seasons, working capital is estimated as 50% of incremental operating costs of the following year. Working capital is recovered at the end of the project life of the equipment.

8/ Includes medium and short term loans. Medium term credit at 14% p.a., one year grace period, maturity period 9 years to cover 90% of equipment costs. Short term credit at 16% p.a. to finance cumulative incremental working capital.

Table A9.1 Financial Budgets For A Hypothetical Acre With Deep Tubewell Irrigation[1]

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12[3]
Model III Low Elevation Soils								
Inflows - Farm Income[2]	2782	2782	4136	4984	5535	5535	5535	5535
Outflows - Production Costs[4]	1214	1214	2257	2882	3299	3299	3299	3299
Investment Costs[5]		5100						(601)[6]
Incremental Working Capital[7]		521	313	209				(1043)
Net Benefits Before Financing - Total	1568	(4098)	1566	1893	2236	2236	2236	3880
Incremental		(5666)	(2)	325	668	668	668	2312
Financing - Loan Receipts[8]		4796	834	1043	1043	1043	1043	
Debt Servicing			1678	1974	2084	1907	1210	1210
Net Financing		4796	(844)	(931)	(1041)	(864)	(167)	(1210)
Net Benefits After Financing - Total	1568	698	722	962	1095	1372	2069	2670
Incremental		(870)	(846)	(606)	(373)	(196)	501	1102
Model IV Low Flood Plain Soils								
Inflows - Farm Income[2]	1912	1912	3342	4199	4771	4771	4771	4771
Outflows - Production Costs[4]	791	791	1656	2175	2521	2521	2521	2521
Investment Costs[5]		5100						(601)[6]
Incremental Working Capital[7]		433	260	173				(866)
Net Benefits Before Financing - Total	1120	(4412)	1426	1854	2250	2250	2250	3717
Incremental		(5532)	306	734	1130	1130	1130	2597
Financing - Loan Receipts[8]		4708	693	866	866	866	866	
Debt Servicing			1576	1811	1879	1702	1005	1005
Net Financing		4708	(883)	(945)	(1013)	(836)	(139)	(1005)
Net Benefits After Financing - Total	1120	290	543	909	1213	1414	2111	2712
Incremental		(830)	(577)	(211)	117	294	991	1592

Notes: See Table A9.0

Table A9.2 **Financial Budget for a Hypothetical Acre With Shallow Tubewell Irrigation[1/]**

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12[3/]
Model I High Flood Plain Soils								
Inflows - Farm Income[2/]	2883	2883	4466	5406	6048	6048	6048	6048
Outflows - Production Costs[4/]	1514	1514	2289	3063	3450	3450	3450	3450
Investment Costs[5/]		2508						(238)[6/]
Incremental Working Capital[7/]		488	287	194				(969)
Net Benefits Before Financing - Total	1369	(1627)	1689	2149	2598	2598	2598	3805
Incremental		(2996)	320	780	1229	1229	1229	2436
Financing - Loan Receipts[8/]		2257	775	969	969	969	969	
Debt Servicing		488	1133	1431	1621	1581	1124	1124
Net Financing		2745	(358)	(462)	(652)	(612)	(115)	(1124)
Net Benefits After Financing - Total	1369	1118	1331	1687	1946	1986	2483	2681
Incremental		(251)	(38)	318	577	617	1114	1312
Model II Medium Elevation Soils								
Inflows - Farm Income[2/]	1963	2963	4435	5317	5906	5906	5906	5906
Outflows - Production Costs[4/]	1523	1523	2618	3280	3722	3722	3722	3722
Investment Costs[5/]		2508						(238)[6/]
Incremental Working Capital[7/]		552	331	221				(1104)
Net Benefits Before Financing - Total	1440	(1620)	1486	1816	2184	2184	2184	3526
Incremental		(3060)	46	376	744	744	744	2086
Financing - Loan Receipts[8/]		2741	883	1104	1104	1104	1104	
Debt Servicing			1207	1556	1785	1745	1288	1288
Net Financing		2741	(319)	(452)	(675)	(641)	(178)	(1288)
Net Benefit After Financing - Total	1440	1121	1167	1364	1509	1543	2006	2238
Incremental		(319)	(273)	(76)	69	103	566	798

Notes: See Table A9.0

Table A9.3 Financial Budget For A Hypothetical Acre With Shallow Tubewell Irrigation[1/]

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12[3/]
Model III Low Elevation Soils								
Inflows - Farm Income[2/]	2782	2782	4136	4984	5535	5535	5535	5535
Outflows - Production Costs[4/]	1214	1214	2143	2698	3069	3069	3069	3069
Investment Costs[5/]		2508						(238)[6/]
Incremental Working Capital[7/]		465	278	186				(929)
Net Benefits Before Financing - Total	1568	(1405)	1715	2100	2466	2466	2466	3633
Incremental		(2973)	147	532	898	898	898	2065
Financing - Loan Receipts[8/]		2722	743	929	929	929	929	
Debt Servicing			1106	1394	1575	1535	1078	1078
Net Financing		2722	(363)	(465)	(696)	(606)	(149)	(1078)
Net Benefits After Financing - Total	1568	(251)	1352	1635	1820	1860	2317	2555
Incremental		(1819)	(216)	67	252	292	749	987
Model IV Low Flood Plain Soils								
Inflows - Farm Income[2/]	1912	1912	3342	4199	4771	4771	4771	4771
Outflows - Production Costs[4/]	791	791	1693	2231	2591	2591	2591	2591
Investment Costs[5/]		2508						(238)[6/]
Incremental Working Capital[7/]		451	269	180				(900)
Net Benefits Before Financing - Total	1121	(1838)	1380	1788	2180	2180	2180	3318
Incremental		(2959)	259	667	1059	1059	1501	2197
Financing - Loan Receipts[8/]		2708	720	900	900	900	900	
Debt Servicing			1090	1367	1541	1501	(1044)	1044
Net Financing		2708	(370)	(467)	(641)	(601)	(144)	(1044)
Net Benefits After Financing - Total	1121	870	1010	1321	1539	1579	2036	2274
Incremental		(251)	(111)	200	418	457	915	1153

Notes: See Table A9.0

Table A9.4 Financial Budget for a Hypothetical Acre With One Cusec Low-Lift Pump Irrigation 1/

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12 3/
Model I High Flood Plain Soils 2/								
Inflows - Farm Income 4/	2883	2883	4466	5406	6048	6048	6048	6048
Outflows - Production Costs	1514	1514	2357	2863	3200	3200	3200	3200
Investment Costs 5/ 7/		1425						(118)6/
Incremental Working Capital		422	253	169				(844)
Net Benefits Before Financing - Total	1369	(478)	1856	2374	2848	2848	2848	3810
Incremental 8/		(1847)	487	1005	1479	1479	1479	2441
Financing - Loan Receipts		1480	675	844	844	844	844	
Debt Servicing							979	979
Net Financing		1480	(81)	(188)	(368)	(310)	(135)	(979)
Net Benefits After Financing - Total	1369	1002	1775	2186	2480	2538	2713	
Incremental		(367)	406	817	1111	1169	1344	
Model II Medium Elevated Soils 2/								
Inflows - Farm Income 4/	2963	2963	4435	5317	5906	5906	5906	5906
Outflows - Production Costs	1523	1523	2493	3074	3462	3462	3462	3462
Investment Costs 5/		1425						(118)6/
Incremental Working Capital 7/		485	291	194				(970)
Netbebenefits Before Financing - Total	1440	(470)	1651	2049	2444	2444	2444	3532
Incremental		(1910)	211	609	1004	1004	1004	2092
Financing - Loan Receipts 8/		1543	776	970	970	970	970	
Debt Servicing			829	1148	1358	1300	1125	1125
Net Financing		1543	(53)	(178)	(388)	(330)	(155)	1125
Net Benefits After Financing - Total	1440	1073	1593	1871	2056	2114	2289	2407
Incremental		(367)	158	431	616	674	849	967

Notes: See Table A9.0

Table A9.5 Financial Budgets for a Hypothetical Acre With One Cusec Low-Lift Pump Irrigation 1/

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12 3/
Model III Low Elevation Soils 2/								
Inflows - Farm Income 4/	2782	2782	4136	4984	5535	5535	5535	5535
Outflows - Production Costs	1214	1214	2086	2610	2959	2959	2959	2959 6/
Investment Costs 5/		1425						(118)
Incremental Working Capital 7/		436	262	175				(873)
Net Benefits Before Financing - Total	1523	(293)	1788	2199	2576	2576	2576	3567
Incremental		(1816)	265	676	1053	1053	1053	2044
Financing - Loan Receipts 8/		1494	698	873	873	873	873	
Debt Servicing			772	1059	1246	1188	1013	1013
Net Financing		1494	(74)	(186)	(373)	(315)	(140)	(1013)
Net Benefits After Financing - Total	1523	1201	1714	2013	2203	2261	2436	2554
Incremental		(322)	191	490	680	738	913	1031
Model IV Low Flood Plain Soils 2/								
Inflows - Farm Income 4/	1912	1912	3343	4199	4771	4771	4771	4771
Outflows - Production Costs	791	791	1631	2135	2471	2471	2471	2471
Investment Costs 5/		1425						(118) 6/
Incremental Working Capital 7/		420	252	168				(840)
Net Benefits Before Financing - Total	1121	(724)	1460	1896	2300	2300	2300	3256
Incremental		(1845)	339	775	1179	1179	1179	2135
Financing - Loan Receipts 8/		1478	672	840	840	840	840	
Debt Servicing			753	1029	1207	1149	974	974
Net Financing		1478	(81)	(189)	(367)	(309)	(134)	(974)
Net Benefits After Financing - Total	1121	(370)	1379	1707	1933	1991	2166	2282
Incremental		(1490)	258	586	812	870	1045	1161

Notes: See Table A9.0

Table A9.6 Financial Budget For a Hypothetical Acre With Two Cusec Low-Lift Pump Irrigation[1]
(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12[3]
Model I High Flood Plain Soils								
Inflows - Farm Income[2]	2883	2883	4466	5406	6048	6048	6048	6048
Outflows - Production Costs[4]	1514	1514	2352	2855	3190	3190	3190	3190
Investment Costs[5]		1350						(100)[6]
Incremental Working Capital[7]		419	252	168				(839)
Net Benefits Before Financing - Total	1369	(400)	1862	2383	2858	2858	2858	3797
Incremental		(1769)	493	1014	1489	1489	1489	2428
Financing - Loan Receipts[8]		1319	671	839	839	839	839	
Debt Servicing			712	990	1171	1122	973	973
Net Financing		1319	(41)	(151)	(332)	(283)	(134)	(973)
Net Benefits After Financing - Total	1369	919	1821	2232	2526	2575	2724	2824
Incremental		(450)	452	863	1157	1206	1355	1455
Model II Medium Elevation Soils								
Inflows - Farm Income[2]	2963	2963	4435	5317	5906	5906	5906	5906
Outflows - Production Costs[4]	1523	1523	2493	3074	3462	3462	3462	3462
Investment Costs[5]		1350						(100)[6]
Incremental Working Capital[7]		485	291	194				(970)
Net Benefits Before Financing - Total	1440	(395)	1651	2049	2444	2444	2444	3514
Incremental		(1835)	211	609	1004	1004	1004	2074
Financing - Loan Receipts[8]		1385	776	970	970	970	970	
Debt Servicing			789				1125	1125
Net Financing		1385	(13)	(142)	(353)	(304)	(155)	(1125)
Net Benefits After Financing - Total	1440	990	1638	1907	2091	2140	2289	2389
Incremental		(450)	198	467	651	700	849	949

Notes: See Table A9.0

Table A9.7 Financial Budget For a Hypothetical Acre With Two Cusec Low-Lift Pump Irrigation 1/

(Taka/Acre)

	Without Irrigation	With Irrigation (Years) 1	2	3	4	5-10	11	12 3/
Model III Low Elevation Soils 2/								
Inflows - Farm Income 4/	2782	2782	4136	4984	5535	5535	5535	5535
Outflows - Production Costs	1214	1214	2086	2610	2959	2959	2959	2959
Investment Costs 5/ 7/		1350						(100) 6/
Incremental Working Capital		436	262	175				(873)
Net Benefits Before Financing - Total	1568	(218)	1788	2199	2576	2576	2576	3549
Incremental 8/		(1741)	265	676	1053	1053	1053	1981
Financing - Loan Receipts		1336	698	873	873	873	873	
Debt Servicing			732	1022	1211	1162	1013	1013
Net Financing		1336	(34)	(149)	(338)	(289)	(140)	(1013)
Net Benefits After Financing - Total	1568	1118	1754	2050	2238	2287	2436	2536
Incremental		(450)	231	527	670	719	869	1013
Model IV Low Flood Plain Soils 2/								
Inflows - Farm Income 4/	1912	1912	3343	4199	4771	4771	4771	4771
Outflows - Production Costs	791	791	1636	2143	2481	2481	2481	2481
Investment Costs 5/		1350						(100) 6/
Incremental Working Capital		423	254	169				(846)
Net Benefits Before Financing - Total	1121	(652)	1453	1887	2290	2290	2290	3236
Incremental		(1773)	332	766	1169	1169	1169	2115
Financing - Loan Receipts 8/		1323	677	846	846	846	846	
Debt Servicing			7177	997	1179	1130	981	981
Net Financing		1323	(40)	(151)	(333)	(284)	(135)	(981)
Net Benefits After Financing - Total	1121	671	1413	1736	1957	2006	2155	2255
Incremental		(450)	293	615	836	885	1034	1134

Note: See Table A9.0

F O O T E N O T E S

CHAPTER ONE: BACKGROUND AND INTRODUCTION

1/ Johnson estimates that the cost ratio of electric to manual energy required to irrigate 5 acres of rice is approximately 1 to 18 with electricity costing Tk. 144 versus Tk. 2,572 for labor based on 400 kg of coarse rice at Tk. 6.4 kg (Johnson, 1983).

CHAPTER TWO: THE ROLE OF IRRIGATION IN DEVELOPMENT

1/ During the 1970s agriculture production in the thirty six poorest nations (excluding China and India) grew at 1.9 percent per year, substantial below population growth of 2.6 percent per year (IBRD, 1981).

2/ Typically planners have estimated agricultural sector ICORs of 1.0 to 1.5. The World Bank in its assessment of Bangladesh's First Five Year Plan assumed agriculture ICORs of .8 to 1.5, 1/5th to 1/3rd those in manufacturing. (IBRD 1974, p. 299).

3/ Based on an analysis of 10 ADB irrigation projects undertaken from 1968 to 1972, and an assessment of six investment options the report concludes that the most economical investment in irrigation is the conversion of rainfed and partially irrigated acreage to fully irrigated acreage. The report suggested that per acre conversion costs of $1500 and $400 respectively would result in per acre increase in production of 5 and 2 tons.

4/ Prices used in the calculations are 1982 average prices for US No. 2 soft red winter wheat, FOB Gulf port. This is the major wheat variety imported in South and Southeast Asia.

5/ The Commission's Report makes a distinction between inadequate and adequately irrigated acreage based on the density of field level distribution canals. Adequately irrigated areas are those with at least 50 meters of canal per hectare, inadequate areas have less.

CHAPTER THREE: IRRIGATION POLICY IN BANGLADESH

1/ Over a 14 year period from 1882 to 1896 expenditures on railroads rose from Rupees 240 million to Rs. 366 million. Irrigation expenditures, during the same period, rose Rs. 30 million to Rs. 55 million, one fourth those of railways.

2/ Between 1860 and 1900 famine or scarcity prevailed in part of India 31 out of 40 years. During the 40 year period preceding 1860, it occurred 12 years and after 1900 only 7 years.

3/ This decision set the precedent for the long tradition of exclusive public irrigation development in South Asia, a policy only now being questioned in Bangladesh.

4/ Irrigation investments were selected on the basis of their ability to produce annual revenues sufficient to meet operating costs and interest on capital invested. This led to investments in areas of potential high productivity or those where investment costs would be lowest.

5/ The "Permanent Settlement" Act of 1793 fixed in perpetuity, land revenue payments in Bengal. Under the Act zamindars were required to pass along ten/elevenths of gross annual rents to government, retaining one/eleventh for themselves. Increases in rents resulting from extensions of cultivation or other causes were theirs to keep (IFIC 1976, p.5).

6/ Some observers reported increases in bed elevation of as much as 9 feet at the point where the Brahmaputra entered Bangladesh.

7/ The Krug Mission (1957), General John Hardin (1963) and Professor Thijsse (1964).

8/ The Plan took over five years to develop and required $12.1 million in foreign support. The Water Board was assisted by the International Engineering Co. a U.S. consultant, in developing it.

9/ Consistent with the large project focus of previous water resource developments in South Asia, the plan was not criticized because it recommended large, lumpy, high-cost projects, but because it was too narrowly conceived and superficial. As a result of the criticism, IECO's contract was terminated in 1968 and Canadian and Dutch consultants hired with donor funds to review and modify the Plan (Khan 1982, p. 30).

10/ This is logical behavior when one accepts that the Water Board's basic staffing pattern, its professional promotion system, and the distribution of non-salaried, irregular benefits depend on the proliferation rather than consolidation, of individual field projects. Repetto believes the Board was pursuing objectives which maximized their control of funds, regardless of the cost to the nation, by establishing feasibility for as many capital intensive projects as possible (Repetto 1971, p. 156).

11/ Installed pumping capacity averaged 3.0 to 3.5 cusec per well. At an exchange rate of Rs. 4.5 = $1.00, the cost per cusec was $19,300.

12/ The wells were located over an excellent water bearing formation, but on porous soils, not the best for irrigated rice production.

13/ To install one well 1-1/3 man-years of unskilled and .45 man-years of skilled labor were required. Installed pumping capacity was 1.5 cusec, somewhat less than stated pump capacity of 2.0 cusecs (Thomas 1975).

14/ Thomas estimated, using field data from Comilla, returns of Rs. 38,000 per 2 cusec well, enough to pay the full costs of well installation in one or two years (Thomas 1972, Appendix c, p.6).

15/ The World Bank estimated that ground water resources were sufficient to irrigate a minimum of 4 million acres (IBRD 1977, p.6).

16/ Investments were suggested to provide an additional 15,000 LLPs, 16,100 DTWs, 13,000 STWs and 340,000 acres of irrigated area under large scale schemes.

17/ The water balance table prepared by the FAO appears in Appendix A 1.0.

18/ Thomas found low cost manually installed deep tubewells had internal rates of returns ranging from 48 to 54 percent. Internal rates of return for medium cost, contractor installed wells ranged from 25 to 33 percent (Thomas 1975, p. 162).

19/ These were sunk by contractors using power drilling equipment, and had imported fiber glass screens, high speed diesel engines produced outside the region and submersible turbine pumps.

20/ Using 1977 land occupancy data and assuming 10 percent of farmers in a typical command area had three plots, 30 percent two plots and the remainder one, groups of 163 and 122 farmers would need to be organized to operate command areas of 100 and 60 acres respectively.

21/ A water rate of 3 percent of gross incremental benefits, accruing to the owners or occupiers of cultivated lands benefiting from irrigation, was prescribed in the bill. Although theoretically valid, incremental benefits are difficult to determine in the field.

22/ LLP prices to be set at present annual rent, times remaining years of life plus salvage value. DTW priced on the basis of applying straight line depreciation between the 1980 government price of Tk. 60,000 and salvage value of Tk. 30,000 (IBRD 1972, Annex 2, p.7).

23/ Bangladesh Diesel Plan (Duetz), Bangladesh Machine Tool Factory (Mitshubishi), Bangladesh Diesel Engine Co. (Yanmar), Bangladesh Diesel Let. (Lister) and Milners Engineering Complex (Kiloskar). Bangladesh Diesel Ltd. is a joint venture involving the GOB and Lister (49/51 percent), while the others are 100 percent locally owned making engines under licenses.

24/ The World Bank provides an excellent review of these important issues in its Minor Irrigation Sector Review (IBRD 1972, Annex 3).

CHAPTER FOUR: ECONOMIC RETURNS TO INVESTMENTS IN IRRIGATION

1/ Unpublished research conducted by the Department of Economics, Dhaka University suggests rice marketing margins of 8% between farms in Tangail and Dhaka, a distance of 60 miles. L. Mayers reports similar margins in Indonesia, averaging 10-12% for all grains.

2/ Adjusts wages paid in an excess supply market to those likely at full employment.

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