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BURIED PIPE IRRIGATION FOR COMMAND AREA DEVELOPMENT

AN ECONOMIC ANALYSIS

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Bangladesh is in short supply of food, and new agricultural strategies are being explored. Government policies aim to devise better techniques for increasing agricultural production. Studies indicate that irrigation is one of the most important constraints on agricultural production.[1/] Agriculture can be made more productive either through an expansion of irrigated area or by an improvement in water efficiency within existing command areas.

The Government of Bangladesh and a number of donor agencies are concentrating their efforts on removing the irrigation constraint. An experimental underground low pressure pipe system developed by FAO with USAID assistance at Narhatta village of Bogra District is aimed at evaluating promising techniques of water conveyance and distribution. Concern regarding future availability of ground water for irrigation is one of the reasons for developing this system. At present, the country's existing irrigation facilities, utilizing earthen channels for water conveyance are inefficient[2/] and it was felt highly necessary to study ways to increase their efficiency. The Narhatta deep tubewell (DTW) area previously using earthen channel was selected for conducting experiments relating to buried pipe adoption.

1/ See Report of IDA President: Report No. P-2709-BD, World Bank, Washington, February, 1980.

2/ Deep tubewell utilization is limited to 50-60 acres compared to the potential of 165-170 acres. Losses are due to seepage, percolation and evaporation.

The new buried pipe system gives a very high conveyance and distribution efficiency besides yielding other economic and non-economic advantages. 3/ However a conversion from earthen channel to buried pipe requires a large additional investment. An assessment of the comparative cost and benefits from earthen channel and buried pipe system is essential to determine the desirability of these additional invesements.

DESCRIPTION OF PROJECT

General

The project area is located in Narhatta area, Kahalu Thana of Bogra District and is about 8 miles from Bogra. The area has had a deep tubewell since 1977 with a command area of 70-75 acres. Rice is the principal crop grown in the area and average size of farms is around 0.3 acres. As with other areas of Bangladesh, the project has three main seasons: the monsoon from June to October, during which about 80% of annual rainfall is recorded; the dry season from November to February which has very little rainfall and the lowest temperatures and humidities, and the pre-monsoon from March to May, which has the highest temperatures and evappration rates with occasional heavy rain storms.

The proposed engineering lay out of the underground system (Figure 1) consists of two closed loops which are each connected by a main line with the header tank and two additional lines. Each loop has six outlets, each serving blocks of between 12 and 13 acres, and the additional lines each have one outlet which together serve on 18 acre

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3/ Irrigation efficiency as measured by proportion of pumped water reaching farmers fields for buried pipe system is calculated to be 80 - 85 percent, while for earthen channel it is 40 - 50 percent (source FAO Report, BDG/80/001 FAO Bogra).

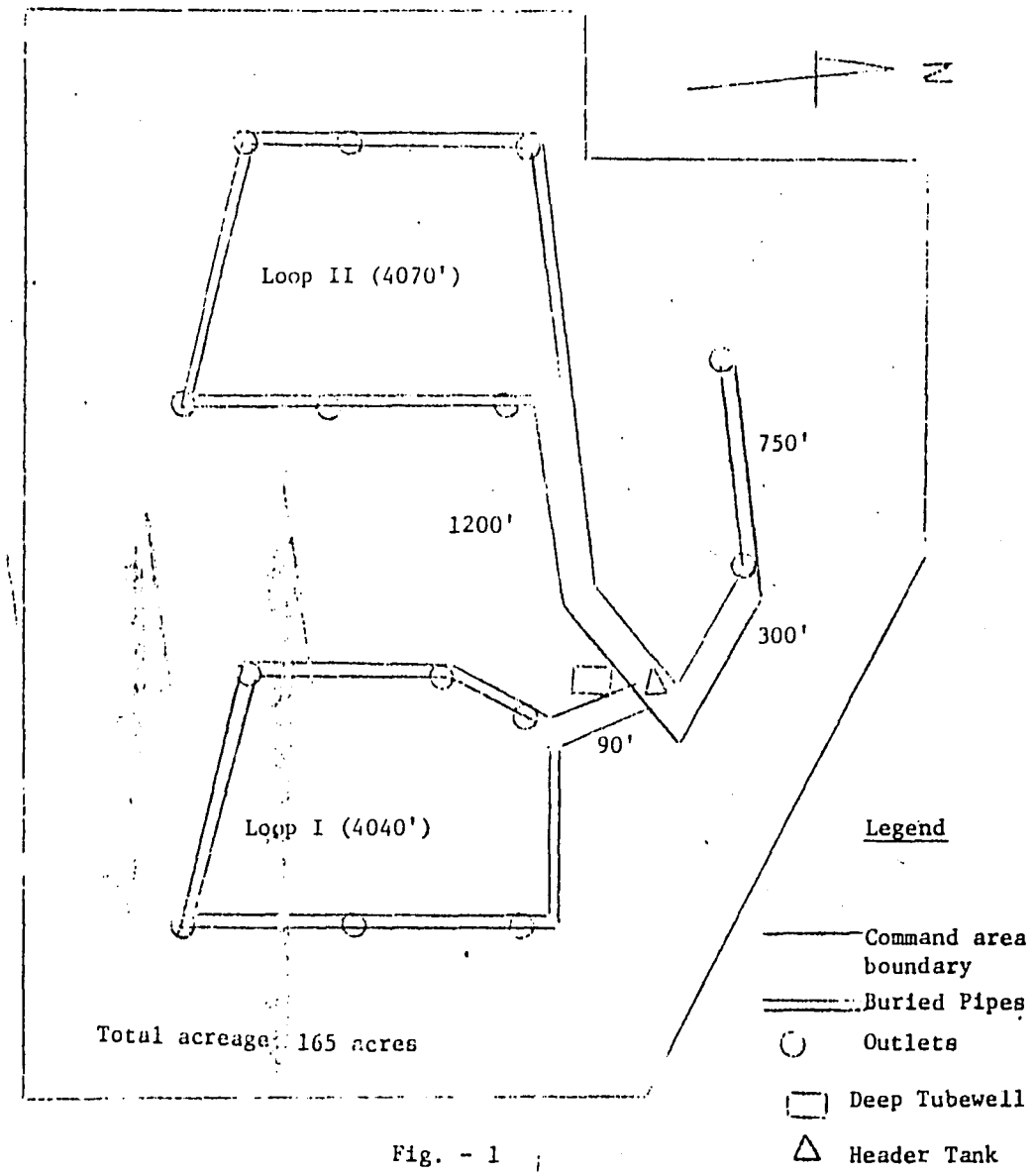

Fig. - 1

Sketch of Pipe Layouts: Buried Pipe Irrigation Project at Narhatta, Bogra.

block. The loops are 4040 feet (loop I) and 4070 feet (loop II), the main lines 90 feet (main I) and 1200 feet (main II), and the additional lines 300 feet (line I) and the 750 feet (line II), respectively. Two 14 inches mild steel stand pipes are used to connect the header tank with asbestos pipes. The buried asbestos pipes are dug to about 3.5 feet below field level.

Topography and Soil

The area is a part of the high elevation Barind tract region ranging in elevation from about 60 to 80 feet above sea level. This is a flood free area with 80-90 inches annual rainfall. Soils are of sandyclay type and rice grows well if soils have adequate moisture. Rain water is used to grow rice in the wet season, however, irrigation is needed for dry season rice production. The absence of rivers and canals make shallow and deep tubewells the only alternatives for irrigation. The ground water table is at a reasonable level and the area is a flat plain making it suitable topographically for channel and low pressure pipe distribution.

Agricultural Production and Cropping Patter

Basic data on agricultural production and cropping pattern observed in the project area as well as some assumptions on future cropping pattern are set forth in table 1. Before DTW irrigation, transplanted local aman was the main crop in the project area. The average yield was around 20 maunds per acre and nearly all farmers grew the crop during the rainy season in June/July. After the harvest of aman in October/November, the land remained mostly fallow during the

winter months. Again with the start of early rains in March/April, a few farmers (around 5 percent) grew local aus with an average yield of 12 maunds per acre. Ninety-five percent of the land remained fallow during the period. The cropping intensity was only 105 percent.

With the introduction of the DTW utilizing earthen channel in an area previously unirrigated production and cropping patterns show a remarkable change in the command area of 75 acres. Transplanted HYV aman, with average yields of 40 maunds, replaced the local veriety. HYV boro, wheat and potatoes began to be cultivated in the land previously remaining fallow. Local aus gave way to HYV aus during the months of March/April to June/July. The cropping intensity rose to 194%.

In March 1983, the area began to be irrigated by buried pipes. The data on crop yield, command area and cropping intensity are available for the first year (table 1). Command area has increased from 75 acres to 136 acres in the first year. It is assumed to rise to 156 acres in the second year and to 165 acres in the years hereafter. With an assured and uniform discharge of water over an increased command area of 90 acres, higher gross production and income should result. HYV varieties of aus and aman have replaced their local counterparts and larger acreages of boro, potato and wheat will be cultivated during the coming dry season in the project area. 4/ The cropping intensity in the first year is 165% and is expected to rise to 300% in the third year

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4/ This is the first year of buried pipe project and the farmer's intention were known by interview.

and years thereafter. The project would also eliminate crop area losses arising from construction of earthen channels.[5/] It's other advantages relate to (a) less problems of right of way, land acquisition, and compensation, (b) solution of problems arising from topographic variation and poor siting of pumps in conventional systems, (c) permission of close control of the prescribed rotational schedules, etc.

Methodology of Analysis

The method of economic analysis used here is a comparison of costs and benefits that result overtime with: (a) DTW irrigation using earthen channel compared to no prior irrigation, (b) DTW irrigation using buried pipe system compared to earthen channel, and (c) DTW irrigation using buried pipe system compared to no prior irrigation.

The measurement of costs relate to expenditures on construction for earthen channels and buried pipe systems as well as for operation of the DTW under each of the above systems. The measurement of benefits require calculation of increased production in the project area due to higher yield, increased cropping intensity, and expanded command area under earthen channel and buried pipe system.

Three measures of project feasibilities are used, the net present value (NPV), benefit-cost ration (B/C) and the internal rate of return (IRR). The first is arrived at by subtracting present cost from present value calculated over the project life, the second by dividing the discounted value of net benefit by the discounted value of costs calculated

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5/ The area lost over a command area of 165 acres for a channel of 5 feet width is calculated to be 4 acres.

over project life and the last is a calculated rate of compound interest that just makes the net present work of the cash flow equal to zero. The formula used for their calculation are shown in appendix table. The first is an absolute measure and estimates project's net present worth. The second is a relative measure and compares benefits per unit of cost. The third is also a relative measure and in a sense represents the average earning power of the money used in the project over the project life. Project feasibilities are judged by whether the benefit-cost ratio is greater than one, and/or, the net present values is greater than zero and/or the internal rate of return (IRR) is higher than the cost of money/capital. The three measures have their relative advantages and disadvantages. The difficulty with with benefit-cost ratios and Net Present Values is that they require determination of a suitable discount rate, generally the opportunity cost of capital, which is often difficult to properly determine. Furthermore, the value of B/C ratio changes depending on where the meeting out in the cost and benefit streams occur. Though the internal rate of return does not require the use of discount rate nevertheless the determination of opportunity cost of capital is required to use as a cut-off rate.

In case of mutually exclusive alternatives[6/] there are some advantages of using NPV criteria[7/] compared to the B/C ratio and IRR: The NPV gives correct ranking of projects so that alternative with highest NPV discounted at opportunity cost of capital should be used. This is accounted by the fact that NPV is an absolute measure and since in mutually exclusive alternatives only one project can be done, it makes sense to go with the one promising the greatest absolute net benefits, (even though the unit-for-unit efficiency represented by B/C ratio and IRR are greater for other alternatives). Furthermore, since the two relative measures, e.g. B/C ratio and IRR fail to take into account the scale effect, they may lead

6/ Mutually exclusive alternatives are competing projects of which only one can be implemented.

7/ J. Price Gittinger (1981), Economic Analysis of Agricultural Projects, IBRD, Washington (Revised Edition).

to erroneous investment choice. B/C ratio and IRR have inherent bias against large projects with relatively high gross returns and cost.[8/]

In the analysis, all of the three measures of project feasibility are calculated and estimated. The current market prices for the project and farmer's input and output are assumed to remain constant throughout the project life. The assumption is consistent with any rate of inflation over the project life so long the relative prices of input and output remain constant. Indirect costs and benefits of the infrastructure investment are not considered.

Cost of Construction for Earthen Channel and Buried Pipe System

Various components of investment, operation and maintenance costs of earthen channel and buried pipe system were identified. Cost of construction for earthen channel was calculated by using FAO furnished data of Tk.10/feet for a total command area of 75 acres for a discharge of 2 cusec.[9/] Construction cost of buried pipe system was obtained from FAO team working in Regional Development Academy of Bogra. Cost figures are shown in table 2. Buried pipe systems require a repair cost of Tk.2,500 for correcting probable damages in pipes and fixtures, and earthen channels are assumed to require a cost of Tk.3,000 per annuam mainly for channel widening, removing grass and silts, and repairing leaks and weak points The salary or opportunity cost of the manager was the same for both systems.[10/] The buried pipe system is assumed to have a working life of 40 years and has no salvage value.The earthen channels, annually maintained and repaired, are assumed to have an infinite life span. But for this analysis, a 40 year project life is assumed for both the buried pipe and open channel systems.

8/ See McKean, R.N., "Efficiency in Government through Systems Analysis with Emphasis on Water Resources Development. New York, Wiley, 1958 (pp 107-116) for discussion of the point with illustrative example.

9/ Length of earthen channel over the entire command area of 75 acres is calculated to be 9,870 feet.

10/ Manager basically performs the function of a block man. His task is to schedule and routing water delivery for each block in a day.

Cost of Installation and Operation of DTW with Earthen Channel and Buried Pipe System (Table 2)

The investment costs of the DTW for the two water conveyance systems were the same at Tk.380 thousand. This includes the cost of pump, engine, well components and drilling. The operation and maintenance cost of DTW under the two water conveyance systems were different. The difference arose because the DTW engine has had to work for extra hours to cover the expanded command area under the buried pipe system. The O & M cost included expenditures on diesel, lubricant oil, repair and spare parts and operator's wage. Annual O&M cost for DTW with earthen channel and buried pipe system were calculated to be Tk.26.6 thousand and Tk.33.5 thousand respectively. The pump and engine are assumed to have a useful life of 15 and 12 years under earthen channel and buried pipe respectively while well components have 20 years in both systems. Replacement costs are charged as project costs whereas salvage values were credited against project costs.

Benefit Estimates

Benefits were measured at net revenues to the farmers, e.g. after deducting total farm costs from farmer's gross revenue. The cost incurred by the farmer were different from those of the project cost and included costs on seed, fertilizer, manure, pesticide, animal power, and hired labor. Farmer's cost of irrigation is excluded from his budget to avoid double counting. Figures on annual gross benefit before and after DTW irrigation appear in table 3. Crop input requirements and farmer's cost per acre are shown in table 4. Finally table 5 shows net product from farming both before and after DTW irrigation.

Benefit Before Irrigation (table 3-5)

Local aman grown on the entire project area of 165 acres and local aus grown on 5% of the area (8.25 acres) were the two crops existing before irrigation. During this time cropping intensity was 105% (table 1). Annual gross value of production on the entire project area amounted to Tk.474.4 thousand; annual total production costs were Tk.266.0 thousand; and annual total net revenue were Tk.208.4 thousand.

Benefit with DTW Irrigation and Earthen Channel (table 3-5)

With DTW irrigation, local varieties of aman and aus have given way to HYV varieties in 75 acres of the command area, while local varieties continued to be grown in the residual project area of 90 acres. HYV boro, wheat and potatoes were grown during winter months in 50, 15 and 10 acres respetively of the command area which previously remained fallow. Cropping intensity increased from 105% to 194% (table 1). Annual gross value of production in the entire project area amounted to Tk.1308.5 thousand; annual total production costs to Tk.[illegible]9.4 thousand, and annual total net revenue to Tk.523.3 thousand.

Benefit with DTW Irrigation and Buried Pipe System (table 3-5)

The conversion of earthen channel to buried pipes is expected to result in an increased command area of 90 acres. Command area development is assumed to be phased over 3 years in the following manner:

Year	0	1	2	3-40
Acre	0	136	150	165
Benefit as Percentage of Full Benefit	0	82	91	100

With DTW irrigation using buried pipes acreages alloted to HYV aus, aman and boro as well as those for wheat and potato did either increase or are expected to increase in the entire command area. Cropping intensity is estimated to rise from 265% in the first year to 300% in the third and final year (table 1). Annual gross value of production in the entire project area amounted to Tk.2037.2 thousand, annual total production cost to Tk.1153.5 thousand, and annual total net revenue to Tk.782.4 thousand.

Results

A discount rate of 14 percent in real term is assumed[11] to find present value of cost and benefit. In the analysis, cost and benefit streams are expressed in current (May, 1983) prices.

[11] This is the interest rate charged by commercial bank for medium term loans. Probably this rate also reflects the opportunity cost to farmers of capital in Bangladesh.

Change Examined	NPV	B/C	IRR
A. DTW irrigation using earthen channel compared to no irrigation	2118	3.97	68.7%
B. DTW irrigation using buried pipe system compared to earthen chaflen	977	1.99	30.1%
C. DTW irrigation using buried pipe system compared to no irrigation	3093	2.84	43.9%

Summary and Conclusion

This paper reports an economic analysis of the investment in buried pipe systems for water conveyance. Three measures of project feasibilities, namely, net present value (NPV), benefit-cost ratio(B/C), and the internal rate of return (IRR) are used to shed light on the feasibility of investing in buried pipes instead of earthen channels. Three alternative options are considered, namely (1) transformation of non-irrigated land to DTW using earthen channel conveyance; (2) conversion of a DTW area using earthen channel to one using buried pipes and; (3) transformation of non-irrigated land into a DTW irrigated area directly using buried pipes.

The preference for using one feasibility measure over another for judging economic viability of alternative options would depend on whether we regard the projects to be mutually exclusive or independent. If earthen channels are converted by phases to become a buried pipe system they can be treated as independent; whereas if construction of earthen channel preempt a buried pipe project, they are to be regarded as mutually exclusive. Both are likely possibilities and consequently all the three project feasibility measures are useful.

Looking at each one of the project singly, all are economically viable, e.g. benefit-cost ratios are all greater than one, net present benefits are positive, and internal rate of returns are higher than the likely cost of capital. The problem of selection among these projects depends on whether there is capital limitation or not. In a situation of no budgetary constraint, all three independent projects that have been found feasible can be implemented. Under the more normal conditions of budgetary limitations, however, use of NPV criterion for project selection is recommended, and the decision rule is to select the projects which yield the highest aggregate NPV within the capital constraint. Under this rule, the set of projects (A and B) that first proposes a transformation of non-irrigated land into DTW irrigated area using earthen channel conveyance and then suggesting its conversion to buried pipes are recommended. The decision rule for selecting among mutually exclusive projects in situations of no capital limitation is to select the project with the highest NPV, B/C or IRR. Where there is capital limitation, however, selection would obviously have to be confined to those alternatives whose investment requirements fall within the capital constraint. Under this rule, our three projects give conflicting results. If the investment decisions are based purely on the magnitude of the computed B/C ratio and IRR, then project A (DTW irrigation using earthen channel compared to no irrigation) is the best alternative. Based on the NPV's, however, project C (DTW irrigation using buried pipe system compared to no irrigation) is

to be selected. One way to resolve the conflict would be to use NPV as the preferred selection criterion[12/]

The analysis used in the report does not incorporate indirect benefits of an intensive irrigation method such as that of a buried pipe system. For a modernizing agriculture relying on manufacturing sectors for supply of inputs and consumer items, these linkages are likely to be substantial and can modify the results upward. Secondly, there might be important non-economic benefits of the project which may justify the expansion of the buried pipe system. Finally, a reduction of the cost of asbestos pipes, which constitute a major portion of total project cost would make the system more profitable.

12/ See arguments given in methodology section and additinally, National Economic Development Authority (1977), A Guide to Project Development, Manila, Philippines (pp. 135-137).

Benefit-Cost Ratio

Present value of incremental benefit is estimated by using the formula:

$$PV = \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \text{----} + \frac{B_{40}}{(1+r)^{40}}$$

and the present value of incremental cost by

$$PC = \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \text{------} + \frac{C_{40}}{(1+r)^{40}}$$

where PV = Present value of benefits

PC = Present value of costs

B_i = Incremental benefit in the ith year

C_i = Incremental cost in the ith year

r = rate of discount

Benefit-cost ratio (B/C) is thus PV/PC.

Net Present Value

Net present value (NPV) is PV-PC.

Internal Rate of Return

Internal Rate of Return (IRR) is simply the rate of interest that equates the discounted present value of incremental benefits and the present value of the incremental costs. In terms of symbols used previously, the rate of return is the rate of interest at which the present value of incremental benefits $\sum_{t=1}^{\infty} \frac{B_t}{(1+r)^t}$, and the present

value of incremental costs $\sum_{t=1}^{n} \frac{C_t}{(1 + r)^t}$ are equal, or in other words the rate of interest at which the difference between discounted incremental benefits and costs is zero, that is, $\sum_{t=1} \frac{B_t - C_t}{(1 + r)^t} = 0$

TABLE 1

AREA CULTIVATED AND CROPPING INTENSITY

CROP	AREA (ACRES) W	WE	WB	$\overline{WB}$
Aus (Local)	8.25 a/	4.5 b/	1.4 c/	0
Aus (HYV)	0	75	136	165
Aman (Local)	165 d/	90 e/	29 f/	0
Aman (HYV)	0	75	136	165
Boro	0	50 g/	95 g/	115 g/
Wheat	0	15 h/	26 h/	32 h/
Potato	0	10 i/	15 i/	18 i/
Total All Crops	173.25	319.5	438.4	495
Net Cultivated Area	165	165	165	165
Cropping Intensity	105%	194%	265%	300%

W = Without irrigation, WE = With DTW irrigation and earthen channel, WB = With DTW irrigation and present buried pipe command area of 136 acres, $\overline{WB}$ = With DTW irrigation and future buried pipe command area of 165 acres.

a/ Grown before DTW irrigation in 5 percent of total command area of 165 acres (8.25 acres).
b/ Grown after DTW irrigation in 5% of 90 acres (165-75) not covered by DTW with earthen channel (4.5 acres).
c/ Grown in 5% of 29 acres (165-136) not presently covered by DTW with buried pipe system (1.4 acres).
d/ Grown in the entire command area of 165 acres.
e/ Grown in 90 acres (165-75).
f/ Grown in 29 acres (165-136).
g/ Grown after DTW irrigation in 70% of command area (50, 95, 115 acres).
h/ Grown after DTW irrigation in 20% of command area (15, 26, 32 acres).
i/ Grown after DTW irrigation in 10% of command area (10, 15, 18 acres).

TABLE 2

COST OF WATER CONVEYANCE SYSTEM AND DEEP TUBEWELLS

	Water Conveyance System		Deep Tubewell Using	
	Earthen Channel	Buried Pipe	Earthen Channel	Buried Pipe
Fixed Investment Cost (Tk.)	98,700 c/	1,003,156	380,000 e/	380,000 e/
Operation and Maintenance Cost (Tk.)				
Maintenance Cost	3,000 c/	2,500 d/	-	-
Diesel f/	-	-	21,065	27,015
Lubricant Oil g/	-	-	2,950	3,765
Repair and Spares h/	-	-	600	770
Manager's Wage i/	1,600	1,600	-	-
Operator's Wage j/	-	-	2,000	2,000
SUB TOTAL	4,600	4,100	26,615	33,550

Source: FAO Team working at Regional Development Academy, Bogra.

a/ Earthen Channel cost is calculated @ Tk. 10/ft for a command area of 75 acres.

b/ Buried pipe cost refers to the total command area of 165 acres.

c/ For channel widening, removing grass and soils, and repplishing leaks.

d/ For repairing damages in pipes, fixtures, and header tanks and replacement of parts.

e/ Cost is measured as of May 1983 assuming DTW is 200 feet deep, have submergible turbine pump, 21.5 hp. diesel engine and rated discharge of 2 cusec. Cost includes expenditures on pump, engine, materials and accessories, drilling and instlllation.

f/ @ .7 gallon/hour and Tk. 34/gallon.

g/ @ 2 gallon/72 hour and Tk. 120/gallon.

h/ For 885 hours annual operation with earthen channel and 1130 hours annual operation with buried pipe system. Working life of DTW pump and engine are assumed to be around 15,000 hours.

i/ 4 months at monthly rate of Tk. 400/month.

j/ 4 months at monthly rate of Tk. 500/month.

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TABLE 3

BURIED PIPE IRRIGATION PROJECT
(ANNUAL GROSS BENEFIT (MAY 1983 PRICES)

ITEM	PRICE (TK./MD.)	GROSS PRODUCTION (MD) W	WE	WB	WB	GROSS VALUE ('000 TK) W	WE	WB	WB
Aus Local	125	99	54	17	0	12.4	6.8	2.1	0
Aus HYV	120	-	2190	4080	4950	-	262.8	489.6	594.0
Aman Local	140	3300	1800	580	0	462.0	252.0	81.2	0
Aman HYV	110	-	2920	5440	6600	0	321.2	598.4	726.0
Boro HYV	130	-	2272	4284	5198	-	295.3	557.0	675.7
Wheat	130	-	480	870	1056	-	62.4	113.1	137.3
Potato	90	-	1200	2176	2640	-	108.0	195.8	237.6
TOTAL GROSS VALUE:						474.4	1308.5	2037.2	2370.6

W = Without irrigation WE = With DTW irrigation and earthen channel, WB = With DTW irrigation and present buried pipe command area of 136 acres, WB = With DTW irrigation and future buried pipe command area of 165 acres.

TABLE 4

BURIED PIPE IRRIGATION PROJECT
CROP INPUT REQUIREMENTS PER ACRE

Item	Aus Local	Aus HYV	Aman Local	Aman HYV	Boro	Wheat	Potato	Price May 1983(Tk.)
Seed (Md.)	1	.4	.4	.4	.5	1.5	30	1/ 280/md.
Fertilizer(Md.) 2/	.1	2.7	.3	3.5	4	3	5.5	3/ 140/md.
Manure(md.)	30	100	100	150	150	125	150	2/md.
Pesticide Cost (Tk.)	0	110	50	110	110	0	70	-
Animal Power/ a-d	12	14	12	14	14	12	12	25/a-d
Hired Labor / m-d 4/	25	40	33	40	48	30	66	20/m-d
Total Cost	1129	1710	1364	2162	2420	2040	7260	
Yield (Md.)	12	30	20	40	45	32	145	

Source: FAO survey data of region.
Authors interview of farmers.

1/ Price of Potato seed is Tk. 150/maund, and Tk. 200/maund for wheat.

2/ Includes urea, T.S.P and MP.

3/ Weighted average price.

4/ Hired labor only.

TABLE 5

BURIED PIPE IRRIGATION PROJECT
ANNUAL CROP PRODUCTION COSTS

Item	QUANTITY USED W	WE	WB	$\overline{WB}$	PRODUCTION COST ('000) W	WE	WB	$\overline{WB}$
Seed (Md)	74.2	385.5	660.2	785.5	20.9	107.9	184.8	219.9
Fertilizer (Md)	50.3	793	1396.9	1684.1	7.0	111.0	195.6	235.8
Manure (Md)	16,748	33,374	56871	65382	33.5	77.7	113.7	130.8
Pesticide Cost	-	-	-	-	8.3	27.3	42.9	50.3
Animal Power (a-d)	2,409	4248	6012	6851	60.2	106.2	150.3	171.3
Hired Labor (m-d)	6,806	12179	18248	20937	136.1	243.5	364.9	418.7
Total Cost					266.0	729.4	1153.5	1349.6
TOTAL GROSS VALUE					474.4	1308.5	2037.2	2370.6
NET PRODUCT					208.4	523.3	782.4	898.2

W = Without irrigation.
WE = With DTW irrigation and earthen channel.
WB = With DTW irrigation and present buried pipe command area of 136 acres.
$\overline{WB}$ = With DTW irrigation and future buried pipe command area of 165 acres.

Table 7: COST AND BENEFIT STREAM FOR DTW IRRIGATION USING EARTHEN CHANNELS AND BURIED PIPE SYSTEM

Year	Cost (000 Tk)		Benefit (000 Tk)			Incremental Cost (000 Tk)			Incremental Benefit (000 Tk)		
	With DTW Irrigation and Earthen Channel	With DTW Irrigation and Buried Pipe System	Without Irrigation a,b/	With DTW Irrigation and Earthen Channel c/	With DTW Irrigation and Buried Pipe System d/	DTW Earthen Channel Compared to No Irrigation	DTW Buried Pipe Compared to Earthen Channel	DTW Buried Pipe Compared to No Irrigation	DTW Earthen Channel Compared to No Irrigation	DTW Buried Pipe System Compared to Earthen Channel	DTW Buried Pipe System Compared to No Irrigation
0	478.7	1383.2	208.4	208.4	208.4	478.7	904.5	1383.2	0	0	0
1	31.2	37.7	208.4	523.3	782.4	31.2	6.5	31.7	314.9	259.1	574.0
2	31.2	34.6	208.4	557.8	862.2	31.2	6.5	34.6	349.4	304.4	653.8
3	31.2	37.7	208.4	628.0	898.2	31.2	6.5	37.7	419.6	270.2	689.8
4-12	280.8	339.3	1875.6	5652.0	8083.8	280.8	58.5	339.3	3776.4	2431.8	6208.2
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
13	31.2	164.4	208.4	628.0	898.2	31.2	133.2	164.4	419.6	270.2	689.8
14-15	62.4	75.4	416.8	1256.0	1796.4	62.4	13.0	75.4	839.2	540.4	1379.6
-	(25.4)	-	-	-	-	(25.4)	-(25.4)	-	-	-	-
16	158.2	37.7	208.4	628.0	898.2	158.2	-120.5	37.7	419.6	270.2	689.8
17-20	124.8	150.8	832.6	2512.0	3592.8	124.8	26.0	150.8	1678.4	1080.8	2759.2
-	(19.8)	(19.8)	-	-	-	(19.8)	-	(19.8)	-	-	-
21	130.2	103.1	208.4	628.0	898.2	130.2	-27.1	103.1	419.6	270.2	689.8
22-24	93.6	113.1	625.2	1884.0	2694.6	93.6	19.5	113.1	1258.8	810.6	2069.4
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
25	31.2	164.6	208.4	628.0	898.2	31.2	133.4	164.6	419.6	270.2	689.8
26-30	156.0	188.5	1042.0	3140.0	4491.0	156.0	32.5	188.5	2098.0	1351.0	3449.0
-	(25.4)	-	-	-	-	(25.4)	-(25.4)	-	-	-	-
31	158.2	37.7	208.4	628.0	898.2	158.2	-120.5	37.7	419.6	270.2	689.8
32-36	156.0	188.5	1042.0	3140.0	4491.0	156.0	32.5	188.5	2098.0	1351.0	3449.0
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
37	31.2	164.4	208.4	628.0	898.2	31.2	133.2	164.4	419.6	270.2	689.8
38-40	93.6	114.6	625.2	1884.0	2694.6	93.6	21.0	114.6	1258.8	810.6	2069.4
-	(41.9)	(83.8)	-	-	-	(41.9)	41.9	(83.8)	-	-	-

a/ Benefit is in net terms, e.g. gross benefit minus cost.
b/ Calculated for the total command area of 165 acres.
c/ Includes loss of production (equivalent to 2 acres) due to channel construction on the 75 acre command area (proportion to crop production).
d/ Buried pipe command area is assumed to increases to 150 acre in second year and to 165 acre in third year and thereafter.

TABLE 6

COST STREAM FOR WATER CONVEYANCE SYSTEM AND DEEP TUBEWELL

	COST: WATER CONVEYANCE SYSTEM ('000 TK.)						COST: DEEP TUBEWELL (000 TK.)					
	EARTHEN CHANNEL			BURIED PIPE SYSTEM			EARTHEN CHANNEL			BURIED PIPE SYSTEM		
Year	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	TOTAL Cost
0	98.7	0	98.7	1003.2	0	1003.2	380.0	0	380.0	380.0	0	380.0
1	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	27.6	27.6
2	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	30.5	30.5
3	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	33.6	33.6
4-12	0	41.4	41.4	0	36.9	36.9	0	239.4	239.4	0 h/	302.4	302.4 h/
-	-	-	-	-	-	-	-	-	-	(25.4)	-	(25.4)
13	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0 i/	33.6	160.5 i/
14-15	0	9.2	9.2	0	8.2	8.2	0 a/	53.2	53.2 a/	0	67.2	67.2
-	-	-	-	-	-	-	(25.4)	-	(25.4)	-	-	-
16	0	4.6	4.6	0	4.1	4.1	127.0b/	26.6	153.6 b/	0	33.6	33.6
17-20	0	18.4	18.4	0	16.4	16.4	0	106.4	106.4	0	134.4	134.4
-	-	-	-	-	-	-	(19.8)c/	-	(19.8)c/	(19.8)c/	-	(19.8)c/
21	0	4.6	4.6	0	4.1	4.1	99.0d/	26.6	125.6d/	99.0d/	33.6	99.0d/
22-24	0	13.8	13.8	0	12.3	12.3	0	79.8	79.8	0	100.8	100.8
-	-	-	-	-	-	-	-	-	-	(25.4)j/	-	(25.4)h/
25	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0k/	33.6	160.5k/
26-30	0	23.0	23.0	0	20.5	20.5	0	133.0	133.0	0	168.0	168.0
-	-	-	-	-	-	-	(25.4)e/	-	(25.4)e/	-	-	-
31	0	4.6	4.6	0	4.1	4.1	127.0f/	26.6	153.6	0	33.6	33.6
32-36	0	23.0	23.0	0	20.5	20.5	0	133.0	133.0	0	168.0	168.0
-	-	-	-	-	-	-	-	-	-	(25.4)l/	-	(25.4)l/
37	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0m/	33.6	160.5m/
38-40	0	13.8	13.8	-	12.3	12.3	0	79.8	79.8	0	100.8	100.8
-	-	-	-	-	-	-	(41.9)g/	-	(41.9)g/	(83.8)n/	-	(83.8)n/

a/ 20% salvage value for pump and engine after 15 years. b/ Replacement cost of pump and engine. c/ 20% salvage value of well components after 20 years. d/ Replacement cost of well components. e/ 20% salvage value of pump and engine after 30 years. f/ Replacement cost of pump and engine. g/ 33% salvage value of pump and engine. h/ 20% salvage value for pump and engine after 12 years. i/ Replacement cost of pump and engine. j/ 20% salvage value for pump and engine after 24 years. k/ Replacement cost of pump and engine. l/ 20% salvage value for pump and engine after 36 years. m/ Replacement cost of pump and engi n/ 66% salvage value of pump and engine.