IMPACT OF LINED CANALS ON SHALLOW TUBEWELL IRRIGATION AND THEIR ACCEPTABILITY BY THE FARMERS

A Thesis

by

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Submitted to the Institute of Water and Flood Management (IWFM),
Bangladesh University of Engineering and Technology
In partial fulfillment of the requirement
for the degree of

MASTER OF SCIENCE
IN
WATER RESOURCES DEVELOPMENT

Institute of Water and Flood Management (IWFM)

Bangladesh University of Engineering and Technology

February, 2010

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Institute of Water and Flood Management

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ACKNOWLEDGEMENT

The author would like to expresses his gratefulness to the Almighty Allah, who has created the universe and who enabled the author to complete this piece of research work and preparation of this thesis successfully and to achieve higher degree in Master of Science in Water Resources Development from the Institute of Water and Flood Management.

The author wishes to express his most sincere gratitude and profound thanks to Dr. Abul Fazal M. Saleh, Professor, Institute of Water and Flood management (IWFM), Bangladesh University of Engineering and Technology (BUET), for kindly supervising this research work. This research is really a product of Professor Saleh's supervising, guidance, encouragement and keen interest Without his cordial supervision, this work would not be completed. The author is indebted to him for the enormous amount of time, effort and support that he has given throughout the process of the study, and feel proud to have a chance to work with Professor Saleh that greatly helped the author to improve her research capability and writing skills.

The author would like to express his sincere gratitude and thanks to Dr. M. Shah Alam Khan, Professor and Director, Institute of Water and Flood Management (IWFM), BUET, for kindly reviewing the draft final copy of this thesis and providing valuable comments and useful suggestions that helped a lot to upgrade the work.

The author also expresses his heartfelt and sincere appreciation and profound indebtedness to Dr. M. Shahjahan Mondal, Associate Professor, Institute of Water and Flood Management (IWFM), BUET, and Engr. Abdus Sattar, Project Director, AETEP, Department of Agricultural Extension, Khamarbari, Farmget, Dhaka, for kindly reviewing the draft final copy of this thesis and providing their realistic suggestions and co-operation in various ways during the preparation of this thesis.

The author expresses his boundless gratitude to his beloved parents, who inspired him with the best of their prayer, great sacrifice and blessing in carrying out the higher study. The author expresses his sincere gratitude to his elder brother Dr. Md. Zahurul Haque who put high ambition about the author's higher studies and sacrificed their happiness to the cause of the author's education.

The author expresses special thanks to his beloved wife Most. Farhana Afroz who put high ambition about the author's higher studies and sacrificed her happiness to the cause of the author's education. The author would like to share his overwhelming feelings with the part of his soul, his loving son Ahmad Musa who used to sit beside him while composing the script in his laptop.

The author thanks to his beloved friends Engr. Dipangkar Kundu, Engr. Sumon, Engr. Mukles, Engr. Suza, Engr. Maria, Safina Naznin, Runu, Santu, Tania, Musfique, Piara for their encouragement, valuable suggestions, constructive criticism and active co-operation while preparing the thesis.

The author gratefully acknowledges the support and cooperation provided by the farmers of the study areas who have voluntarily participated in the survey. Thanks are due to Thana level office personnel of the study area including DAE officials who have provided different data and information regarding the study.

Cordial co-operation, friendly collaboration, fruitful advice and guidance were received from many persons from the starting to the ending of this piece of work, The author is immensely grateful to all of them and regrets for his inability to mention everyone by name.

Finally, the author expresses his thanks to all the employees of the Institute of Water and Flood Management, Bangladesh University of Engineering and Technology.

The author

Abstract

The study was undertaken in Boro season at three Upazilas: Manikgonj Sadar of Manikgonj district, Dhamrai of Dhaka district and Mithapukur of Rangpur district to compare conveyance losses between lined and unlined canal, to assess the impact of water saving on command area development and irrigation cost and to determine the economic benefits and farmers' acceptability of lined canal in shallow tubewell (STW) irrigation schemes under the hood of "Enhancement of Agricultural Production and Rural Employment through Extension of Agricultural Engineering Technologies Project" (AETEP). Nine improved earthen canals, three pre-cast lined canals and six existing earthen canals under STW were selected for field study. In this study conveyance loss through lined and unlined canals was measured using inflow-outflow method. Farmers' surveys were carried out in each Upazila to assess the impact of water saving on command area development and the acceptability of lined canal technology by the farmers. For this purpose, focus group discussion (FGD) was carried out with the pump owners and farmers at all the selected schemes. Conveyance losses were found to be 41%, 48% and 45% in existing earthen canals, 18%, 21% and 24% in improved earthen canals and 12%, 11% and 13% in pre-cast canals at Mithapukur (M_1), Manikgonj Sadar (M_2) and Dhamrai (D) schemes, respectively. Average amount of water saved by improved earthen canals and pre-cast canals were 23%, 17% and 21%; 29%, 37% and 32% for M_1, M_2 and D schemes, respectively, over earthen canal. The water saving did not increase the command area in any of the schemes but decreased the irrigation time and saved the fuel requirement for irrigation. Average time saved by improved earthen canals and pre-cast canals were 27%, 20% and 24%; 40%, 44% and 45% for M_1, M_2 and D schemes, respectively, over earthen canal. Again average fuel saved by improved earthen canals and pre-cast canals were 32%, 23% and 30%; 45%, 46% and 48% for M_1, M_2 and D schemes, respectively, compared to earthen canal, which reduced irrigation cost. The economic analysis of improved earthen canal and pre-cast canal system in STW is encouraging. The benefit-cost ratio (BCR) of improved earthen canal and pre-cast canal were 1.36, 1.38 and 1.30; 3.36, 4.28 and 3.34 for M_1, M_2 and D schemes, respectively. The internal rates of return (IRR) from investment on water distribution was over 50% at Mithapukur, Manikgonj and Dhamrai schemes for improved earthen canals and 49.78%, over 50% and 49.67% for pre-cast canals, respectively, for Mithapukur, Manikgonj and Dhamrai schemes. The technology was also technically and economically acceptable to pump owners, but did not impress the farmers very much. As a result, acceptability of this kind technology is questionable to the farmers who share the crop with the pump owners as price of irrigation or on the basis of irrigated area. In order to make the technology acceptable to the farmers, rules must be framed to share the benefits of lining by the pump owners with the farmers. Otherwise, the pump owners must bear the cost of lining construction.

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List of Abbreviations

AETEP	=	Agricultural Engineering Technology Extension Project
AEZ	=	Agro- Ecological Zone
BADC	=	Bangladesh Agricultural Development Corporation
BARC	=	Bangladesh Agricultural Research Council
BAU	=	Bangladesh Agricultural University
BCR	=	Benefit Cost Ratio
CA	=	Command Area
DAE	=	Department of Agricultural Extension
DTW	=	Deep tubewell
FGD	=	Focus Group Discussion
HYV	=	High yield verity
ICID	=	International Commission on Irrigation and Drainage
IRR	=	Internal Rate of Return
LLP	=	Low lift pump
MPO	=	Master Planning Organization
MoWR	=	Ministry of Water Resources
NMIDP	=	National Minor Irrigation Development Project
NPW	=	Net Present Worth
PRA	=	Participatory Rural Appraisal
STW	=	Shallow Tubewell

Chapter 1
INTRODUCTION

1.1 General

Irrigation plays a critical role in Bangladesh through increasing yield and cropping intensity. Since there is no new land to be brought under cultivation and the existing agricultural land is declining on account of increased use of land for other purposes, increased food production is critically dependent on increased yield. Presently, 220 ha of land is being lost from agricultural use per day due to rapid spread of urbanization and industrialization (AETEP, 2005). So, there is no other way but to intensify use of the existing cropland. With expanded irrigation water and supplementary irrigation at Aman season, two or three crops can be grown and yields of all crops could be increased. Erratic climatic conditions cause a high degree of uncertainty in the agricultural sector. Investment in irrigation can also be of further advantage by reducing this uncertainty.

Out of about 9.1 Mha of cultivable land of Bangladesh about 6.8 Mha is considered as suitable for irrigation. Presently, about 5 Mha has been brought under irrigation, of which more than 95% is covered by minor or small scale irrigation (BADC, 2008). Over the years, the proportion of irrigated area based on groundwater has changed significantly. The contribution of groundwater in relation to total irrigated area increased from about 41% in 1982-83 to over 75% in 2008. Shallow tubewell (STW) is the main mode of extracting groundwater and at present about 63% of the total irrigated area is based on STW (BADC, 2008). As groundwater is the only limiting resource for further intensification of agriculture, its rational use should be ensured both in terms of quality and quantity.

In Bangladesh, most of the irrigation canals are earthen because of high initial cost for the construction of lined canals. These earthen canals suffer from a number of problems like low conveyance and distribution efficiency, less irrigated area and high maintenance cost (Maniruzzaman *et al.*, 2002). The water loss through earthen canals in minor irrigation projects is a matter of great concern. As reported in the literature, this loss (mainly through seepage and percolation) is generally as high as 50% or even more of the water pumped/delivered, although it varies from soil to soil (Biswas *et al.,* 1984; Matin, 1991; Sattar *et al.,* 2002). Therefore, some sort of on-farm water control measures for avoiding water losses in the irrigation distribution system are realized important because of high cost of energy inputs in lifting the water for irrigation. To avoid such a huge national investment for irrigation water lost through canal section, alternative low cost water saving irrigation techniques are needed. A well-compacted earthen lining can be highly impermeable and is almost comparable to good concrete lining (ICID, 1967). In a recent study, the conveyance loss under improved earthen canal was measured only as10% (Sattar *et al.*, 2002).

Improvement of the efficiency of resource utilization for irrigation has been emphasized in the National Water Policy (MoWR, 1999). In the National Water Management Plan (WARPO, 2001), it has been mentioned that the government would take steps to improve the on-farm water management in the form of improved farm channels, as a potentially useful measure for saving irrigation water that would result in expansion of irrigated area.

Recently, much concern has also been expressed about improving the performance of existing irrigation systems, as many have lower efficiency and crop yields below their potential. Planners, administrators and donor agencies seem to be shifting attention from building new irrigation systems to improving the performance of the existing ones. To realize this goal there is a need to develop and implement practical methodologies to upgrade the performance of the existing irrigation systems and allow the farmers to achieve higher benefits from the use of irrigation water.

The command area of the STWs, which is the main mode of minor irrigation, has been steadily declining and was 4 ha in the early eighties. But in the recent years it has come down to about 2.5 ha (BADC, 2008). The reasons for this decrease are not well documented. As a follow up of the plan on improvement of the farm channels, the Government has recently taken up the AETEP (Enhancement of Agricultural Production and Rural Employment through Extension of Agricultural Engineering Technologies Project) under the Department of Agricultural Extension (DAE) to persuade the farmers to use improved or lined canal, so as to enhance the command area. Some of the important objectives of this project are to increase the command area, reduce the cost of irrigation and enhance production through appropriate on-farm water management practice. Under this program, the DAE with the help of Upazila Agricultural Office has taken up pilot projects in each Upazila to improve three earthen canals and construct one pre-cast lined canal in farmers' fields per year (AETEP, 2005). In this context, it is necessary to know the impact of the canal improvement and lining by AETEP on the irrigation development and management and the acceptability of the technologies by the farmers.

This study focuses on the impact of canal lining on irrigation management of STWs and addresses two key questions: how canal lining influences the improvement of irrigation management (command area development and irrigation cost) and the acceptability of the technologies by the farmers (their willingness to replicate the technologies at their own cost).

1.2 Objectives with specific aims

The main objective of the study was to identify the impact of canal improvement and lining on irrigation development using shallow tubewell. The specific objectives are:

1. To determine the conveyance efficiency of traditional and lined canals.
2. To assess the impact of water saving by lining / improvement of canals on command area development and irrigation cost.
3. To determine the economic benefits and farmers' acceptability of lined / improved canal.

Chapter 2
REVIEW OF LITERATURE

2.1 Introduction

Water is the most valuable asset of irrigated agriculture in both developed and developing countries. Accurate measurement of irrigation water permits more intelligent use of this valuable resource Such a measurement reduces excessive waste and allows the water to be distributed among users according to their needs and rights. Conveyance loss in earthen canal is the movement of water through the bed and sides and thus water gets lost through the pore space of canal sub grades.

Considerable work on seepage loss and canal lining has been reported in literature, but very little or no work was carried out in Bangladesh before the mid seventies. A broad based assessment of conveyance and seepage losses and of eventual utilization of canal supplies in different countries of the world indicated that as much as 50% of the total water diverted / pumped for irrigation is lost in conveying it to the fields and farms (Kraatz, 1977).

Water losses by seepage, dead storage, percolation, evaporation and overtopping occurred due to improper design, alignment, maintenance and construction. Seepage and percolation of earthen canal also depend on topography (Biswas *et al.*, 1983). Seepage water may reappear at the surface as wet spots or may percolate to join the ground water or may join the sub-surface flow to springs or streams.

2.2 Canal loss measurement

Various methods are used to estimate the canal seepage rate such as empirical formula, analytical studies and the direct seepage measurement techniques. Seepage from existing canals is usually evaluated by direct measurements and various methods are used such as inflow-outflow method, ponding method and seepage meter method. These methods have their merits, demerits and limitations, which are well understood. Between the two common methods of seepage measurement–ponding and inflow-outflow, the ponding method is considered to be more accurate and dependable (ICID, 1967; Kraatz, 1977; Weller, 1981; Deacon, 1984). The most dependable and reliable method for measuring the quantity of water loss through seepage from the existing canals in a particular reach is by the ponding method (Sarki *et al.*, 2008). It is proved that inflow–outflow tests should not be used for seepage investigations where seepage rates are fairly small and there is no possibility to use sufficiently long reaches. This method has been extensively applied for seepage measurement of the large canals in India (Central Board of Irrigation and Power, 1975) and Pakistan (Ashraf *et al.*, 1977).

In inflow-outflow method, the seepage rate is obtained by estimating the difference in the flow into and out of a selected reach of a canal. The canal dischargers at the two points are determined either by discharge measuring structures of current meter. The results obtained by inflow-outflow method are more reliable than the other (Ponding method and Seepage Meter method) methods (Shahid *et al.*, 1991). Due to the problem of accuracy of measurement by either of these two methods, a reliable estimate of canal discharge is extremely difficult to obtain using inflow-outflow method (Deacon, 1984). Ponding test measured water losses 23% less than inflow-outflow test (Sarki *et al.*, 2008). Reason for this difference may be over estimation of discharge through cut-throat flume and under estimation of seepage loss through ponding test due to silt deposition in the water course, and actual seepage loss could be expected somewhere between these two. Ali (1978) indicated that the flume loss overestimation varied from 5% to 30% compared to the actual loss of the channel.

2.3 Canal Lining

Lining is an effective way of minimizing conveyance losses. The decision about the extent of lining of water courses depends on the cost of lining and its benefits. In Bangladesh, the pioneering work on seepage loss and canal lining was done by Biswas and Islam (1975). They developed a low cost lining using indigenous materials like clay and cow dung. Studies on seepage loss were carried out on Deep Tubewell (DTW) irrigation projects and revealed that as much as 50% of the total water pumped for irrigation was lost before reaching farmers' fields (Khair and Hossain, 1978; Miah, 1979). Extensive studies on low cost lining were carried out by Khair and Dutta (1983), Biswas *et al.* (1984) and Hamid and Khair (1989). Although these low cost materials (earth linings, soil-cement and clay-rice husk / saw dust of asphalt impregnated mats) reduce seepage loss and incur low cost, they are not durable, require extensive repair every year and have not been accepted by the farmers (MPO, 1985).

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Compared to low cost linings, pre-cast cement concrete lining was durable, cost effective and attractive to farmers (Arif, 1984). Brick lining, which is the most common type of lining used in the different irrigation projects because of availability of materials and manpower for construction, is the most expensive of the commonly used lining materials (Biswas *et al.*, 1984). A comprehensive list of the types of lining material tested in the field during 1980-85 periods is given by Michael (1987).

2.4 Water loss in earthen canal

Lauritzen and Terrell (1967) studied seepage loss in 46 irrigation projects in the USA and the average seepage loss has been reported as 40% of the total water diverted.

Kinori (1970) conducted an experiment on seepage through different soil textures. The results are given in Table 2.1.

Table 2.1 Seepage through different soils.

Types of soil	Seepage loss(m^3/m^2/day)
Impervious clay loam	0.07-0.01
Medium clay loam	0.10-0.15
Clay loam, silty clay	0.15-0.23
Clay loam with gravel, sandy clay loam	0.23-0.30
Sandy loam	0.30-0.45
Sandy soil	0.45-0.55
Sandy soil with gravel	0.55-0.75
Pervious gravelly soil	0.75-0.90
Gravel with some earth	0.90-1.80

By using the inflow and outflow methods Kraatz (1971) found conveyance losses amounting to as high as 40% of the total inflow in an earthen canal.

Hassan (1975) carried out a study on water losses in the watercourses located at Shadab (Lahore) and Lar (Multan). The inflow-outflow method was used to estimate the conveyance efficiency and cut-throat flumes were used as measuring devices. The study concluded that watercourse delivery losses ranged from 30% to 60%.

Extensive studies on seepage loss were carried out in different irrigation projects in India and Pakistan. In India, the loss of water through seepage has been estimated as 45% of the total utilizable water (Central Board of Irrigation and Power, 1975). Similar studies in Pakistan assessed the delivery loss as near 50% (Early *et al.*, 1978; Clyma *et al.*, 1981).

From 76 seepage tests in USA on unlined canal, Worstell (1976) showed that the seepage rates vary from 0.03 m/day to 0.6 m/day depending upon the soil type.

CSU & MREP (1977) conducted a study on a watercourse in district Sargodha. The delivery efficiency was worked out as 34% to 44% and the water losses accordingly ranged from 56% to 66%.

Kraatz and Mahajan (1977) reported that seepage loss substantially decreases ranging from 20% to 80% over time due to silt accumulation but later has little influence in the condition of the field canal prevailing in minor irrigation project.

Thomas (1977) carried out research on one watercourse at Fatehpur Distributary in district Sargodha. On the basis of inflow and outflow measurements, the water losses to the extent of 56% were reported from the watercourses.

Water is lost during conveyance through seepage from main canal, branches, distributaries, minors, watercourses and field channels. The average water losses from unlined canals, branches, distributaries and water courses are 8%, 17%, 20% respectively, of water released from reservoir (Singh *et al.*, 1978).

WAPDA and CSU-1 (1978) carried out a study on three watercourses in Bhakkar, Bahawalpur (Punjab) and Moro (Sindh). The flow rates were measured with cut-throat flumes and they determined the water losses 40% to 51% in the watercourse conveyance system.

Siddique *et al.* (1980) carried out socio-technical survey by interviewing 12 farmers, each at head, middle and tail of the selected watercourses in district Sargodha. The information on water use efficiency in terms of time taken to irrigate on acre of land was collected from the farmers. It was observed that 85 percent more time was taken to irrigate one acre of land at the tail as compared to that at head reach. A water loss of 46% was estimated from this study.

Thomas (1977) adopted inflow-outflow method to estimate the water losses on 5 village level watercourses located in districts of Sargodha and Faisalabad. It was reported that total losses were 45% of the inflow.

Copland (1987) used inflow-outflow measurement with cut-throat flumes installed at head, middle and tail sections on a sample of three watercourses. It was found that the delivery losses ranged from 38% to 62% in the watercourses of Khushab district.

PERI (1987) evaluated the performance of Command Water Management and adopted inflow-outflow method with the use of cut-throat and broad crested flumes. This study was undertaken in the commands of 27 watercourses located in Niazbeg, Shahkot, Vehari and Haroonabad. The water losses ranged from 47% to 50% were reported.

In Bangladesh, the leading work on water loss measurement through earthen canal was done by Biswas and Islam (1975). Extensive studies on conveyance loss measurement through earthen canal were also carried out by other researchers in Bangladesh are given below.

Khair and Hossain (1978) and Khair *et al.* (1980) observed that about one fourth to one third of all water diverted for irrigation purpose at various places in Bangladesh is lost in conveyance through the unlined earthen canal where seepage accounts to high rates due to various socio-technical reasons.

Dutta (1982) found from two case studies of deep tubewells and low lift pump irrigation project located in Mymensingh district that the water loss in the main canal ranged from 25% to 60% of the total flow. He also pointed out the losses occurred due to insufficient gradient of canals, porosity of soils, insufficient canal cross section and existence of cracks and holes in the canals. Sharma *et al.* (1984) found seepage loss in irrigation water conveyance system was very significant as it formed the major portion of the loss in the irrigation canals, and it depends upon the season, water table, soil topography and canal geometry as well as flow characteristics.

Miah (1986) carried out a study on the overall irrigation efficiencies of 11 deep tubewell in Dhaka and Thakurgaon district. He reported that the water losses per 100m length of the canal ranged from 13% to 23% of pump discharge. Although the author did not mention the details about the type and the nature of the systems, he realized conveyance losses in lined and earthen canals were significantly high.

Sattar *et al.* (1988) reported the performance of the North Bangladesh Tubewell Project- The Deep Tubewell Irrigation system in Thakurgaon. On an average the pump discharge efficiency was 91 $l/ha/m^2$ and 138 $l/ha/m^2$ of wetted area, respectively. The total distribution loss (both lined and earthen canal) through the conveyance system was about 40% of the tubewell discharge.

Dutta (1991) reported that the water loss in the main canal varied from 32% to 65% for distances of 34 m to 213 m respectively from the source of water in Mymensingh district.

Uddin (1992) found by seepage test using ponding methods that soil porosity of the canal sites has significant impact on seepage rate in general and the height of the canal bed has profound effect on seepage rate in Madhupur tract.

A field study was conducted by Hassan *et al.* (1992) in two selected tubewells of North Bangladesh tubewells project to evaluate the water distribution status in relation to maximizing the command area of the tubewells. Water losses in earthen canals were 105.0 $L/ha/m^2$ and 208.0 $L/ha/m^2$ which were 8% or 9% of the outlet discharges.

Shahajahan *et al.*, (1997) carried out a study on the Buri Teesta irrigation project and showed that over a 10 years period only 50% of water reaches the field and another 50% gets lost during conveyance from the source to the irrigation fields. The causes are poor management of the main system, a faulty schedule for water distribution and waste water management at the field level.

Mondal (2000) carried out a study on performance evaluation of some selected deep and shallow tubewells in irrigation development. He observed in STWs which are unlined, the average loss per 100m was 3.7 l/s.

Sattar *et al.*, (2002) under took a study in north-western region of Bangladesh during Boro, 2002 to assess the technical and economical performance of alternative irrigation distribution system in shallow tubewell (STW). They observed the conveyance losses were 42% under existing earthen canal.

Maniruzzaman *et al.*, (2002) studied the operation of flexible hose pipes compared to earthen canal for water distribution in four shallow tubewell (STW) schemes at Nakla and Sreebordi Upazilas of Sherpur district in 1998-99 Rabi season. It was found that there were variations in the water losses among the schemes depending of the soil texture and soil structures of earthen canal. The looses through earthen canal varied from 5.70 l/s/100m to 6.72 l/s/100m averaging 6.08 l/s/100m of canal length.

In a study on alternative hose pipe fitting for efficient irrigation water distribution in STW area, Maniruzzaman *et al.*, (2002) found that conveyance loss varied from 6.08 to 7.74 lit/sec/100m in earthen canal.

2.5 Water loses in improved earthen canal/lined canal

The improved water distribution system is very useful for minor irrigation in respect to minimizing the conveyance water losses, land and time savings, command area increases and economical use for crop production.

Hydraulics Research (1975) reviewed seepage rates of 17 types of canal linings under different hydraulic conditions (depth, discharge and wetted perimeter). The review showed that for different lined canals the mean seepage rate varied from 0.01 m/day to 0.25 m/day. In other

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Hussain (1977) examined the impact of watercourses improvement on the farm economy in the command of Tubewell No. MN 56 in Mona Project area. In this study watercourse losses were as reduced by about 38% as a result of kacha improvement.

Jhonson *et al.* (1978) reported that brick masonry lining found to reduced the water losses by 88% to 95%. It was concluded that using 85% saving of water losses, the conveyance efficiency of a lined watercourse was, thus, improved from 64% to 96%. Based on the conveyance efficiencies reported in various studies, the average efficiency of 65% or conveyance water losses of 35% were used in the analysis.

OFWM (1981) reported that watercourse improvement in Sahiwal Tehsil saved about 242 acre feet of water annually per watercourse on an average with earthen improvement and partial lining having 85% delivery efficiency. It was found that it enhanced the growth of an additional about 125 acres of wheat and about 100 acres of cotton per watercourse command annually.

Renfro (1983) conducted a study on 10 improved and 10 unimproved watercourses in Faisalabad. It was concluded that farms on improved watercourse received 18% more canal water per acre as compared with the unimproved watercourse. Moreover, the gross income per acre was estimated to be 12% higher on improved watercourses.

Irrigation Research Institute (1992) tested various lining materials to reduce seepage losses from the watercourses. This study conducted on 16 watercourses revealed that water seepage losses from lined watercourses ranged from 8% to 20% of inflow.

PERI (1993) estimated that conveyance losses rates on thousand meters on the improved and unimproved watercourses were 32% and 39% respectively, which showed a significant difference. On improved watercourses about 14% and 19% water losses were found in corresponding figures of 21% and 25% of unimproved watercourses, respectively. Thus conveyance losses on unimproved watercourses were 7% higher as compared to improved watercourses. In case of main and branch watercourses such losses were by 7% and 6% respectively on unimproved than improved ones.

Moghazi and Ismail (1996) observed by ponding methods that process of compacting the canal bed reduced the rate of seepage by considerable value and that lining of field canals by pre-fabricated bitumen jute mats caused a significant reduction in seepage rate.

IWASRI (2004) reported the studies carried out by watercourse Monitoring and Evaluation Directorate of WAPDA. Accordingly, water losses measurements were made on 26 watercourses of which 10 were lined and 16 were unlined. On the lined watercourses a net increase of 12%-14% in the conveyance efficiency was found from head to tail reach. The analysis of agronomical data revealed an increase of 3% of cropping intensity in the lined watercourses areas as compared to the unlined.

In Bangladesh, the pioneering work on seepage loss measurement and canal lining was done by Biswas and Islam (1975). Extensive studies on conveyance loss measurement through lined canal were carried out by other researchers in Bangladesh are given below.

Rashid *et al.* (1990) observed that the compaction of earthen canal could reduce conveyance losses to about 34% but the authors failed to mention the range of compaction on the level of moisture content at which the canal sub-grades were compacted.

According to Jenkins (1981) water losses in the earthen canal could be as high as 50% of discharge of a typical DTW.

Haradhan and Zillur (1991) found that the flow through the lined canals were 24.8 l/s (0.0248 cumec) at a distance of 30.48m (100ft) and 19.2 l/s (0.0192 cumec) at a distance of 60.96m (200ft) of a 50.5 l/s capacity DTW. The conveyance loss was found to be 1.045 l/s per 30.48m.

Sanjit and Khan (1996) studied on canal lining and reported that lining of the canal may save about 20% to 30% of the water that is lost by seepage.

Sattar *et al.*(2002) undertook a study in north-western region of Bangladesh during Boro, 2002 to assess the technical and economical performance of alternative irrigation distribution system in shallow tubewell (STW). Among the technical parameters, conveyance losses were 10% and 1% under improved earthen canal and hosepipe respectively. Water saved by improved earthen canal and hosepipe was 32% and 95% respectively, compared to existing earthen canal. Similarly time saved through improved earthen canal and hosepipe was 27% and 48% respectively, compared to existing earthen canal, which increased command area and reduced irrigation cost.

It is important to note here that all the studies on seepage loss and canal lining done in Bangladesh and reported in literature so far, are for small scale irrigation (deep tubewell of low lift pump) projects, with a discharge capacity of up to 0.057 cumec (2cusec). Few studies were undertaken of lining of canals of the large irrigation projects of the country (Saleh, 1991). This is probably because all the large irrigation projects combinedly irrigate about 0.19 mha which is about 8% of the total irrigated area of the country (BADC, 2008). The major thrust for irrigation development from the early seventies has been through small scale irrigation projects because of their small gestation period and high return to investment.

2.6 Economic Analysis

Although a numbers of studies on conveyance loss in lined and unlined canals have been carried out, literature on the economics of canal lining is scanty.

Studies on economics of lining have shown that in India, the lined canal costs nearly 3.25 times as much as the unlined canal; but taking the value of seepage water lost, the unlined canal costs about 1.08 times as much as the lined canal. In Europe and USA the lined canal costs are estimated to be two times as much as the unlined canal (ICID, 1967).

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Jones (1986) compared brick lining with low cost linings (soil-cement and bitumen) in three DTW projects and concluded that low cost linings were much more cost effective than brick lining.

Miah (1984) made an economic evaluation of brick lining in four DTW projects of Dhamrai and concluded that brick lining was not economical. The benefit cost ratio of brick lining varied from 0.52 to 0.86 in the four projects.

Ahammed (1987) performed an economic analysis for three buried pipe and two lined canal systems of Tangail Agricultural Development Project. He found that all systems were economically viable. The BCR varied from 2.75 to 12.08.

Saleh *et al.* (1991) studied on canal lining for the secondary and tertiary canals of Teesta Barrage project and reported that cast in situ concrete lining was the most cost effective lining.

Sattar *et al.* (2002) undertook a study in north-western region of Bangladesh during Boro, 2002 to assess the technical and economical performance of alternative irrigation distribution system in shallow tubewell (STW). BCR of improved earthen canal and hose pipe irrigation were 1.01 and 1.64 at 25% discount rate. IRR from investment of water distribution by improved earthen canal and hosepipe irrigation were 32% and over 50%.

Chapter 3
METHODOLOGY

3.1 Introduction

The Department of Agricultural Extension is involved in experimentation of improved water distribution system in order to develop different low cost canals for minor irrigation schemes. As of now, the DAE through its AETEP has innovated several new technologies in respect of lining of irrigation canals. These linings are superior over the traditional earthen canal especially in respect of efficiency. In this study the lining recommended by AETEP were constructed and field tested in order to assess their positive impacts on the traditional earthen canals.

3.2 Study Area

The study was undertaken in Boro season at three Upazilas: Manikgonj Sadar of Manikgonj district, Dhamrai of Dhaka district and Mithapukur of Rangpur district. Nine improved earthen canals, three pre-cast lined canals and six existing earthen canals under STW were selected for field study. The location map of the study sites is given in Figure 3.1. The detail features of the study schemes are described below.

3.2.1 Mithapukur scheme

The experimental fields belong to the Agro-ecological region of the Teesta Meander Floodplain (AEZ-3). Most of the areas have broad flood plain ridge and almost level basins. More or less all the study areas are dominated with the soil type of loamy soils on the floodplain ridges and grey or dark grey, slowly permeable, heavy silt loam or silty clay loam in the basins. Soils in general have a good moisture holding capacity (BARC, 2005). The geographical location of the experimental area is in $25^0 26' N$ to $25^0 41' N$ latitude and $89^0 06' E$ to $89^0 27' E$ longitudes.

The area experiences a tropical climate characterized by a very humid, wet south-west monsoon from June to November. The annual precipitation of study area is 2112 mm, which occurs mostly in monsoon and very little rainfall during Boro season (CIMMYT, 2003). The average maximum temperature is 29^oC and average minimum temperature is 20^oC.

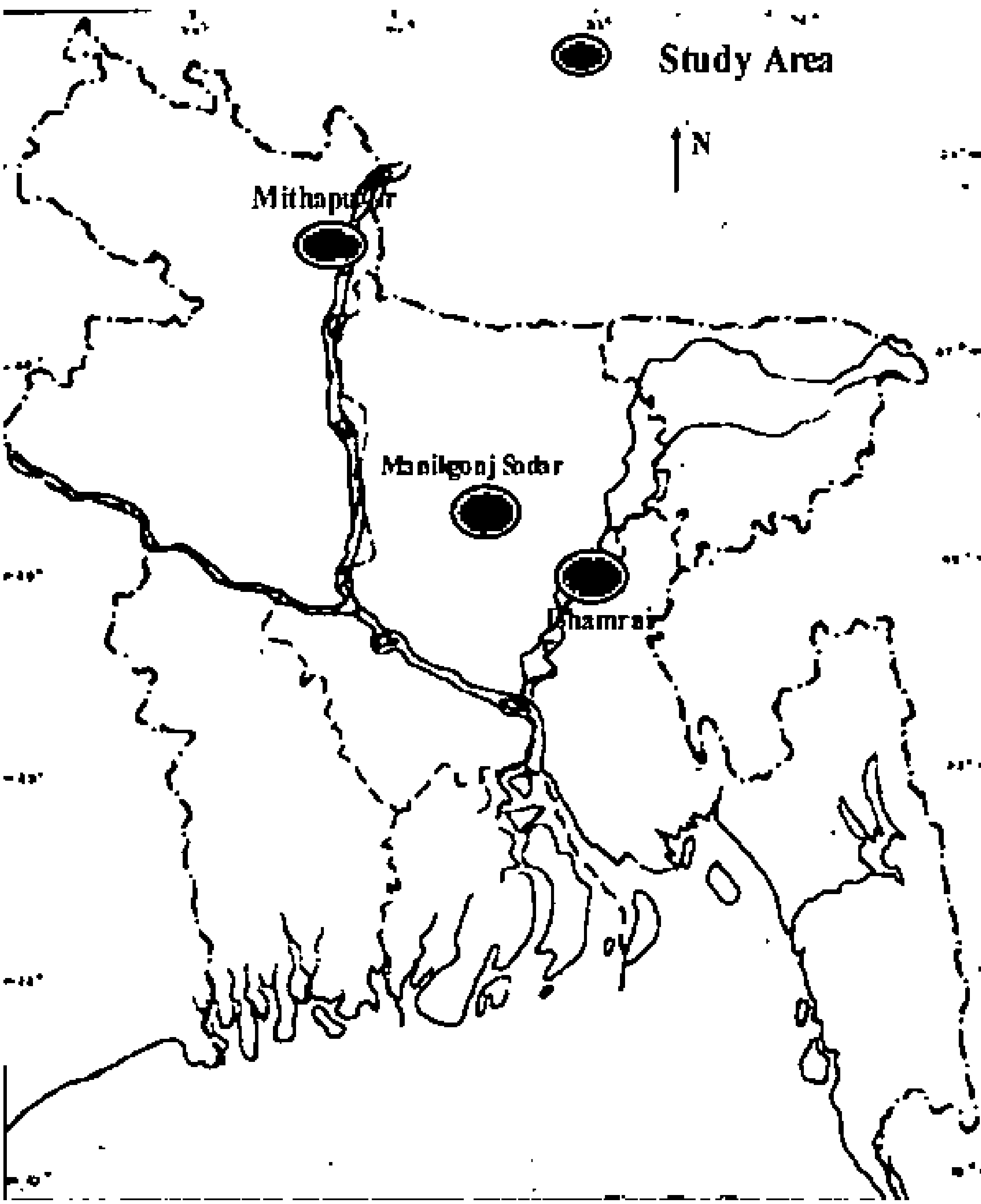

Fig.3.1. Location Map of the Study areas.

Mithapukur covers a total area of 51584 ha of which the cultivable land is 44904 ha. It is estimated that about 26000 ha of total cultivable land was brought under irrigation (DAE, 2009). The cropping intensity is 215%. Rabi (Nov-Feb) crops such as wheat, mustard, spices and vegetables are mainly grown on residual moisture and sometimes with available irrigation water. HYV Boro is the main rice crop, which is mainly irrigated by 10356 shallow tubewells, 78 deep tubewells and some LLPs.

In Mithapukur, output based crop share payment system is dominantly practiced as price for irrigation water. The price of irrigation water varies depending upon the energy sources of irrigation modes. In case of electricity run modes (both STW and DTW), farmers pay one fourth of their total crop. In case of diesel run modes (both STW and DTW), farmers themselves pay for fuel and 370 kg of dry rice for getting access to irrigation.

3.2.2 Manikgonj scheme

The geographical location of the experimental area is in $23^0\,42'$ N to $23^0\,56'$ N latitude and $89^0\,57'$ E to $90^0\,08'$E longitudes. This area belongs to the Agro-ecological region of the Young Brahmaputra and Jamuna Floodplain (AEZ-8). The area is occupied by permeable silt loam soils on the ridges and impermeable clays in the basins. General soil types include predominantly Grey Floodplain soils (BARC, 2005). The annual precipitation of study area is 2617 mm. The average maximum temperature is 35.85°C and average minimum temperature is 15.38°C (BARC, 1998).

Manikgonj Sadar covers a total area of 21515 ha, of which the net cultivable land is 19343 ha. It is estimated that about 14000 ha of total cultivable land was brought under irrigation (DAE, 2009). The cropping intensity is 227%. Rabi (Nov-Feb) crops such as wheat, mustard, spices and vegetables are mainly grown on residual moisture and sometimes with available irrigation water. HYV Boro is the main rice crop which is mainly irrigated by 4065 shallow tubewells, 70 deep tubewells and some LLPs. Output based crop share payment system is the most common water pricing method used in Manikgonj Sadar. In this method, in case of electricity run modes farmers pay one–third (five bundle out of fifteen bundle of paddy) of the total crop from the land for both the modes STW and DTW. In case of diesel run modes (both STW and DTW) farmers pay seven bundle of paddy out of fifteen.

3.2.3 Dhamrai scheme

The geographical location of the experimental area is in $23^0 49'$ N to $24^0 03'$ N latitude and $90^0 00'$ E to $90^0 15'$E longitude. This area belongs to the Agro-ecological region of the Low Ganges River Floodplain (AEZ-12). Soils of the region are silt loams on the ridges and silty clay loam to heavy clays on lower sites. General soil types predominantly include Calcareous Dark Grey and Calcareous Brown Floodplain soils (BARC, 2005). The annual precipitation of study area is 2102 mm. The average maximum temperature is 42.2°C and average minimum temperature is 19.5°C (BARC, 1998).

Dhamrai covers a total area of 30633 ha of which the cultivable land is 30470 ha It is estimated that about 17873 ha of total cultivable land was brought under irrigation (DAE, 2009). The cropping intensity is 220%. Rabi (Nov-Feb) crops such as, mustard, spices and vegetables are mainly grown on residual moisture and sometimes with available irrigation water. HYV Boro is the main rice crop, which is mainly irrigated by 5925 shallow tubewells, 105 deep tubewells and some LLPs. In Dhamrai, area based cash payment system and output based crop share payment system are dominantly practiced. The price of irrigation water in case of electricity run modes (both STW and DTW) is one fourth of their total crop or Tk.60 to Tk.70 per decimal. In case of diesel run modes (both STW and DTW) farmers themselves pay for fuel and Tk. 30 to Tk. 40 per decimal for getting access to irrigation.

3.3 Methods of Computation of Conveyance loss

In this study inflow-outflow method is used for conveyance loss measurement. The inflow-outflow method was widely used by most of the researchers in Bangladesh for its simplicity and accuracy (Dutta, 1991; Sattar *et al.*, 2002; Maniruzzaman *et al.*, 2002). This method is very suitable to measure the canal water loss as unlike ponding method, the irrigation can continue while the discharge measurements are taken. Consequently, inflow-outflow method was employed for this study.

3.4 Inflow - Outflow Method

This is a very simple method that consists of measuring the quantity of water entering a reach and the quantity of water going out of that reach. The difference gives the amount of water lost. Discharge can be measured with the help of a flume, weir or current meter. The accuracy of the method increases with the difference between the quantity of inflow and outflow rates.

The inflow-outflow method is the most dependable and reliable method for measuring the quantity of water loss through seepage from the existing canals. The results obtained by inflow-outflow method are more reliable than the other (Ponding method and Seepage Meter method) methods (Shahid *et al.*, 1991). The inflow-outflow method has been used by number of researchers for conveyance loss measurement. Sarki *et al.* (2008) observed that ponding test measured water losses 23% less than inflow-outflow test. Brockway and Worstell (1965) also found ponding test measured water losses 30% less than inflow-outflow test.

Among all the three methods for measuring the water conveyance loss inflow-outflow methods was selected due to the following reasons:

- The method is very simple but accurate.
- The method requires simple instruments that can be manufactured by our local technology.
- The results obtained by this method are more reliable than the other two methods.

There are various types of water measuring device by which flow of water can be determined In this study the cut-throat flume was used for conveyance loss measurement. The cut-throat flume is an improvement of the Parshall flume, mainly by simplifying the construction details. The flume has a flat bottom with vertical walls and zero length throat section. Since it has no throat section it has been given the name cut-throat flume by the developers (Skogerboe *et al.*, 1973).

The most obvious advantage of cut-throat flume is economy. The cut-throat flume can operate either as a free or submerged flow structure. Under free flow condition critical depth occurs in the vicinity of minimum width w, which is called the flume throat or the flume neck. The attainment of critical depth makes it possible to determine the flow rate, knowing only an upstream depth h_a. This is possible because whenever critical depth occurs in the flume, the downstream depth is h_b. For free flow the ratio of inlet flow depth h_a to flume length should preferably be less than 0.4 (Michael, 1987).

3.5 Experimental set up

The STW discharge and flow at different sections of the canal were measured using two 60 cm x 20 cm, cut-throat flumes. In order to get accurate measurement, the cut-throat flume was installed obeying the following rules (Skogerboe *et al.*, 1973).

1. The flume was as far as possible in a straight section of the canal.
2. The flume was aligned straight with the canal and leveled both longitudinally and laterally.
3. The ratio of the flow depth to flume length was always less than or equal to 0.4.
4. Flow depths at both the upstream and downstream measuring marks on the cut-throat flume were recorded simultaneously after ensuring the steady state flow.

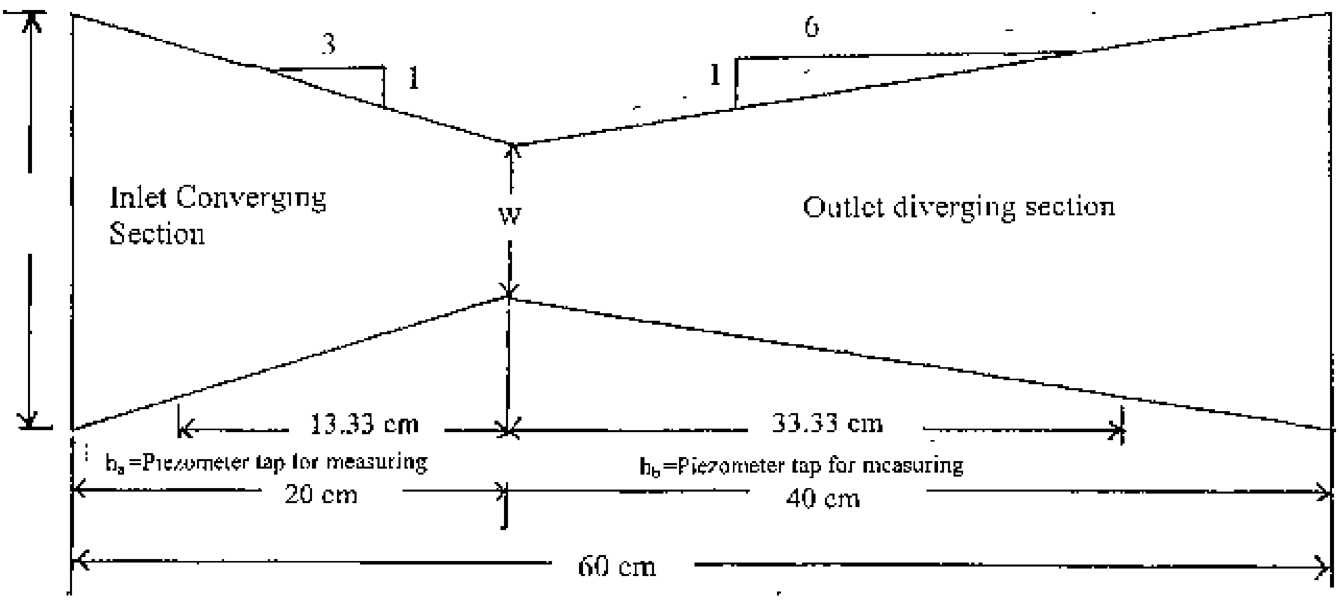

Fig. 3.2. Definition sketch of cut-throat flume (Skogerboe *et al.*, 1973).

3.6 Determination of Discharge

The flow in the irrigation canals may be either free or sub-merged flow depending on the transition submergence, S_t (the value of submerge at which the discharge pass from free flow to submerged flow or vice versa). If the submergence, S (defined as the ratio and expressed as a percentage of the down stream depth, h_b to the upstream depth, h_a) is less than S_t the flow is free and the equation to find the discharge is given by (Skogerboe *et al.*, 1973).

$$Q = C_1 (h_a)^{n_1} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3.1)$$

Where, Q = flow rate in cfs

C_1 = free flow co-efficient

h_a = upstream flow depth in ft

n_1 = free flow exponent

The value of C_1 is given by

$$C_1 = K_1 W^{1.025}$$

Where, K_1 = flume length co-efficient

W = throat width in ft

Values of n_1 and k_1 with respect to length of cut-throat flume (for free flow condition) were taken as: n_1 = 1.98 and k_1 = 5.2 (For 60 cm length cut-throat flume; Ref.)

If the flow is submerged, the equation employed to find out the discharge is given by

$$Q = \frac{C_2(h_a-h_b)^{n_1}}{(-\log S)^{n_2}} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3.2)$$

Where, C_2 = submerged flow co-efficient

n_1 = free flow exponent

n_2 = submerged flow exponent

h_a = upstream flow depth in ft

h_b = down stream flow depth in ft

$S = h_b/h_a$

S = degree or percentage of submergence

For submerged flow $S = h_b/h_a = 0.65$ to 0.90

For free flow $S = h_b/h_a =$ less than 0.65

3.7 Determination of Conveyance loss

Conveyance loss can be calculated by the following formula:

$CL = \{(Q_1-Q_2)/L\} \times 100$ ... ... (3.3)

Where, CL = rate of conveyance loss in the canal in cfs

Q_1 = rate of flow at the inlet in cfs

Q_2 = rate of flow at the outlet in cfs

L = distance between two points in ft

$\% CL_1 = (CL/Q_1) \times 100$ ... ... (3.4)

Where, $\% CL_1$ = percent conveyance loss per 100 ft canal

Water loss of respective canal was measured by cut-throat flume with two conditions. These were:

i. Natural condition (existing earthen canal)

ii. Improved condition (after compaction and lining)

Following steps were considered to determine the conveyance loss from the canal:

1. The suitable canal was selected under STW installed at study area.
2. The existing canal was well excavated according to pump discharge
3. Two individual cut-throat flumes were set in existing earthen canal with proper leveling at suitable position keeping a distance of 100 ft from one another.
4. The outer portion of the canal in each section was blocked with clay soil so that water could only pass through the flume.
5. Reading was taken first after 10 (ten) minutes when the discharge was steady.
6. Then flume was set as before and reading was taken in improved earthen canal.

Flow measurement in the field of an improved earthen canal is presented in Fig. 3.3.

Fig.3.3. Flow measurement in the field of an improved earthen canal.

3.8 Construction Details of Earthen and Lined canal

A properly designed water distribution system will make irrigation easy and efficient. Unlined and lined structures are used to convey, irrigation water on the farm. Efficient structures will save labors, land and water. In Bangladesh, most of the irrigation canals of the small irrigation project are unlined. These can be built and maintained by unskilled labor. As such, there is no standard methodology for designing unlined canals. But lined canal that are performed by different department followed specific design according to discharge capacity. In the following sections, the design parameter and the construction specification that were followed in this study are presented.

3.8.1 Earthen canal

Earthen canal can be built on stable side slopes with banks strong enough to carry the required flow of water safely. They should have ample capacity to carry the design discharge at non-erosive velocities. Side slopes should be flat enough so that the banks will neither care in nor slide when they saturated with water. In study schemes, the average bottom width, the top width and water depth of earthen canal was 40 cm, 100 cm and 30 cm, respectively. The design values of the earthen canal are tabulated in the Table 3.1. The cross-section of earthen canal and a view of existing earthen canal in Study area are shown in Fig. 3.4 and Fig. 3.5, respectively.

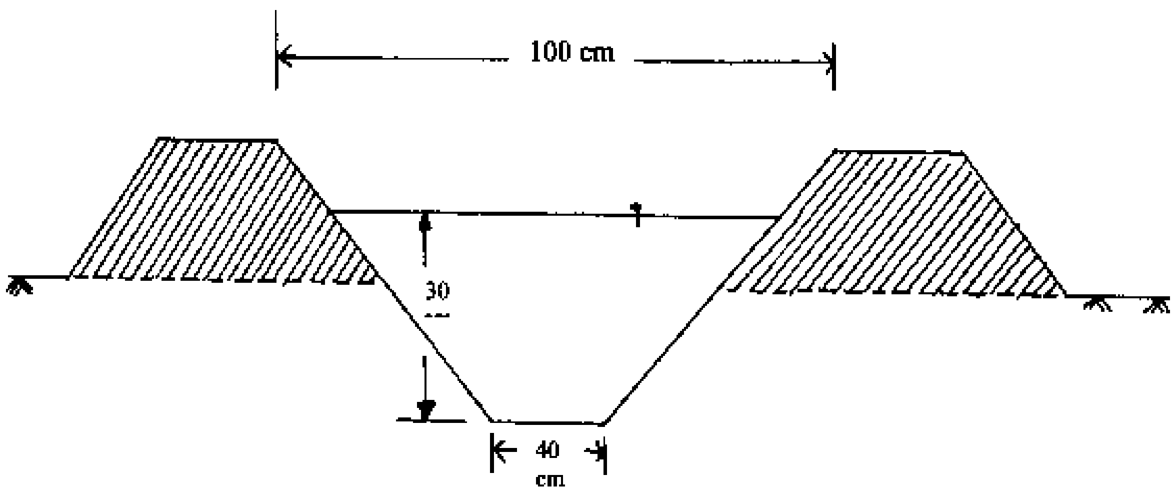

Fig. 3.4. Cross- section of earthen canal.

Fig. 3.5. A view of existing earthen canal in Study area.

3.8.2 Improved earthen canal

The improved earthen canal was designed according to AETEP model. The design values of the selected canal are tabulated in the Table 3.1. The design canal bottom width, top width and canal height was 14 cm, 58 cm and 17 cm, respectively. The side slope and longitudinal slope would be taken as, 1:1 and 0.001, respectively. For improved earthen canal, the freeboard would be taken as 5 cm. The cross-section of improved earthen canal and a view of improved earthen canal in Study area are shown in Fig. 3.6 and Fig. 3.7, respectively.

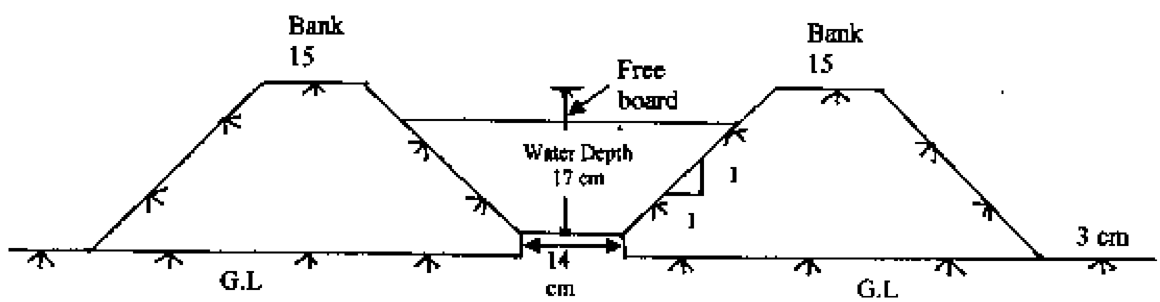

Fig. 3.6. Cross- section of improved earthen canal.

Fig. 3.7. A view of an improved earthen canal in study area.

3.8.3 Pre-cast canal

If a canal is to be lined, then the design problem reduces to one of determining the best hydraulic section (Chow, 1959). In study area the pre-cast canal was designed according to AETEP model. The design values of the selected pre-cast canal are tabulated in the Table 3.1. The width of bottom slab and height of side slab of pre-cast canal was 36 cm and 19 cm, respectively. The cross-section of pre-cast canal and a view of pre-cast canal in study area are shown in Fig 3.8 and Fig. 3.9, respectively.

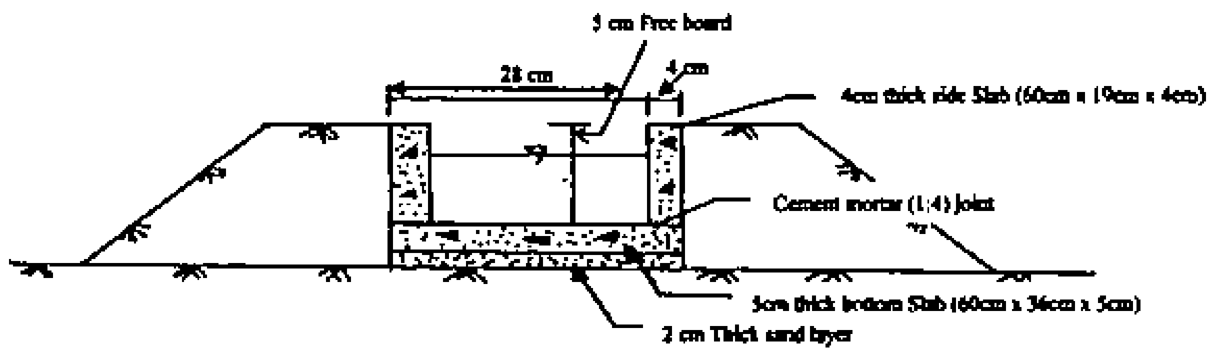

Fig. 3.8. The cross-section of pre-cast canal.

Fig. 3.9. A view of pre-cast canal in Study area.

Table 3.1 Design values of earthen canal, improve earthen canal and pre-cast canal.

Types of Canal	Bottom Width, B(cm)	Top Width T (cm)	Water Depth, D(cm)	Freeboard F (cm)	Canal bed slope, S	Side slope
Earthen	40	100	30	-	-	-
Improve Earthen	14	58	17	5	0.001	1:1
Pre-cast	36	36	14	5	0.0025	-

3.9 Land occupied by canal

In Kharif season, most of the growers leveled down their earthen canal to grow Aman paddy. They generally do not provide supplementary irrigation for Aman crop. But when improved earthen canal are constructed as demonstration, they are not leveled down, as such, the land required for the construction of the canals go out of production. To measure land occupied by canal, length and width of main canal were identified and measured in consultation with the scheme manager and pump operator.

3.10 Economic analysis

Economical analysis is the process of determining the total return (social or economical return) to the whole society or economy of all the resources committed to the project. An economic analysis was carried out for the distribution system in order to ascertain the profitability of the lining technology. For this purpose discounting method of the appraisal technique was used. By discounting, future cash flows are reduced to their present worth. For measuring the relative worthiness of the system, the following three alternative discounted measures were used.

3.11 Net Present Worth

Net Present Worth (NPW) is obtained by deducting the discounted costs from the discounted benefits. The benefits and costs are discounted by opportunity costs of capital, which is represented by the interest rate of commercial bank loans. The NPW may be treated as:

$$\text{NPW} = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+i)t} \quad \ldots \quad \ldots \quad \ldots \quad (3.5)$$

Where,

B = Annual project benefits.

C = Annual project costs.

T = Number of years.

i = Discount rate

The given discount rate was 12% for agriculture land.

In other words, the NPW approximated by,

NPW= Present worth of benefit - Present worth of cost.

3.12 Benefit Cost Ratio

This criterion compares the sum of discounted benefits with the sum of discounted costs. In other words, the benefit cost ratio was estimated by dividing the sum of present worth of benefits by the sum of present worth of costs as follows.

$$\text{BCR} = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+i)^t}} \quad \ldots \quad \ldots \quad \ldots \quad (3.6)$$

Where,

B, C, T and i have same meanings as above

or, BCR = Present worth of benefits /Present worth of costs.

3.13 Internal Rate of Return

Internal Rate of Return (IRR) may be defined as that discount rate which makes

$$\sum_{t=1}^{T} \frac{B_t - C_t}{(1+i)} = 0 \quad \ldots \quad \ldots \quad \ldots \quad (3.7)$$

Where,

B,C,T and i have same meanings as above.

In other words, IRR is defined as the rate of discount, which will make the net present worth of the project zero. The IRR was calculated by the following formula.

IRR = Lower discount rate + Difference between two discount rate x (Present worth at the lower discount rate / Absolute different between the present worth at two discount rates).

3.14 Farmers' survey

Farmers' surveys were carried out in each of the Upazilas to assess the impact of water saving on command area development and the acceptability of lined canal technology by the farmers. Participatory rural appraisal (PRA) approach was used for collection of socio-economic data and information. The PRA approach aims to incorporate the knowledge and opinions of rural people in the planning and management of development projects and programmes. Focus group discussion (FGD) have been used for socio-economic data and information collection.

3.14.1 Focus Group Discussions

Focus Group Discussions (FGD) is an efficient and effective tools for collection of various information. FGD brings together a small and homogeneous group of 6-12 peoples who are the representative of a much larger sector of a society or of the community. The purpose is to create an informal situation in which the members of the groups discuss topic of concern amoung themselves with the help of a facilitator and in the presence of one or more observers For collection of socio-economic information, nine FGDs were conducted in the selected study areas. Traditional farmers and pump owners were the main source of data colection. Each FGD involed 9-11 peoples. Average age of the people were 34 years and all of them were male. There were no female pump ower and female manager farm in the study areas.

In each Upazila one FGD was conducted with the pump owners. All the owners were also famers and had land within the pumps operated by them.

For the FGDs conducted with the farmers, the farmers were divided into two broad groups. In one group were the farmers who shared their crops with the pump owners as price of irrigation water. In each Upazila one FGD was conducted with this type of farmers. The crop share system of water pricing is common in Manikgonj and parts of Dhamrai and Mithapukur Upazilas. In another group, the farmers themselves provided the fuel for irrigation and paid a fee to the pump owners for access to irrigation.. In each Upazila one FGD was also conducted with this type of farmers. So in total, six FGDs were conducted with general farmers in the study area.

Chapter 4

RESULTS AND DISCUSSION

The water loss through earthen and lined canals, the economics and the acceptability of the lined canals by the farmers were analyzed in this study. The details of the analysis are presented in the following section.

4.1 Physical Characteristics of the Study Schemes

It has already been mentioned (Article 3.2) that for the purpose of the study six earthen schemes, nine improved earthen schemes and three lined schemes were selected. For each of these schemes the discharge, command area, length of main canal and the length of lined canal were measured. These physical characteristic of the schemes are presented in Table 4.1. The measured average discharge of the existing earthen canals, improved earthen canals and pre-cast canals of the selected study areas were 18.3 lps, 18.7 lps and 22.5 lps, respectively. The command area of the existing earthen canals, improved earthen canals and pre-cast canals were 3.05 ha, 3.39 ha and 3.91 ha, respectively. The average length of the main canals of the existing earthen canals, improved earthen canals and pre-cast canals were 263m, 322m and 370m, respectively. The total lengths of lining of all the schemes were 200m.

Table 4.1 Physical characteristics of the study schemes.

Types of canal	Schemes	Discharge (lps)	Command area (ha)	Length of main canal (m)	Length of lining (m)
Earthen canal	Mithapukur (M_1)	14.07	2.94	243	-
		23.00	4.26	400	-
	Manikgonj (M_2)	16.30	2.56	225	-
		21.40	3.74	316	-
	Dhamrai (D)	13.00	1.07	90	-
		22.30	3.74	305	-
	Average	18.34	3.05	263	-
Improved Earthen canal	(M_1)	17.70	3.08	288	288
		21.62	3.84	352	352
		23.28	4.65	472	472
	(M_2)	21.52	4.19	425	425
		16.24	2.95	308	308
		13.78	1.47	110	110
	(D)	13.10	2.08	160	160
		23.48	4.62	470	470
		17.52	3.60	320	320
	Average	18.69	3.39	322	322
Pre-cast canal	(M_1)	21.80	3.87	366	200
	(M_2)	23.30	4.30	435	200
	(D)	22.30	3.55	310	200
	Average	22.47	3.91	370	200

4.2 Water Loss Measurement

The water losses from earthen canals and lined canals of the study schemes were measured by inflow-outflow method by using Equation 3.3. The detailed calculations of discharge and loss measurements are given in Appendix-A.

4.2.1 Water loss in earthen canal

The conveyance losses of the existing earthen canals of the selected study schemes ranged from 6.9 to 8.2 lps per 100m (Table 4.2). Considering the pump discharge, the conveyance loss varied from 37% to 53%. The average conveyance losses of Mithapukur, Manikgonj and Dhamrai scheme are 7.7, 7.4 and 7.5 lps/100m, respectively, which were about 41%, 48% and 45% of the pump discharge, respectively. This is in agreement with the findings of a recent study by Sattar *et al.* (2002). They found loss rates 5.25 to 6.44 lps/100m which was on an average about 42% of the pump discharge in the north-western region of Bangladesh. Maniruzzaman *et al.* (2002) also found the loss 6.08 to 7.74 lps/100m at Kapasia in Gazipur District. The results of the study indicated that nearly 50% of the pumped water is lost before arriving at the farmers' fields. Improved earthen canal and pre-cast canal could minimize the conveyances losses of the existing earthen canal.

Table 4.2 Water losses in earthen canals of the study scheme.

Schemes	Discharge (lps)	Conveyance loss per 100m			
		lps	Average	% of pump discharge	Average
Mithapukur	16.30	7.2	7.7	44	41
	21.40	8.2		38	
Manikgonj Sadar	14.07	7.6	7.4	53	48
	23.00	7.2		43	
Dhamrai	13.00	6.9	7.5	53	45
	22.30	8.2		37	
		Average	7.5	45	45

4.2.2 Water loss in improved earthen canal

The conveyance losses of the improved earthen canals varied from 3.0 to 4.5 lps/100m (Table 4.3). Considering the pump discharge the conveyance losses varied from 14% to 26%. In the study schemes the average conveyance loss was 3.6 lps/100m which is about 21% of the pump discharge. This is similar to the findings of Sattar *et al.* (2002). They found loss rates as 3.67 to 3.97 lps/100m. Maniruzzaman *et al.*. (2002) also found the loss as 3.7 to 4.8 lps/100m.

Table 4.3 Water losses in improved earthen canals of the study schemes.

Schemes	Discharge (lps)	Conveyance loss per 100m			
		lps	Average	% of pump discharge	Average
Mithapukur	17.7	4.3	3.7	24	18
	21.6	3.7		17	
	23.3	3.3		14	
Manikgonj Sadar	21.5	3.0	3.6	23	21
	16.2	3.3		14	
	13.8	4.5		26	
Dhamrai	13.1	3.3	3.4	24	24
	23.5	4.0		25	
	17.5	3.0		23	
Average			3.6	21	21

4.2.3 Water loss in pre-cast canal of the study schemes

The conveyance losses of the pre-cast canals varied from 2.5 to 2.9 lps/100m (Table 4.4). The average loss per 100m is about 12% of the pump discharge. Karim (2004) reported that the conveyance losses of the pre-cast canals in three different schemes in Bogra were 2.3 to 2.6 lps/100m, which is similar to the results of this study.

Table 4.4 Water losses in pre-cast canals of the study schemes.

Schemes	Discharge (lps)	Conveyance loss per 100m	
		lps	%
Mithapukur	21.8	2.6	12
Manikgonj Sadar	23.3	2.5	11
Dhamrai	22.3	2.9	13
	Average	2.7	12

4.2.4 Variation of conveyance loss in earthen and lined canals

The variations of conveyance loss as percent (%) of pump discharge for the different lined and unlined schemes are shown in Figure 4.1. It shows that the conveyance loss is highest through the existing earthen canals followed by improved earthen canals and pre-cast canals.

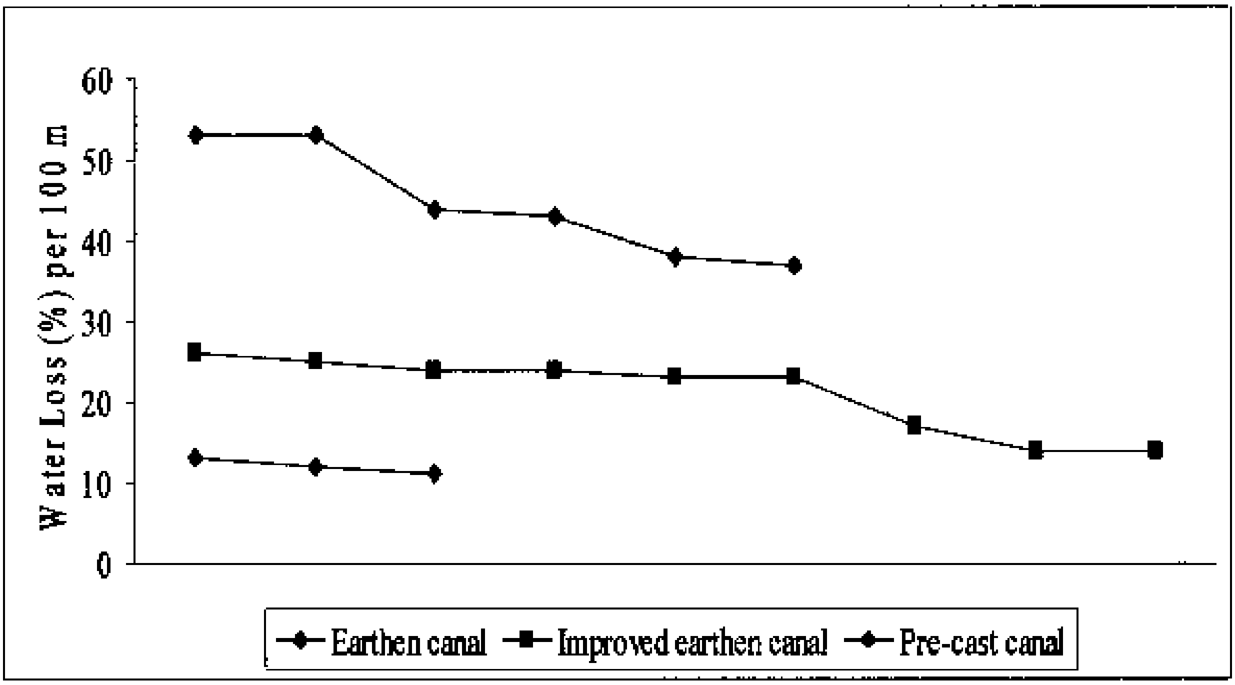

Fig. 4.1 Conveyance losses by unlined and lined canals of study area.

4.3 Impact of lined canal system

The purpose of lining is to save water by reducing the conveyance loss. It is generally assumed that the water saved through lining would be used to irrigate additional area under irrigation. But for the schemes under the study area, the command areas remained unchanged after the introduction of improved distribution system. In the study area more shallow tubewells are working than are needed. There is no new land to be brought under cultivation and the existing agricultural land is declining on account of increased use of land for other purposes. As a result the command area under each STW with lining remained the same even though they saved water compared to pre-lining condition.

4.3.1 Water saved by improved earthen canal and pre-cast canal

The results of field measurements on the water saved by using improved earthen canal and pre-cast canal as compared to the existing earthen canal are presented in Table 4.5. The water saved varied from 21% to 27% by improved earthen canal and from 29% to 37% by pre-cast canal over earthen canal. Sattar *et al.* (2002) found that the water saved varied from 29% to 38% by improved earthen canal over earthen canal. The result was lower (29% to 38%) to the findings of present study (29% to 37%). The water saved also varied from 6% to 11% by pre-cast canal over improved earthen canal. The variation of the results indicated that on average water could be saved up to 24% to 33% by adopting lined canal method instead of the traditional earthen canal system.

Table 4.5 Impact of improved earthen canal and pre-cast canal on water saved.

Schemes	Water saved by improved canal over earthen canal (%)	Water saved by pre-cast canal over earthen canal (%)	Water saved by pre-cast canal over improved earthen canal %
Mithapukur	23	29	6
Manikgonj Sadar	27	37	10
Dhamrai	21	32	11
Average	24	33	9

4.3.2 Time saved by improved earthen canal and pre-cast canal

As has been mentioned earlier, the saved water through lining was not used for expanding the command area. Instead, the pumps were operated for fewer hours in order to irrigate the same command area. The total irrigation time during the crop season and the corresponding command area were recorded for each of the existing schemes of the earthen canal, improved earthen canal and pre-cast canal (Tables 4.6 and 4.7). It was observed from the selected study schemes that the time saved over earthen canal varied from 20% to 27% by improved earthen canal and 40% to 45% by pre-cast canal (Table 4.8). In a similar study, savings of 28% by improved earthen canal and 48% by pre-cast canal over earthen canal were observed (Sattar *et al.*, 2002). The time saved also varied from 18% to 30% by pre-cast canal over improved earthen canal. The results indicated that on average the irrigation time could be saved by 24% to 43% by adopting lined canal method instead of the traditional earthen canals.

Table 4.6 Impact of improved earthen canal on time saved over earthen canal.

Schemes	Existing earthen canal				Improved earthen canal				Average time saved	
	Area (ha)	Total time (hr)	hr/ha	Average	Area (ha)	Total time (hr)	hr/ha	Average	hr/ha	%
Mithapukur	4.26	1134	266	272	4.65	907	195	197	75	27
	2.94	815	277		3.08	578	187			
	-	-	-		3.84	806	210			
Manikgonj Sadar	2.56	733	276	293	1.47	334	227	233	60	20
	3.74	1161	310		4.19	974	232			
	-	-	-		2.95	712	241			
Dhamrai	1.07	343	320	307	2.08	487	234	233	74	24
	3.74	1099	294		4.62	1053	227			
	-	-	-		3.60	853	237			

Table 4.7 Impact of pre-cast canal on operating time saved over earthen canal.

Schemes	Existing earthen canal				Pre-cast canal			Average time saved	
	Area (ha)	Total time (hr)	hr/ha	Average	Area (ha)	Total time (hr)	hr / ha	hr/ha	%
Mithapukur	4.26	1134	266	272	3.87	626	162	110	40
	2.94	815	277		-	-	-		
Manikgonj Sadar	2.56	733	276	293	4.30	706	164	129	44
	3.74	1161	310		-	-	-		
Dhamrai	1.07	343	320	307	3.55	592	167	140	45
							Average	126	43

Table 4.8 Impact of improved earthen canal and pre-cast canal on time saved over earthen canal.

Schemes	Average time saved by improved canal over earthen canal		Average time saved by pre-cast canal over earthen canal		Average time saved by pre-cast canal over improved earthen canal	
	hr/ha	(%)	hr/ha	(%)	hr/ha	(%).
Mithapukur	75	27	110	40	35	18
Manikgonj Sadar	60	20	129	44	71	30
Damrai	74	24	140	45	66	28
Average	69	24	126	43	57	25

4.3.3 Fuel saved by improved earthen canal and pre-cast canal

As fewer hours were required to irrigate the same command area of lined schemes, less amount of fuel was also required. The amount of fuel required for the different schemes are shown in Tables 4.9 and 4.10. It was observed from the selected study areas that fuel saved varied from 23% to 32% and 45% to 48% (Tables 4.9 and 4.10) in improved earthen canals and pre-cast canals, respectively. Table 4.11 shows that the fuel saved also varied from 20% to 30% by pre-cast canal over improved earthen canal. The results indicated that average fuel could be saved up to 28% to 46% by adopting improved earthen and pre-cast canal instead of the earthen canal (Table 4.11).

Table 4 9 Impact of improved earthen canal on fuel saved over earthen canal.

Schemes	Existing earthen canal				Improved earthen canal				Average fuel saved	
	Area (ha)	Total fuel (L)	L/ha	Average	Area (ha)	Total fuel (L)	L/ha	Average	L/ha	%
Mithapukur	4.26	1281	300.7	311	4.65	983	211	211	100	32
	2.94	945	321.4		3.08	679	197			
			-		3.84	862	224			
Manikgonj Sadar	2.56	828	323.43	337	1.47	388	264	261	76	23
	3.74	1312	350.80		4.19	1092	260			
	-	-	-		2.95	762	258			
Dhamrai	1.07	408	381.31	354	2.08	521	250	248	106	30
	3.74	1221	326.47		4.62	1116	241			
	-	-	-		3.60	913	253			

Table 4.10 Impact of pre-cast canal on fuel saved over earthen canal.

Schemes	Existing earthen canal				Pre-cast canal			Fuel saved	
	Area (ha)	Total fuel (L)	L/ha	Average	Area (ha)	Total fuel (L)	L /ha	L/ha	%
Mithapukur	4.26	1281	300.70	311	3.87	656	169	142	45
	2.94	945	321.43						
Manikgonj Sadar	2.56	828	323.43	337	4.30	779	181	156	46
	3.74	1312	350..80						
Dhamrai	1.07	408	381.31	354	3.55	655	184	170	48
	3.74	1221	326.47						
				Average				156	46

Table 4.11 Impact of improved earthen canal and pre-cast canal on fuel saved.

Schemes	Average fuel saved by improved canal over earthen canal		Average fuel saved by pre-cast canal over earthen canal		Average fuel saved by pre-cast canal over improved earthen canal	
	L/ha	(%)	L/ha	(%)	L/ha	(%)
Mithapukur	100	32	142	45	42	20
Manikgonj Sadar	76	23	156	46	80	30
Dhamrai	106	30	170	48	64	26
Average	94	28	156	46	62	25

4.3.4 Variation of time and fuel saved in earthen canal and lined canal

Time and fuel saved for the lined schemes are shown in Figure 4.2 and Figure 4.3 respectively. It shows that the time and fuel saved is highest through the pre-cast canals and improved earthen canals compared to by earthen canals.

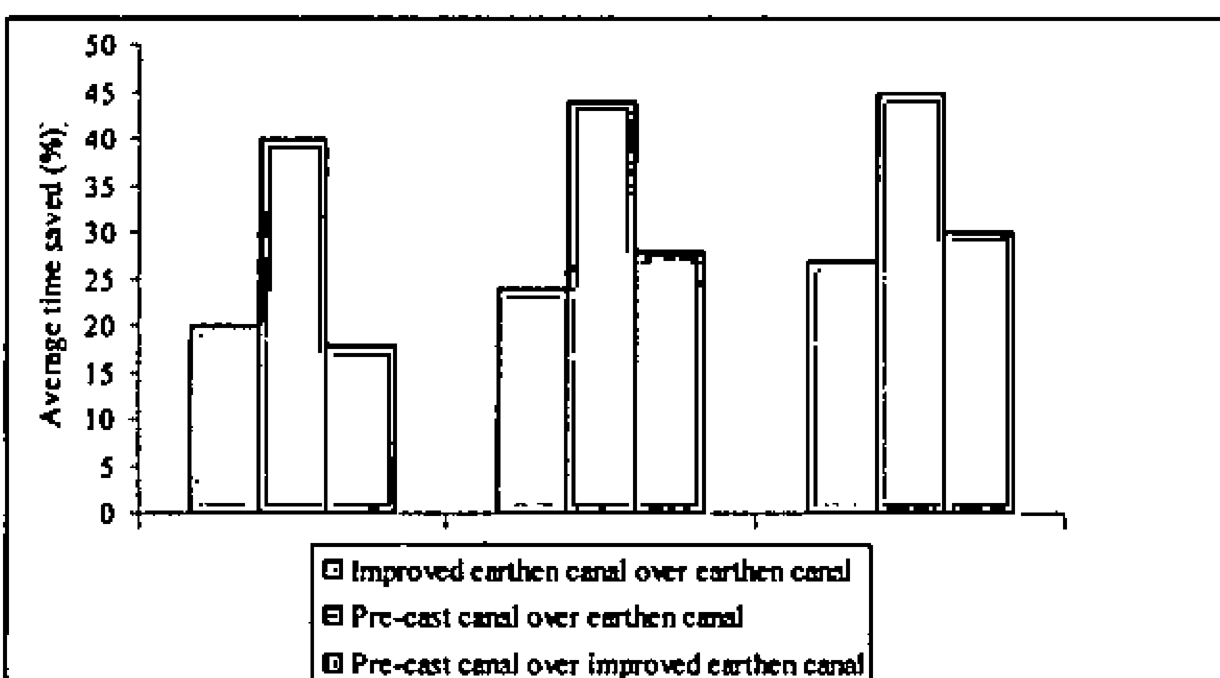

Fig. 4.2 Time saved by improved earthen canal and pre-cast canal over earthen canal.

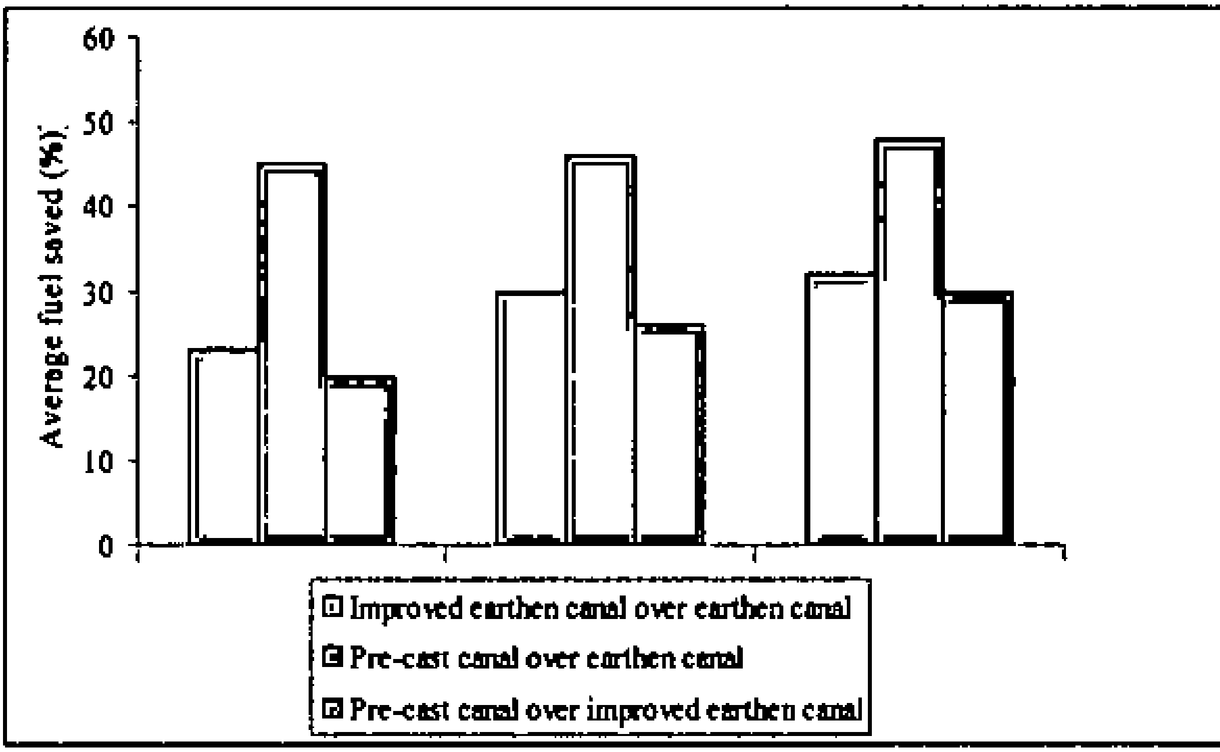

Fig. 4.3 Fuel saved by improved earthen canal and pre-cast canal over earthen canal.

4.3.5 Discussion on impact of lining

Construction of improved distribution system is an integral part of command area development activities. Lining of irrigation canals offers one of the best opportunities to expand command area. But, it was observed from this study that although about 24% to 33% water was saved by lined canal but command area did not increase due to saving of water. Instead, it was observed that the farmers / pump owners were irrigating the same area with fewer pumping hours and requiring less fuel. On average, about 24% to 43% less time was required to irrigate the same command area by improved earthen canal and lined canal over traditional earthen canal. Similarly, the average amount at fuel saved varied from 28% to 46% by improved earthen canal and lined canal over traditional earthen canal. Thus, the lined canal system not only saved conveyance loss it also saved fuel cost, maintenance cost and reduced the time required for irrigation. The average savings in diesel fuel varied from 94 to 156 liters per irrigated hectare (Table 4.11) in the case of a STW command area.

4.4 Economic Analysis

Economic analysis of lined canals in shallow tubewell irrigation schemes was performed by calculating the Net Present Worth (NPW), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR). The costs of lining are the construction costs, the operation and maintenance costs and the benefits of lining are the savings due to less amount of fuel required for the operation of the schemes.

4.4.1 Cost of Construction

The study concentrated on two major water distribution systems namely i) unlined irrigation canal (existing earthen canal) ii) lined canal irrigation system with improved earthen canal and pre-cast concrete slab. Various components of investment, operation and maintenance costs of earthen canal and lined canal systems were identified. The construction costs vary with the prevailing cost of materials, labor and other charges. The cost is usually expressed on a unit length basis such as cost per meter length and in terms of cost per unit area of the surface area of the canals. The cost of engineering and supervision were not included in the present estimate. Estimated construction costs of three different distribution systems are presented in the Table 4.12.

Table 4.12 Estimated construction cost of different distribution systems.

Name of scheme	Description	Quantity	Rate (Tk.per running meter)	Total cost of construction (Tk)
Existing Earthen canal	Labor cost of cutting, filling and plastering	500m	18	9000
Improved Earthen canal	i) Labor cost of cutting and filling ii) Labor cost of compacting and cutting according design. iii) Plastering	500m -do- -do-	12 10 3	6000 5000 1500
Sub total				12500
Pre-cast canal	i) Labor cost of earth work ii) Slab iii) Slab jointing	200m -do- -d0-	10 160 15	2000 32000 3000
Subtotal				37000

Most of the farmers involved in the construction of-earthen canal are of the view that earthen canal requires minimum time and cost for construction. The cost of earthen canal is more or less the same in the three schemes and is around Tk.18 per running meter. The cost of improved earthen canal is higher than earthen canal and is around Tk.25 per running meter. The pre-cast concrete slab, which is reportedly more convenient for construction and popular as well, needs more care during installation work and regular maintenance. The cost of pre-cast canal is around Tk 185 per running meter.

4.4.2 Operation and Maintenance Costs

Earthen canal systems no require maintenance cost because they have a life span of one year (Article 4.4.4). Improved earthen canals require a cost of Tk.5 per running meter for first year and Tk.12 per running meter for second and third year mainly for canal removing grass and silt and repairing leaks and weak points. Less amount of cost (Tk.5 per running meter per annum) is required for annual repair only for plastering of pre-cast canals. There is no widening in pre-cast canal and no removal or grass or silt is required.

4.4.3 Land occupied by canal

In Kharif (Aman) season, most of the earthen canals are run down by the farmers to grow Aman paddy. On the other hand, the area required for the construction of the improved earthen canal and pre-cast canal remain out of production during the Aman season. To measure land occupied by such canals, length and width of main canals were identified in consultation with the scheme manager and pump operator. The area under the canal varied from 1.0 to 1.5 percent of the command area. This is in agreement with the results reported by Mridha (1993). Land occupied by canal at selected schemes is shown in Table 4.13. The table also shows the loss of production (in Tk.) considering the average Aman yield of 4t/h and price of paddy as Tk. 12/kg.

Table 4.13 Land occupied by canal at selected schemes.

Schemes	C.A	Canal area		Total area		% C.A	Production loss	
		Main canal length(m)	Width (m)	m^2	ha		kg/ha	Tk/ha
Mithapukur	3.08	288	1.38	397	0.0397	1.29	159	1908
	3.84	352	1.38	486	0.0486	1.26	195	2340
	4.65	472	1.38	651	0.0651	1.40	260	3120
Manikgonj Sadar	4.19	425	1.38	587	0.0587	1.40	235	2820
	2.95	308	1.38	425	0.0425	1.44	170	2040
	1.47	110	1.38	152	0.0152	1.03	61	732
Dhamrai	2.08	160	1.38	221	0.0221	1.06	89	1068
	4.62	470	1.38	649	0.0649	1.41	260	3120
	3.60	320	1.38	442	0.0442	1.23	177	2124

4.4.4 Expected life of canal lining

When annually maintained and repaired, the improved earthen canals are assumed to have a three years life span (AETEP, 2005). A 15 years project life span is assumed for pre-cast canal (AETEP, 2005). As the traditional earthen canals are prepared every year, they have a life span of one year.

4.4.5 Net Present Worth

The Net Present Worth (NPW) value was calculated for improved lined canals and pre-cast canals of shallow tubewell irrigation system located at three Upazilas. The results are presented in Tables 4.14 & 4.15. From the tables, it is found that Net Present Worth (NPW) of Mithapukur, Manikgonj Sadar and Dhamrai is Tk. 7545; Tk. 7068 and Tk. 6054 for improved earthen canal and Tk. 94689; Tk. 152947 and Tk. 93571 respectively for pre-cast canal at 12% discount rate. A detailed cost estimate of one improved earthen canal and one pre-cast lined canal of every study scheme on shallow tubewell irrigation system and detail calculation of NPW value of three schemes are shown in Appendix-B and Appendix- C.

4.4.6 Benefit Cost Ratio

The Benefit Cost Ratio (BCR) for improved carthen canals and pre-cast canals were found to be 1.36, 1.38 and 1.30; 3.36, 4.28 and 3.34 (Tables 4.14 and 4.15) at 12% discount rate for Mithapukur, Manikgonj Sadar and Dhamrai schemes, respectively. The detail calculation of BCR for improved carthen canal and pre-cast canal are shown in Appendix-B and Appendix- C.

Table 4.14 Economic analysis of improved earthen canal.

Schemes	Establishment cost (Tk)	Life Span (Year)	Total Benefit (Tk)	Net Present Worth (Tk)	Benefit – cost Ratio	IRR(Internal Rate of Return)
Mithapukur	11800	3	16600	7545	1.36	Over 50%
Manikgonj Sadar	10625	3	15120	7068	1.38	Over 50%
Dhamrai	11750	3	15680	6054	1.30	Over 50%

Table 4.15 Economic analysis of pre-cast canal.

Schemes	Establishment cost (Tk)	Life Span (Year)	Total Benefit (Tk)	Net Present Worth (Tk)	Benefit – cost Ratio	IRR(Internal Rate of Return)
Mithapukur	37000	15	20320	94689	3.36	49.78 %
Manikgonj Sadar	37000	15	29120	152947	4.28	Over 50%
Dhamrai	37000	15	20160	93571	3.34	49.67 %

4.4.7 Internal Rate of Return

The Internal Rate of Return (IRR) value was calculated for improved lined canals and per-cast canals of shallow tubewell irrigation systems in the study area. The results are presented in Tables 4.14 and 4.15. From this table it is found that the Internal Rate of Return (IRR) was over 50% of Mithapukur, Manikgonj and Dhamrai schemes for improved earthen canals and 49.78%, over 50% and 49.67% for pre-cast canals, respectively, for Mithapukur, Manikgonj and

Dhamrai schemes. The detail calculation of IRR for improved earthen canal and pre-cast canal are shown in Appendix-B and Appendix- C.

4.5 Acceptability of lined canal by the farmers

Another main purpose of this study was to determine acceptability of improved earthen canal and pre-cast canal offered by the AETEP project by the farmers considering the technical as well as economic aspects. In order to know farmers' acceptability about lined canal irrigation systems, only FGDs have been conducted at all the selected schemes. The results of PRA are presented in the following sections.

4.5.1 FGDs with pump owners

As for the lined canal, all the pump owners expressed their complete satisfaction as it reduced the wastage of water, fuel cost and maintenance cost. Regarding the pump owners preference for this different types of canal innovated by the AETEP, about 70% expressed their views in support of the pre-cast canal irrigation system and about 30% for improved earthen canal. Regarding their preference for pre-cast canal, they cited several reasons, which may be presented in descending order of importance as: a) negligible water loss b) less maintenance cost c) reduction in fuel cost and d) reduction in time required in reaching the water from the sources of supply to the farthest plot of scheme.

Regarding improved earthen canal the respondents pointed out as many as four advantages over earthen canal. They are: a) reduction in wastage of irrigation water b) reduction in fuel cost c) reduction in time required in reaching the water from the source of supply to the farmers' field and d) less maintenance cost.

As regards the acceptability of the lined canal, 90% of the respondents expressed their views in favor of it and indicated their inability to afford it from their own because of the lack of proper knowledge, capital and technical support. According to them, if technical support is ensured by DAE and other relevant agencies of government and non-government organization, they are interested to take loan from Bank/NGO for the development of lined irrigation canal in their schemes.

4.5.2 FGDs with general farmers

As for the lined canal all the farmers also expressed their satisfaction as it reduced the wastage of water, fuel cost and maintenance cost. But they have informed that lined canal is not beneficial to the farmers. So they have not yet shown their attention to lined canal as improved technology. This issue was discussed with the farmers during the FGDs. The farmers have reported that irrigation systems are mostly dominated by the pump owners and they operate machines according to the farmer's given fuel or without fuel. Mainly, irrigation charge is paid by farmers as output based crop share payment system which is the most common water pricing system in Manikgonj Sadar, parts of the Dhamrai and Mithapukur Upazilas.

It is reported that in case of electricity operated schemes, farmers pay one-fourth of their total crop from the land which is equivalent to Tk. 9000/ha (900 kg rice/ha). In case of diesel run modes (fuel given by the pump owner) farmers pay one third or one-fourth of their total crop. In some places of Dhamrai and Mithapukur Upazilas, farmers pay Tk.40 per decimal and Tk.60 per decimal for electricity mode and diesel mode STW, respectively. In these schemes (crop share and area based pricing), the lined canal is not beneficial to farmers as they have to pay the same amount of water charge in every season whether the canal is improved or not. In these cases, lined canals are beneficial only for the pump owners. Although the lined canals require less water withdrawal, less irrigation time, less fuel and less maintenance cost, such benefits are not shared by the pump owners with the farmers. In the study areas on average 94 l/ha and 156 l/ha fuel were saved by improved earthen canal and pre-cast canal respectively. As a result most of the farmers have no interest on lined canal and the positive impact / benefit of a lined canal is only enjoyed by the pump owners.

On the other hand, when farmers themselves pay for fuel as irrigation charge (in case of diesel run modes) lined canal is beneficial to farmers. This is because the farmers save their fuel from every irrigation (at the rate of 1.0 to 1.3 litters per irrigation depending upon the distance of paddy field from STW).

During the FGDs, it was observed that all the farmers (even those providing fuel as price for irrigation) were unwilling to give land for the construction of lined canal (especially improved earthen canal). This is because for the construction of the improved earthen canal, a considerable amount of land and a lot of earth are required. The farmers usually do not agree to provide that much of land for construction or provide earth from their land. The reason for not providing either land or earth is that they do not want to lose the cultivable land and ultimately lose production to some extent. To gain the profit out of improved earthen canal or lined canal, the canal needs to be in the field without destruction. But as paddy cultivation is run in two seasons, the farmers usually level down the irrigation canals that are made in Boro season to increase the command area of cultivation during Aman season.

It was evident from the FGDs that the canal lining has only benefited the pump owners. Although a section of the farmers (providing diesel as price for irrigation) have been benefited by canal lining, they were unwilling to provide land and earth for construction of irrigation canal. All other farmers have neither been benefited by lining nor are interested about the new technology. In future, if DAE is to replicate the technology in new schemes, the DAE should ensure that the benefits of lining are shared by the pump owners with the farmers by reducing the price of irrigation water or reduce their share of crop taken as irrigation fee.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

At present nearly 63% of the total irrigated area of Bangladesh is covered by STW and most of these schemes are unlined. In this study an attempt was made to analyze the impacts of canal lining on water savings and cost reductions of STW schemes in these Upazilas. The economic viability of lining and their acceptability by the farmers were also analyzed. The conclusions of the study are as follows:

- The losses of irrigation water were found to be on average 41%, 48% and 45% for Mithapukur, Manikgonj and Dhamrai, respectively, for earthen canal; 18%, 21% and 24% for improved earthen canal and 12%, 11% and 13% for pre-cast canal.

- The pre-cast canal on average saved about 43% and improved earthen canal saved about 24% irrigation application time as compared to earthen canal. The pre-cast canal and improved earthen canal also saved about 46% and 28%, respectively, of fuel cost and consequently saved the operation and maintenance cost.

- The saved water through lining was not used for expanding the command area. Instead, the pumps were operated for fewer hours in order to irrigate the same command areas.

- From the economic analysis, it was observed that among the two types of lined canals, the values of the economic indicators used (BCR, NPW and IRR) were the highest for pre-cast concrete lining. The BCR of improved earthen canal and pre-cast canal were 1.36, 1.38 and 1.30; 3.36. 4.28 and 3.34 at 12% discount rate for Mithapukur, Manikgonj Sadar and Dhamrai schemes, respectively. The Internal Rate of Return (IRR) were over 50% at Mithapukur, Manikgonj and Dhamrai schemes for improved earthen canal and 49.78%, over 50% and 49.67% for pre-cast canals at Mithapukur, Manikgonj and Dhamrai schemes, respectively. The Net Present Worth (NPW) of Mithapukur, Manikgonj Sadar and Dhamrai are Tk. 7545; Tk. 7068 and Tk. 6054 for improved earthen canal and Tk. 94689; Tk. 152947 and Tk. 93571, respectively, for per-cast canal at 12% discount rate.

- From the FGDs it was observed that the lined canal technologies offered by the AETEP are only acceptable to pump owners and only those farmers who pay the price of irrigation by supplying the fuel. But the technologies are not acceptable to the majority of the farmers who pay out on the basis of crop share method and area based cash payment method, as irrigation charge.

- Based on the technical and economic analyses performed it can be concluded that lined canal technologies are suitable for shallow tubewell irrigation schemes. But in order to make the technologies acceptable to the farmers, the benefit of lining must be shared by the pump owners with the farmers.

5.2 Recommendations

Between the two different linings studied in the field, pre-cast concrete lining has been determined as the most cost effective lining, and is recommended for further replication.

If in future the cost of lining is borne by AETEP, then rules should be imposed on the shallow scheme owners to share the benefits of lining by reducing the irrigation fee collected from the farmers. Otherwise, the pump owners should share the cost of construction of linings.

As the pump owners are interested to adopt the lining technology, easy-term loan may be arranged for them by the Government/NGOs.

Since the findings of this study are based on two years of field measurements, it is necessary to carry out the seepage loss study for few more years (perhaps three more years) in order to observe how the seepage rates, maintenance cost and the durability of both lined and unlined canal sections change with time. Beside it is necessary to conduct the study in different parts of the country to find out the technical and socio-economic viability of this technology in different agro-ecological zones.

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APPENDICES

Appendix A-1 Conveyance loss of water through earthen canal.

Schemes	First flume L = 60cm; W = 15 cm			Second flume L = 60cm; W = 15 cm			Conveyance loss in	
	h_a (inch)	Discharge (lps)	Average discharges (lps)	h_a (inch)	Discharge (lps)	Average discharges (lps)	lps	%
Manikgonj	5.40	15.95	16.30	5.20	14.50	14.10	2.20	13.50
	5.45	16.20		5.00	13.55			
	5.50	16.55		5.00	13.55			
	5.45	16.20		5.20	14.50			
	5.50	16.55		5.10	14.00			
	5.50	16.55		5.10	14.00			
Manikgonj	6.40	21.00	21 40	6.10	18.70	18.90	2.50	11.68
	6.40	21.00		5.90	17.75			
	6.50	21.60		6.20	19.25			
	6.55	21.70		6.20	19.25			
	6.50	21.60		6.20	19.25			
	6.50	21.60		6.20	19.25			
Dhamrai	4.61	12.5	13.0	4.30	10.7	10.89	2.11	16.12
	4.90	13.6		4.38	11.05			
	4.90	13.6		4.40	11.10			
	4.64	12.6		4.35	10.90			
	4.64	12.6		4.30	10.70			
Dhamrai	6.50	21.70	22.30	6.20	19.25	19.80	2.50	11.21
	6.60	22.50		6.30	20.10			
	6.65	22.30		6.35	19.25			
	6.70	22.70		6.35	20.10			
	6.75	22.30		6.40	20.10			
	6.75	22.30		6.42	20.40			
Mithapukur	5.00	14.10	14.07	4.30	10.90	11.74	2.33	16.56
	4.95	13.95		4.55	11.80			
	5.00	14.10		4.60	12.00			
	5.00	14.10		4.60	12.00			
	5.00	14.10		4.60	12.00			
Mithapukur	6.50	26.00	23.00	6.20	21.92	20.00	2.20	13.00
	6.60	22.00		6.30	19.25			
	6.65	22.30		6.35	20.10			
	6.70	22.50		6.35	20.10			
	6.75	22.70		6.40	20.40			
	6.75	22.70		6.42	20.50			

Appendix A-2 Conveyance loss of water through improved earthen canal.

Schemes	First flume L = 60cm; W = 15 cm			Second flume L = 60cm; W = 15 cm			Conveyance loss in	
	h_a (inch)	Discharge (lps)	Average dis. (lps)	h_a (inch)	Discharge (lps)	Average dis.(lps)	lps	%
Mithapukur	5.60	17.00	17.70	5.50	15.90	16.40	1.30	7.34
	5.75	17.80		5.60	16.34			
	5.80	18.00		5.68	16.70			
	5.75	17.80		5.65	16.60			
	5.75	17.80		6.60	16.34			
	5.75	17.80		5.60	16.34			
Mithapukur	6.50	21.60	21.62	6.45	21.35	20.47	1.15	5.32
	6.70	22.50		6.40	20.40			
	6.60	22.00		6.40	20.40			
	6.40	21.00		6.35	20.10			
	6.40	21.00		6.35	20.10			
Mithapukur	6.80	22.80	23.28	6.65	21.80	22.26	1.02	4.38
	6.95	23.50		6.70	21.95			
	6.95	23.50		6.80	22.47			
	6.90	23.30		6.80	22.47			
	6.90	23.30		6.83	22.60			
Manikgonj	6.50	21.6	21.52	6.42	20.50	19.94	1.58	7.34
	6.60	22.00		6.40	20.40			
	6.60	22.00		6.40	20.40			
	6.40	21.00		6.30	19.20			
	6.40	21.00		6.30	19.20			
Manikgonj	5.20	15.00	16.24	5.00	13.55	15.00 (m^3/s)	1.24 (l/s)	7.63
	5.40	15.95		5.27	14.80			
	5.48	16.45		5.35	15.25			
	5.55	16.80		5.40	15.50			
	5.60	17.00		5.50	15.90			
Manikgonj	4.80	13.30	13.78	4.70	12.40	12.82	0.96	6.96
	5.00	14.10		4.85	12.95			
	5.00	14.10		4.90	13.15			
	4.90	13.70		4.80	12.80			
	4.90	13.70		4.80	12.80			
Dhamrai	4.60	12.45	13.10	4.50	11.60	12.20	0.90	6.87
	5.00	14.10		4.85	12.95			
	5.00	14.10		4.90	13.15			
	4.60	12.45		4.50	11.60			
	4.60	12.45		4.55	11.75			
Dhamrai	6.90	23.30	23.48	6.75	22.20	22.48	1.00	4.26
	7.00	23.60		6.75	22.20			
	7.00	23.60		6.80	22.47			
	6.90	23.30		6.80	22.47			
	7.00	23.60		6.90	23.05			
Dhamrai	5.60	17.00	17.52	5.40	15.50	16.14	1.38	7.87
	5.70	17.50		5.50	15.90			
	5.75	17.80		5.60	16.34			
	5.75	17.80		5.65	16.60			
	5.70	17.50		5.60	16.34			

Appendix A-3 Conveyance loss of water through Pre-cast canal.

Schemes	First flume L = 60cm; W = 15 cm			Second flume L = 60cm; W = 15 cm			Conveyance loss in	
	h_a (inch)	Discharge (lps)	Average discharges (lps)	h_a (inch)	Discharge (lps)	Average discharges (lps)	lps	%
Mithapukur	6.50	21.60	21.80	6.42	20.50	21.00	0.80	3.67
	6.75	22.50		6.66	21.80			
	6.60	22.00		6.52	21.30			
	6.60	22.00		6.53	21.70			
	6.50	21.60		6.45	20.60			
	6.50	21.60		6.44	20.54			
	6.50	21.60		6.44	20.54			
Manikgonj	6.75	22.50	23.00	6.70	21.95	22.24	0.76	3.30
	6.90	23.30		6.80	22.47			
	6.85	23.15		6.75	22.25			
	6.85	23.15		6.75	22.25			
	6.80	22.80		6.75	22.25			
	6.80	22.80		6.75	22.25			
Dhamrai	6.60	22.00	22.30	6.50	21.60	21.40	0.90	4.03
	6.60	22.00		6.50	21.60			
	6.65	22.30		6.57	21.20			
	6.68	22.40		6.59	21.38			
	6.70	22.50		6.61	21.45			
	6.71	22.50		6.61	21.45			

Appendix B-1 Detailed calculation of Internal Rate of Return value for total Benefit of improved earthen canal at Mithapukur (C-4, R-10 of Table 4.1)

Year	Scheme costs						Scheme Benefits				Dis. Factor (50%)	PW at 50% discount factor
	Capital cost	O & M cost	Land occupied cost	Total cost	Discount Factor (12%)	Present Worth at 12%	Total benefit	Discount factor (12%)	Present Worth at 12%	Incremental Benefit		
0	3304	2360	-	5664	-	5664	-	-	-	-5664		-5664
1	-	5664	3120	8784	0.893	7844	16600	0.893	14824	7816	0.667	5213
2	-	5664	3120	8784	0.797	7001	16600	0.797	13230	7816	0.444	3470
Total:						20509			28054	-	-	3019

Net Present Worth (NPW) at the lower (12%) discount rate = Tk.28054 – Tk.20509= Tk.7545
BCR =28054/20509 = 1.36
Internal Rate of Return (IRR) = Over 50 %

Calculation:

Earthen canal:

Command area = 4.26 ha
Main canal = 400 m
Capital cost = Tk. 7200 (Tk.18 per running meter)
Fuel consumption = 1281 liters
Now, for C.A = 4.65 ha
Fuel consumption = 1398 liters
Capital cost for 472m = Tk.8496

Incremental cost = (Tk.11800 – Tk.8496) = Tk.3304
Fuel saved = (1398 – 983) = 415 liters
Total benefit = Tk.40 x 415 =Tk.16600 (1 liter diesel = Tk.40)

Improved earthen canal:

Command area = 4.65 ha
Main canal = 472 m
Capital cost = Tk.11800 (Tk.25 per running meter)
Fuel consumption = 983 liters
O & M cost = 472*Tk.5 = Tk.2360 (for Ist year)
= 472*Tk.12 =Tk.5664 (2nd and 3rd year)
Land occupied cost = Tk.3120 (Table 4.13)

Appendix B-2 Detailed calculation of Internal Rate of Return value for Total Benefit of Improved earthen canal at Manikgonj Sadar (C-4, R-11 of Table 4.1).

Year	Scheme costs						Scheme Benefits				Dis. Factor (50%)	Project Benefit
	Capital cost	O & M cost	Land occupied cost	Total cost	Discount Factor (12%)	Present Worth at 12%	Total benefit	Discount factor (12%)	Present Worth at 12%	Incremental Benefit		PW at 50%
0	2975	2125	-	5100	-	5100	-	-	-	-5100	-	-5100
1	-	5100	2820	7920	0.893	7073	15120	0.893	13502	7200	0.667	4802
2	-	5100	2820	7920	0.797	6312	15120	0.797	12051	7200	0.444	3197
Total						18485	-	-	25553		-	2899

Net Present worth (NPW) at the lower (12%) discount rate = Tk 25553 – Tk 18485 = Tk. 7068
BCR =25553/18485 = 1.38
Internal Rate of Return (IRR) = Over 50 %

Calculation:

Earthen canal:

Command area = 3.74ha
Main canal = 316 m
Capital cost = Tk.5688 (Tk.18 per running meter)
Fuel consumption = 1312 liters
Now, for C.A = 4.19 ha
Fuel consumption = 1470 liters
Capital cost for 425m = Tk.7650

Incremental cost = (Tk.10625 – Tk.7650) = Tk.2975
Fuel saved = (1470 – 1092) = 378 liters
Total benefit = Tk.40 x 378 =Tk.15120 (1 liter diesel = Tk.40)

Improved earthen canal:

Command area = 4.19 ha
main canal = 425 m
Capital cost = Tk.10625 (Tk.25 per running meter)
Fuel consumption = 1092 liters
O & M cost = 425*Tk.5 = Tk.2125 (for lst year)
= 425*Tk.12 =Tk.5100 (2nd and 3rd year)
Land occupied cost = Tk.2820 (Table 4.13)

Appendix B-3 Detailed calculation of Internal Rate of Return value for Total Benefit of Improved earthen canal at Dhamrai (C-4, R-15 of Table 4.1).

Year.	Scheme costs						Scheme Benefits				Discount Factor	Project Benefit
	Capital cost	O & M cost	Land occupied cost	Total cost	Discount Factor (12%)	Present Worth at 12%	Total benefit	Discount factor (12%)	Present Worth at 12%	Incremental Benefit	50%	PW at 50%
0	3290	2350	-	5640	-	5640	-	-	0	-5640	-	-5640
1	-	5640	3120	8760	0.893	7823	15680	0.893	14002	6920	0.664	4595
2	-	5640	3120	8760	0.797	6982	15680	0.797	12497	6920	0.444	3072
Total:						20445	-	-	26499	-	-	2027

Net Present worth (NPW) at the lower (12%) discount rate = Tk 26499 – Tk 20445 = Tk 6054
BCR =26499/20445 =1.30

Internal Rate of Return (IRR) = Over 50 %

Calculation:

Earthen canal:

Command area = 3.74 ha
Main canal = 305 m
Capital cost = Tk.5490 (Tk.18 per running meter)
Fuel consumption = 1221 liters
Now, for C.A = 4.62 ha
Fuel consumption =1508 liters
Capital cost for 470m = Tk.8460

Incremental cost = (Tk.11750 – Tk.8460) = Tk.3290
Fuel saved = (1508 – 1116) = 392 liters
Total benefit = Tk.40 x 392 =Tk. 15680 (1 liter diesel = Tk.40)

Improved earthen canal:

Command area = 4.62 ha
main canal = 470 m
Capital cost = Tk.11750 (Tk.25 per running meter)
Fuel consumption = 1116 liters
O & M cost = 470*Tk.5 = Tk.2350 (for 1st year)
= 470*Tk.12 =Tk.5640 (2nd and 3rd year)
Land occupied cost = Tk. 3120 (Table 4.13)

Appendix C-1 Detailed calculation of Internal Rate of Return value for total Benefit of pre-cast canal at Mithapukur (C-4, R-18 of Table 4.1).

Year	Scheme costs					Scheme Benefits			Discount Factor (50%)	Incremental costs	Project benefit
	Capital cost	O & M cost	Total cost	Discount factor (12%)	Present Worth at 12%	Total Benefit	Discount factor (12%)	Present Worth at 12%			PW at 50%
0	33400	-	33400	-	33400	0	-	0	-	-33400	-33400
1	-	1000	1000	0.893	893	20320	0.893	18146	0.667	19320	12886
2	-	1000	1000	0.797	797	20320	0.797	16195	0.444	19320	8578
3	-	1000	1000	0.712	712	20320	0.712	14468	0.296	19320	3825
4	-	1000	1000	0.636	636	20320	0.636	12923	0.198	19320	2550
5	-	1000	1000	0.567	567	20320	0.567	11521	0.132	19320	1700
6	-	1000	1000	0.507	507	20320	0.507	10320	0.088	19320	1140
7	-	1000	1000	0.452	452	20320	0.452	9185	0.059	19320	753
8	-	1000	1000	0.404	404	20320	0.404	8209	0.039	19320	502
9	-	1000	1000	0.361	361	20320	0.361	7335	0.026	19320	328
10	-	1000	1000	0.322	322	20320	0.322	6543	0.017	19320	232
11	-	1000	1000	0.287	287	20320	0.287	5832	0.012	19320	155
12	-	1000	1000	0.257	257	20320	0.257	5222	0.008	19320	97
13	-	1000	1000	0.229	229	20320	0.229	4653	0.005	19320	58
14	-	1000	1000	0.205	205	20320	0.205	4166	0.003	19320	39
					40029	-	-	134718	-		-557

Net Present worth (NPW) at the lower (12%) discount rate = Tk 134718 – Tk 40029 = Tk 94689
BCR = 134718/40029 = 3.36
Net Present worth (NPW) at the higher (50%) discount rate = Tk 134718 – Tk 40029 = - Tk 557

$$\text{Internal Rate of Return (IRR)} = 12 + \left[\frac{94689}{(94689 + 557)}\right] x\ (50\text{-}12) = 49.78\ \%$$

<u>Calculation:</u>

Earthen canal:

Command area = 4.26 ha,
Fuel consumption = 1281 liters, for 3.87 ha = 1164 liters
Incremental cost = (Tk.37000 – Tk. 18*200) = Tk.33400
Fuel saved = (1164 – 656) = 508 liters
Total benefit = Tk.40 x 508 =Tk. 20320 (1 liter diesel = Tk.40)

Pre-cast canal:

Command area = 3.87 ha, Main canal = 200 m
Fuel consumption = 656 liters
O & M cost = 200*Tk.5 = Tk.1000

Appendix C-2 Detailed calculation of Internal Rate of Return value for total Benefit of Pre-cast canal at Manikgonj (C-4, R-19 of Table 4.1).

Year	Scheme costs					Scheme Benefits			Discount Factor (50%)	Incremental costs	Project benefit
	Capital cost	O & M cost	Total cost	Discount factor (12%)	Present Worth at 12%	Total Benefit	Discount factor (12%)	Present Worth at 12%			PW at 50%
0	33400	-	33400	-	33400	0	-	0	0.667	-33400	-33400
1	-	1000	1000	0.893	893	29120	0.893	26004	0.444	28120	18756
2	-	1000	1000	0.797	797	29120	0.797	23208	0.296	28120	12485
3	-	1000	1000	0.712	712	29120	0.712	20733	0.198	28120	5567
4	-	1000	1000	0.636	636	29120	0.636	18520	0.132	28120	3712
5	-	1000	1000	0.567	567	29120	0.567	16511	0.088	28120	2474
6	-	1000	1000	0.507	507	29120	0.507	14764	0.059	28120	1659
7	-	1000	1000	0.452	452	29120	0.452	13162	0.039	28120	1097
8	-	1000	1000	0.404	404	29120	0.404	11764	0.026	28120	731
9	-	1000	1000	0.361	361	29120	0.361	10512	0.017	28120	478
10	-	1000	1000	0.322	322	29120	0.322	9377	0.012	28120	337
11	-	1000	1000	0.287	287	29120	0.287	8357	0.008	28120	225
12	-	1000	1000	0.257	257	29120	0.257	7484	0.005	28120	141
13	-	1000	1000	0.229	229	29120	0.229	6610	0.003	28120	84
14	-	1000	1000	0.205	205	29120	0.205	5970	0.002	28120	56
					40029	-	-	192976	-	28120	14402

Net Present worth (NPW) at the lower (12%) discount rate = Tk 192976– Tk 40029 = Tk 152947
BCR = 192976/40029 = 4.82
Internal Rate of Return (IRR) = Over 50 %

Calculation:

Earthen canal:

Command area = 3.74 ha,
Fuel consumption = 1312 liters,
For 4.30 ha. Fuel consumption = 1507 liters
Incremental cost = (Tk.37000 – Tk. 18*200) = Tk.33400
Fuel saved = (1507 – 779) = 728 liters
Total benefit = Tk.40 x 728 =Tk. 29120 (1 liter diesel = Tk.40)

Pre-cast canal:

Command area = 4.30 ha, Main canal = 200 m
Fuel consumption = 779 liters

O & M cost = 200*Tk.5 = Tk.1000

Appendix C-3 Detailed calculation of Internal Rate of Return value for total Benefit of Pre-cast canal at Dhamrai (C-4, R-20 of Table 4.1).

Year	Scheme costs					Scheme Benefits			Discount Factor (50%)	Incremental Benefit	Project benefit
	Capital cost	O & M cost	Total cost	Discount factor (12%)	Present Worth at 12%	Total Benefit	Discount factor (12%)	Present Worth at 12%			PW at 50%
0	33400	-	33400	-	33400	0	-	0	-	-33400	-33400
1	-	1000	1000	0.893	893	20160	0.893	18003	0.667	19160	12780
2	-	1000	1000	0.797	797	20160	0.797	16067	0.444	19160	8507
3	-	1000	1000	0.712	712	20160	0.712	14354	0.296	19160	3794
4	-	1000	1000	0.636	636	20160	0.636	12822	0.198	19160	2529
5	-	1000	1000	0.567	567	20160	0.567	11431	0.132	19160	1686
6	-	1000	1000	0.507	507	20160	0.507	10221	0.088	19160	1130
7	-	1000	1000	0.452	452	20160	0.452	9112	0.059	19160	747
8	-	1000	1000	0.404	404	20160	0.404	8145	0.039	19160	498
9	-	1000	1000	0.361	361	20160	0.361	7278	0.026	19160	326
10	-	1000	1000	0.322	322	20160	0.322	6491	0.017	19160	230
11	-	1000	1000	0.287	287	20160	0.287	5786	0.012	19160	153
12	-	1000	1000	0.257	257	20160	0.257	5181	0.008	19160	96
13	-	1000	1000	0.229	229	20160	0.229	4576	0.005	19160	57
14	-	1000	1000	0.205	205	20160	0.205	4133	0.003	19160	38
					40029		-	133600	-		-829

Net Present worth (NPW) at the lower (12%) discount rate = Tk 133600 – Tk 40029 = Tk 93571

BCR = 133600/40029 = 3.34

Net Present worth (NPW) at the lower (12%) discount rate = - Tk 829

$$\text{Internal Rate of Return (IRR)} = 12 + \left[\frac{93571}{(93571 + 829)}\right] x\ (50-12) = 49.67\ \%$$

Calculation:

Earthen canal:

Command area = 3.74 ha,
Fuel consumption = 1221 liters, for 3.55 ha = 1159 liters
Incremental cost = (Tk.37000 – Tk. 18*200) = Tk.33400
Fuel saved = (1159 – 655) = 504 liters
Total benefit = Tk.40 x 504 = Tk. 20160 (1 liter diesel = Tk.40)

Pre-cast canal:

Command area = 3.55 ha, Main canal = 200 m
Fuel consumption = 655 liters
O & M cost = 200*Tk.5 = Tk.1000