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Comparative Study on Improved Earthen Canal, Pre-Cast Canal and Buried Pipe Irrigation System in STW Schemes

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Abstract

A study was conducted on water distribution systems in three different STW irrigation schemes at Nalchity Upazila in Jhalakati district, Bangladesh. Water distribution systems were improved earthen canal, pre-cast canal and buried pipe irrigation system.The main objectives of the study were to compare among improved earthen canal, pre-cast canal and buried pipe irrigation systems for water distribution to the field. The capacity of selected three STWs was 14 litre/sec. The construction costs of improved earthen canal, pre-cast canal and buried pipe system were Tk. 43.85 Tk. 285.5 and Tk. 590.25 per running meter respectively the average water loss through improved earthen canal, pre-cast canal and buried pipe systems were 4.85 1/s/100 m, 3.23 1/s/100 m and 0.35 1/s/100 m respectively. The command area of shallow tubewell under improved earthen canal, pre-

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cast canal and buried pipe system were found 3.22 ha, 4.6 ha and 6.13 ha respectively. The minimum water loss was observed from the buried pipe and minimum cost of construction was found for improved earthen canal. The highest serviceable life and command area was found for buried pipe distribution system. Considering the water loss, construction cost, command area and serviceable life of canals, the buried pipe distribution system was economically superior to others for command area development and reducing water losses. Thus, water losses from shallow tube well can be decreased by providing pre-cast canal substantially to be buried pipe distribution system.

Keywords: canal, buried pipe, water loss, command area, pre-cast canal, earthen canal

INTRODUCTION

Bangladesh is predominantly agricultural country with a total area of 14.39million hectares of which 9.57 million hectares (66 percent) are under cultivation. Irrigation facilities in the country started to develop during the late60's and about 12 percent (1.16 million ha) of the total cultivable land wasbrought under irrigation during 1978 to meet full or partial demand (Bhuiyan, 1976).Obviously, various types of studies are carried out for addressing the issues and problems associated with both the operation and management of irrigation systems. Amongst these, Improvement of performance of water distribution system is the prominent one.

Irrigated agriculture has been playing a vital role for increasing crop production in Bangladesh. Farmers, in this country, used to irrigate their lands in the long past using traditional devices like Don and Swing basket. By these devices, they could irrigate only a very small piece of land by lifting surface water to a small height.

Small scale irrigation using modern technologies was introduced in early sixties. These technologies included low lift pumps (LLP), deep tubewells (DTW) and shallow tubewells (STW). While LLPs were limited to areas where surface waters were available, tubewell irrigation was feasible anywhere in the country because of existence of vast ground water resource at a relatively shallow depth.

Of the two types of tubewell technologies, STW began to be more popular soon after its introduction for its low cost and simpler technology. In the eighties, components of STW became readily available in the market at reasonable prices. As a result, the STW technology began to spread all over the country at an accelerated rate.

Proper water distribution system and its efficient management play very important role in the command area development of any irrigation project. In Bangladesh, use of earthen open channel for water distribution is common in the minor irrigation sector. These earthen open channel distribution systems generally have very low conveyance and distribution efficiencies, resulting in less irrigated area (Sattar*et al.*1988; Sanjit and Tareq, 1996; Hasan*et al.* 1992) and high maintenance cost. It is fact that, traditional earthen channel distribution systems confront some physical obstructions and canals suffer from high seepage, leakage and evaporation losses. One ofthe major weakness of the minor irrigation sector is the huge amount of lossesof irrigation water that occur to lack of knowledge of management as well as,to some extent, due to negligence of farmer.

Water loss in the irrigation channel network is presumable responsible for suchlow coverage. This loss in the field ranged from 15 to 20 percent of the totalwater supply (Dutta, 1982).Michael (1978) in a consultancy report mentioned that the farmers in Bangladesh mainly used earthen canals for conveying water to irrigate their fields because of low initial cost, and considerable conveyance losses occurred mainly due to leakage. Recent literatures reveal that, this loss may be as high as 50-60 %, although it varies with soil type and channel conditions. Channel water loss adds to the pumping cost in minor irrigation systems, and thus reduces the command area, as well as overall efficiency of irrigation.

Field open channels in surface water distribution systems in Bangladesh generally originate from a DTW or a STW, or even from a major canal outlet, run in a random manner with a little consideration of topographical features of the areas (BARI 1988). Seepage and evaporation losses are high in such systems. Besides these, Michael (1987) reported that about 2 to 4 percent of the cultivable land area is taken up by open channels in these systems.

Plausible economic solutions of some of these problems, in the areas with plain topography and having heavy to medium textured soils, include construction of improved (compact) earth channel with necessary water control structures and strengthen operation and maintenance to improve performance of the system. Water loss depends upon season, water table, soil land topography, channel geometry and other flow characteristics. Amongst the water losses, water lost through the irrigation channel network is quite significant (Miah, 1984). Kraatz (1971)reported that seepage rates from channel built in sandy soil are often very highand can be fairly low if the conveyed water carries a heavy sediment load which deposits and build up a fairly impermeable layer on the bank bed of the channel.If improvement is made up in the channel network e.g.canalalignment, canal dimension, removing grass and compaction of channel, using lining material or polythene sheet, a considerable amount of pumped water can be saved.A properly designed water distribution system will make irrigation easy and efficient. Several types of structures are used to convey, divert and controlirrigation water on the farm. Good irrigation structures are essential part of anirrigationlayout. Earthen channel can be built stable side slopes with banks strong enough to carry the required flow of water safely. Theyshould have ample capacity to carry the design discharge at no-erosive velocities.Side slops should be flat enough so that the banks will neither cave in nor slide when they saturated with water.However, the buried pipe distribution system (BPDS) may be the best solution to these problems (Bentum and Smout, 1993), especially for uneven topography and light textured soils (Jenkins, D. 1983).

Various studies have been carried out for addressing the issues and problems associated with both the operation and management of those irrigation schemes, among those issues loses of irrigation water, irrigation structures and command area development are frequently and prominently talked about. Hence the main objective of this work was to determine and estimate construction cost and loss of water and compare among improved earthen canal, pre-cast canal and buried pipe irrigation systems for water distribution to the field providing useful information for the improvement of command area for surface irrigation and for efficient use of water at the farm level towards reducing cost of irrigation.

MATERIALS AND METHODS

Location of the study area

The study site is located at Nalchity Upazila under Jhalakati district which is about 20 km away from district headquarters. The study was conducted on demonstration of irrigation canals. The land distribution of the area is mostly as follows:

High land	19%
Medium high land	30%
Medium low land	16%
Low land	20%
Homestead and water bodies	15%

More or less all the areas are dominated by sandy loam soil. The topography of the land is relatively medium and flat. There are shallow tubewells and deep tubewells in these areas with a fairly good water distribution system.

The climate of the study area is tropical. The average annual rainfall in this area as recorded at the nearest meteorological station, Barisal was 170 cm. The highest mean monthly temperature was 37^0C in May and the lowest was15^0C in February. The percentage of relative humidity ranged between 46% and 84%. The mean monthly evaporation rate varied from 58 mm to 131 mm over the year. From the relationship between the rainfall and the evaporation, it was found that the period from November to April was moisture deficit period. The dry season is very important for the farmers to determine irrigation water application.

Design of the canal section

The normal discharge capacity of a STW in Bangladesh is 14 L/s. The canals are to be designed so that it can carry this discharge 20-25% free board is generally considered canal, in this study the canal was designed for a capacity amounting16 L/s.

Improved earthen canal

From Maning's formula, as suggested by (Michael, 1978) for lined canal,

$$\text{Velocity, } V = \frac{1}{n} \mathrm{R}\ ^{2}/_{3} S\ ^{1}/_{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where,
V = Velocity of flow, m/sec ,A = Area of cross section, m^2, n = Roughness co-efficient, R = Hydraulic depth, m, S = Bedslope,Q = Discharge, m^3/s

For improved earthen canal of shallow tubewell Q = 0.014 m3/sec, Side slope = 1:1, Rugosity or roughness' co-efficient, n = 0.023
Let us assume, Bed width B; Design Depth of water = D
Assumed Section: Trapezoidal
Here, A = (B+D) D
For best trapezoidal section, B = 2D tanɵ/2
Where ɵis the angle between horizontal and side line
For slope 1:1, B = 2D tan $45^0/2$ = 0.82843 D
A = (B + D) D = (0.82843 D + D) D= $1.828431D^2$
P=B+2X2^0D = B + 2.82843 D = 0.82843 D + 2.82843 D =3. 65686 D
R = A/P = 0.5 D
We Know, Q = AV ………………………… (2)
From equation (1) and (2)
$D = (Q \times S^{1/2})^{3/8} \times \frac{1}{50}$
The dimensions of canals are below:Discharge, Q = 0.014 m^3/s ,Bed slope = 0.001, Depth of water = 0.17 m, Bed width = 0.20 m, Free board = 0.05, Top width = 0.58 m, Bank width =0.15 m, Width of canal base = 0.88 m, Height of canal bedfrom field = 0.03 m, Height ofcanal base = 0.25 m

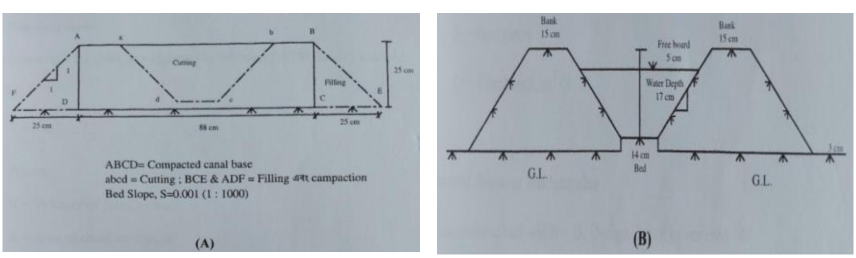

Figure 1: Cross section of improved earthen canal

Pre- cast canal

Formula, as suggested by Michael (1978) for lined canal,
Velocity,$V = \frac{1}{n} R^{2/3} S^{1/2}$…………………………… (3)
Where,
V = Velocity of flow, m/sec, A = Area of cross section, m^2,n = Roughness co-efficient, R = Hydraulic depth, m, S = Bed slope, Q = Discharge, m^3/S

Assumed Section: Rectangular

Let us assume, bed width B; Design Depth of watered =D,Rugosity co-efficient, n = 0.015, A = BXD and P = B+2D

For best hydraulic section of rectangular section

$A = 2D^2$, $P = 4D$, and $R = 0.5D$

From equation (3), $D = (Q \times S^{1/2})^{3/8} \times \frac{1}{83.993}$

The dimensions of canals are below: Discharge, Q = 0.014 m^3/s, Bed slope = 0.001, Depth of water = 0.14 m, Bed width = 0.28 m, Free board = 0.05, Top width = 0.36 m, Bank width =0.15 m, Width of canal base = 0.66 m, Height of canal bed from field = 0.03 m, Height of canal base = 0.22 m

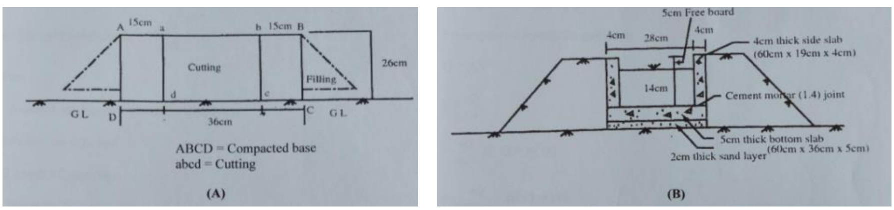

Figure 2: Cross section of apre-cast canal

Buried pipe system

Irrigation pipe

From Darcy's Formula, $h_f = f \frac{L}{2g} \frac{V^2}{R}$ .... (4)

Where,

h_f = Amount of energy loss due to friction, m f =Friction co-efficient, L =Length of pipe, m, V = Velocity of water, m/s, G =Gravitational acceleration, m/s^2, R = Hydraulic radius, m = D/4, D = Diameter of pipe, m

From general hydraulic guideline, Q = AV

$V = \frac{4Q}{1000\pi r^2}$ (When Q = l/s), Hence, from equation (4)

$h_f = 0.331 \times 10^{-6} \times f \frac{LQ^2}{D^5}$..............................(5)

Assumed, f = 0.009 (Michael, 1981), Q = 14 l/s, L = 200m

. Entrance head, $h_e = 0.5 \times \frac{V^2}{2g} = 0.083 \times 10^{-6} \times \frac{Q^2}{D^4}$ .... (6)

From equation (4), (5) and (6) and analysis, Internal diameter of main cc pipe= 15 cm , Internal diameter of pump stand = 60 cm, Height of pump stand = 2.25 m, Diameter of rises pipe = 15 cm, No. of rises pipe =4, No. of air vent = 5

Height of air vent = (2.16, 2.12, 1.52, 1.21, 0.65)

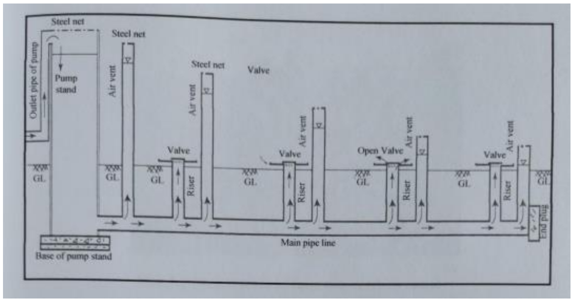

Figure 3: Line figure of buried pipe irrigation system

Construction of canal

Improved earthen canal

The canal was constructed according to design dimensions. The length of the canal was 200 meter. The side and bottom slope were maintained properly according to design criteria. The side and bottom slope were used for checking bottom slope and a wooden from constructed according to designed dimensions was used to maintain uniform side slope. The canal bed and sides were compacted by wooden hammer. The constructed earthen canal is shown in Figure 4 and 5.

Figure 4: Preparation of improve earthen canal

Figure 5: Finished improve earthen canal

Pre-cast canal

Bed slab (60 cm x 36 cm x 5cm) and side slab (60 cm x 19 cm x 4cm) wereconstructed by cement, sand, khoa (1/4") at the ration of 1:2:4. After earth work, the slabs were set-up according to designed criteria. Bed slabs and side slabs were adjusted by cement mortar (1.4). Bed slope was maintained in pre- cast canal as well as in improved earthen canal. The constructed pre-cast canal is shown in Fig. 6 and 7.

Curing of pre-cast rectangular slab

Finished pre-cast rectangular canal

Buried pipe

As underground pipeline water distribution system consists of buried pipes and some allied structures for the efficient functioning of the system. The use of this system is usually limited to areas irrigated by wells using pumps. With pumps, the necessary pressure head to operate the underground distribution system can be obtained with very little extra power. Some important components of a typical buried pipe system are: Pump stand, Conveying pipe line, Riser pipe, Delivery valve, Outlet platform, Air vent, End plug.

Table 1: Quantity of works for the buried pipe

Item No.	Description of work Item No.	Length of width (m)	Depth Height(m)	Number	Unit	Quantity
01	Earth work in excavation					
	a). Foundation trench	200	0.7	0.9	cum	126
	b). Under pipe joints	0.9	0.38	0.15	cum	5.64
	c). Under tree bend etc	0.15	0.3	0.15	cum	0.07
	d). Trench for pump stand	Dia = 9m		12	cum	0.76
	Total					**132.47**
02	Sand filling					
	a) Foundation trench	200	0.7	0.15	cum	21
	b). Under pipe e joints	0.9	0.38	0.075	cum	2.82
	c). Under tree bend etc	0.15	0.3	0.075	cum	0.03
	d). Trench for pump stand			0.075	cum	0.02
	Total					**23.88**
03	Sand filling					
	a). Main line	200		2.08	rm	200
	b). Air vent pipe			1.05	rm	10.4
	c). Rise pipe (.9+.15+.3)				rm	4.2
	Total					**214.6**
04	Jointing pipe					
	a) Mortar (1:3:6) bonded single flatsoling	0.25	0.38	0.105	sqm	10.45
	b) cc (1:3:6) at the pipe side along length	0.25	0.075		cum	0.43
	c) Braiding in cement slurry, cc mortar (l :3),				nos	120

	Jute, bandage etc					
05	Construction of outlet structure					
	a) Flat soling below tee joint	0.25	0.25	1.2	sqm	0.25
	b) cc around pipe (out side dimension 25cmx 25cm)				cum	
	c) Flatform (.3 x .3m) (l) flat soling	0.6	0.6	0.075	sqm	1.44
	(2) cc (1:3:6) 7.5 mm thick	0.6	0.6	0.15	cum	0.11
	d) brick work (1.6) 12.5mm wide	1.8			sqm	1.08
	e) Plastering (1:2) with NCF				sqm	2.5
06	Construction of air vent structure					
	a) Flat soling below tee joint	0.255	0.25	1.2	sqm	0.25
	b) cc around pipe (outside dimension (25cm x 25cm)				cum	0.27
	c) double layer FI wire netting at the top			1.33	nos	5
	d) Painting air vent pipes with synthetic enamel				sqm	3.13
	e) Plastering (1.2) with NCF				sqm	1.50
07	Supplying, fixing outlet valve				nos	4
08	Construction of Pump stand					
	a) Flat soling	Dia = .09m		0.075	sqm	064
	b) 33 (1:3:6)	Dia = .09m		0.15		
	c) cc pipe, dia =.60m, 5mm thick			3.3		
	d) making stepping with MS angle (.38mm x .3mm) and MS bar dia 19.06mm					
9	Construction of outlet value					
	a) Supplying, fixing 3000mm dia 3mmthick plate				nos	1
	b) Picing 150mm thick, 400mm dia cc (l :3:6) at the end				cum	0.02
10	Back filling					
	a) Main trench	200	0.7	0.6	cum	84
	b) Trench of pump stand	Dia = .90m		0.9	cum	0.57
	Total				cum	84.57
11	Connection between pump and pump stand					
	a) PVC pipe with socket and necessary fittings, water grade 100 mm dia	5			rm	5
12	Commissioning the pipe line with necessary fuel and oil				nos	1

Methods of measuring canal water loss

Seepage and percolation losses are the main concern of water loss in irrigation canal. The most common methods that are used for the measurement of loss in the irrigation canals are: a) Ponding method and b) Inflow-outflow method.

Inflow-outflow method

In this experiment, inflow-outflow method was used. Because; ponding method isused to measure seepage and percolation loss in a short selection of small irrigation canals. Water leakage, spillage and piping may be controlled easily. Consequently, inflow-outflow method was employed for this study. The following materials were required for measuring water loss by inflow- outflow method: flume-1, Flume-2, meter sale, ruler, spade, paper, pencil etc.

Canal water loss measurement by inflow-outflow method

Canal water loss in between two sections of the canal is the difference between the discharges measured at the head section and the tail section. This method determines the losses under operational condition and estimates reliable figures if the discharge measurements are accurate. Sufficient cares were taken to avoid any side flow(both in and out) between the sections through rat holes, cracks, etc. The conveyance loss was estimated using the following equation:

$$S1 = \frac{(Q1-Q2)}{L}\ x\ 100 \qquad (1)$$

S1 = Loss in the canal, l/s/ 100 m

Q1 = Flow rate at section 1, l/s

Q2 = Flow rate at section 2, l/s

L = Distance between section 1 & 2, m

Discharge measurement by using a cut-throat flume

The cut-throat flume is an attempt to improve on the parshall flume, mainly by simplifying the construction details. The flume has a flat bottom, vertical walls and a zero-length throat section. Since it has not throat section (Zero throat length) it was given the name cut-throat by the developers (Skogerboe et al., 1973). Under free flow conditions, critical depth occurs in the vicinity of minimum width (w), which is called the flume throat or the flume neck (Fig.8).When the flow conditions are such that the downstream flow depth, is raised to the extent that the flow depths at every point through the structure become greater than critical depth, resulting in a change in the upstream depth, the flume is operating under submerged flow conditions and requires that two flow depths be measured, one upstream (h_a) and the other downstream (h_b) from the flume neck. The submergence (S) is defined as the ratio of the downstream depth to the upstream depths, often expressed as percentage.

$$S = h_b/h_a \qquad (2)$$

The attainment of critical depth it possible to determine the flow rate knowing only an upstream depth (e.g.,ha). This is possible because whenever critical depthoccurs in thee flume the upstream depth, ha is not affected by changes in the downstream depth, lib. For free flow, the ratio of inlet flow depth h_a to flume length should preferable be less than 0.4. The relationship between flow rate Q and upstream depth of flow h_a in a cutthroat flume under free flow conditions can be written as:

$$Q=C_1 h_a^{n_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where,

Q = flow rate, cusec

C_l = Free flow coefficient

The value of ni was found to be dependent only upon the flow depth, L. Therefore, the value of n_l is constant for all cut-throat flumes of the same length, regardless of the throat width, w. Furthermore, the values of $n_1$from the flumes tested plotted as a smooth curve as shown in Fig. 9.

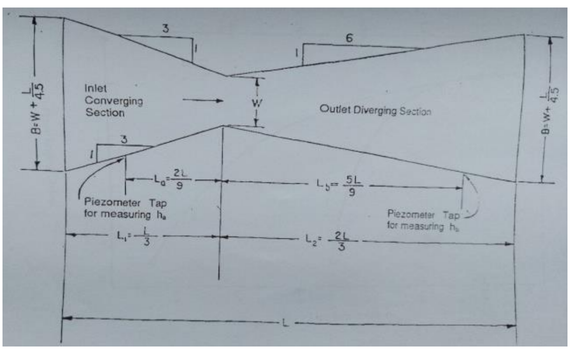

Figure 8: Cutthroat flume

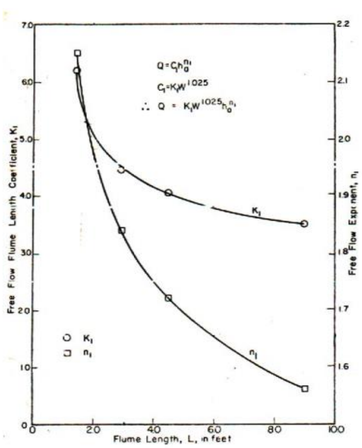

Figure 9: Generalized free flow ratings for cutthroat flumes

The value of the free flow coefficient is a function of the flume length and throat width, W. This relationship is:

$$C_1 = K_1 W^{1.025} \qquad (4)$$

Where

C_1= the free flow coefficient

K_1 = the flume length coefficient (Fig.9)

W = the throat width in feet

Pre-cast canal

Seepage and percolation loss of water through pre-cast canal were measured same as earthen canal. The seepage and percolation loss of water through the bottom and sides of the pre-cast section were measured by inflow-outflow method for design canal section.

Buried pipe system

Water losses in the buried pipes as well as the earthen canal originated from the outlets of the selected systems were measured during the Rabi season. Water losses in the buried pipes were determined by both inflow-outflow and ponding methods.

Ponding method

The ponding test was used to measure water loss in buried pipe distribution system. A flap valve was fitted on the discharge pipe. All outlet valves on the pipe lines under test were closed completely to stop leakages. The header tank and the pipelines were filled with pumped water until overflow occurred through the air-vents(s), when the pump was stopped and the flap valve was closed automatically be back water pressure. After sometimes, when the water level in pump stand stabilized, the drop of water level in the tank with time was recorded. Then the cumulative volume loss was calculated using the following equation:

$$V_c = 1000\, L\, \pi\, (D^2 + nd^2)/4 \qquad (5)$$

Where

V_c = Cumulative volume loss in the pump stand and the air vents, litres

n = No. of air vent on the line under test

D = Internal diameter of pump stand, m

d = Internal diameter of a an air vent, m

L = Cumulative drop of water level in the pump stand, m

In flow-outflow method

Two standard cutthroat flumes of size 91.44 cm x 20.33 cm were set in a Channel (flume l) near the outlet of buried pipe and (flume 2) a distance apart. The flume readings were taken simultaneously when steady flow occurred in the channel. The distance between the two flumes was measured. Then from the known flume discharges and the distance between the losses of water per 100m was calculated using the following relationship.

$$CL = \frac{(Q1-Q2)}{L}\, x\, 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

Where

CL = Water loss in the channel, l/s/100

Q1 = Discharge in flume l, l/s

Q2 = Discharge in flume 2, l/s

L = Distance between two flumes, m

Methods of measuring command area for shallow tube well

Gross command area was determined by walking through the whole scheme as well as by marking area on the site map which was irrigated and also could be irrigated from the tube well. Utilization of land under the gross command area were also demarcate on the site map. Knowing the plot area with the help of manager and the respective landowner, the gross command area was calculated. The actual command area was obtained in consolation with pump operator, Scheme manager and prominent villagers. This was checked 'by filed visits on the basis of mouja map and block registers, plots under each outlet and crops grown in each plot.

The intended command areas of each STW were taken from the respective managers who collected the same from the department of agriculture extension, Nalchity, Jhalakati. The intended area was based on 14 1/s pump discharge. The same was also calculated based on actual available discharge. Total irrigated area covered by a pump is called command area of that pump. Command area was calculated by following equation.

Estimated command area (m^2),

$$\text{CA}= \frac{Total\ discharge\ irrigation\ pump\ per\ day\ (m^3)}{\text{Net irrigation requirement (m)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

Data collection for seepage and percolation measurement

To calculate the water using the equation (6) discharge Q_1 and discharge Q_2 were measured at a distance L. The upstream flow depth, h_a and down stream flow depth h_b were also measured. The flow depths of water of the canal were recorded by means of a graduated scale. There are some losses of water as evaporation from the surface of the canal. But in the field condition, evaporation is generally neglected in most of the cases. So, in this study, evaporation losses were avoided i.e., these was considered as seepage loss.

Data collection for command area

All meteorological data (evapotranspiration, running time of irrigation pump, crop co-efficient) were collected from Department of Agriculture Extension, Nalchity, Jhalakati.

Command area Development

Command area under improved earthen canal

Assumed, (Michael, A.M. 1987)

Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency = 40%, Conveyance efficiency = 50%

$$\text{Net irrigation requirement} = \frac{(45\ x\ 1.25)}{(0.50\ x\ 0.40)} = 28.12 \text{ mm} = 0.0281 \text{ m}$$

$$\text{Total discharge of irrigation pump per day} = \frac{14\ x\ 60\ x\ 18}{1000} = 907.2 \text{ m}$$

$$\text{Estimated command area, CA} = \frac{907.2}{0.0281} = 32284.6 \text{ m}^2 = 3.22 \text{ hec}$$

Command area under pre-cast canal

Assumed, (Michael, A.M. 1987)

Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency = 40%, Conveyance efficiency = 72%

$$\text{Net irrigation requirement} = \frac{(45\ x\ 1.25)}{(0.72\ x\ 0.40)} = 19.53 \text{ mm} = 0.0195 \text{ m}$$

$$\text{Total discharge of irrigation pump per day} = \frac{14\ x\ 60\ x\ 18}{1000} = 907.2 \text{ m}$$

$$\text{Estimated command area, CA} = \frac{907.2}{0.0195} = 46523.07\ m^2 = 4.6\ hec$$

Command area under pre-cast canal

Assumed,(Michael, A.M. 1987)

Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency 40%, Conveyance efficiency = 95%

$$\text{Net irrigation requirement} = \frac{(45\ x\ 1.25)}{(0.95\ x\ 0.40)} = 14.80\ mm = 0.0148\ m$$

$$\text{Total discharge of irrigation pump per day} = \frac{14\ x\ 60\ x\ 18}{1000} = 907.2\ m$$

$$\text{Estimated command area, CA} = \frac{907.2}{0.0148} = 64340.4\ m^2 = 6.13hec$$

Cost of construction

The cost construction of improved earthen canal, pre-cast canal and buried pipe systems includes (i) labour cost and (ii) material cost. The cost of construction material and labour vary widely from place to place and from year to year. These costs were estimated according to present market prices. The construction cost reduces greatly at a place where suitable materials are available at or near the irrigation field.

Irrigation cost

Irrigation cost of improved earthen canal, pre-cast canal and buried pipe systems includes (i) fixed cost and (ii) variable cost. The serviceable life for improved earthen canal, pre-cast canal and buried pipe systems were considered 1.5 years, 15 years and 50 years respectively. To calculate variable cost electric bill and driver's honorarium were considered.

Water losses of different types of canals

The Conveyance loss of water through improved earthen canal, pre-cast rectangular canal and buried pipe system were measured in Shankorpasha, and Bhairabpasha area near about Nalchity Upazila under Jhalakati District. The conveyance loss of water through improved earthen canal was determined byinflow-outflow method is presented in Table 2. The conveyance loss of water through pre-cast canal was determined by both ponding method and inflow-outflow methods are presented in Table 3. The water loss through buried pipe system was determined by both ponding method and inflow-outflow methods are presented in Table 4.

Cost of different types of canals

To determine the cost of construction of per-cast canal, the cost of earthwork and cost of making slabs were considered. The cost for construction of 200 m long canal was calculated. The cost of materials was done on the basis of present market price. The cost of construction of improved earthen canal, pre- cast canal and buried pipe systems includes (i) Labour cost and (ii) Material cost. The cost of construction material and labour vary widely from place to place and from year to year. These costs were also estimated according to present market prices. The construction cost reduces greatly at a place where suitable materials are available at or near the irrigation field. Thus, the costs for construction of different types of canals were compared.

RESULTS AND DISCUSSION

Irrigation water supplies to the field without losses or even negligible losses at lower initial costs are always preferable from the view point of economic consideration. Proper utilization of canal for the whole year without damage is also an important factor to the farmers of developing countries. Hence, to minimize initial costs, water losses and to have efficient water distribution system at farm level, the feasibility and suitability of earthen canal, pre-cast canal and buried pipe system were experimented.

Water loss through seepage, percolation and evaporation is a dynamic property of a soil, which depends on soil texture and structure, location of field, weather and climatic condition of the field, depth of plough pan, bulk density, porosity and organic matter content of the soil, depth of water table, topography and vegetative matter on the soil, types of canals, structure of canal and irrigation distribution system. The canal water loss varied at different locations under different conditions. Usually, the water loss was high under earthen canal, moderate in precast canal and low in buried pipe system.

Comparison of water loss in different canals

The canal water loss through the improved earthen canal was found in the range of 4.04 1/s/100 m to 5.66 1/s/100 m (Table 2). The average canal water loss through improved earthen canal was found to be 4.85 1/s/100 m (Table 5). This is an agreement with Rashid et al. (1990) who found to be 7 1/s/100 m in the improved (compacted) earth canal in the Manikganj district, Bangladesh. Biswas et al. (1984) reported that about 50% of pumped water may be lost using earthen canal system. The canal water loss through the pre-cast canal was found in the range of 2.26 I/s/100 m to 4.2 l/s/100m (Table 3). The average canal water loss through the pre-cast canal was 3.23 1/s/100 m (Table 5 i.e. about 28% of pumped water lost when pre-cast used. The canal water loss though the buried pipe distribution system was found to range in between 0.31 1/s100 m to 0.39 1/s/100 m (Table 4). The average canal water loss through buried pipe distribution system was 0.35 l/s/ 100 m (Table 5) i.e., about 5% of pumped water lost in BPDS. Water from different canal includes seepage, leakage, percolation and evaporation. Sometimes flow over the canal banks (spillage) occurs and was included in the water loss.

Table 2: Water loss from pre-cast canal

Obs. No.	Flume No.	h_a (in.)	h_b (in.)	h_a/h_b	Flow cond^n	K_1	n_1	C_1	Q (cusec)	Distance bet^n two sections(m)	Conve-yance loss(l/s/100m)
1	1	6.66	3.60	0.54	Free flow	5.2	1.98	3.431	1.06	40	**5.66**
	2	6.40	3.55	0.55		5.2	1.98	3.431	0.98		
2	1	6.55	3.50	0.53		5.2	1.98	3.431	1.03	35	**4.85**
	2	6.38	3.50	0.54		5.2	1.98	3.431	0.97		
3	1	6.00	3.40	0.56		5.2	1.98	3.431	0.86	35	**4.04**
	2	5.80	3.40	0.58		5.2	1.98	3.431	0.81		

Table 3: Water loss from pre-cast canal

Obs. No.	Flume No.	h_a (in.)	h_b (in.)	h_a/h_b	Flow cond^n	K_1	n_1	C_1	Q (cusec)	Distance bet^n two sections(m)	Conve-yance loss(l/s/100m)
1	1	5.6	3.2	0.57	Free flow	5.2	1.98	3.431	0.70	40	**4.2**
	2	5.4	3.2	0.59		5.2	1.98	3.431	0.64		
2	1	4.9	2.6	0.53		5.2	1.98	3.431	0.58	35	**3.23**
	2	4.8	2.6	0.54		5.2	1.98	3.431	0.54		
3	1	4.7	2.5	0.51		5.2	1.98	3.431	0.53	25	**2.26**
	2	4.6	2.5	0.53		5.2	1.98	3.431	0.51		

Table 4: Water loss from buried pipe

Obs. No.	Length of pipe (m)	Water Level in the pumpStand (m)		Total Volume lost (litre)	Time, t(min.)	Water loss(l/s/100m)
		At the beginning	At the end			
1	200	1.74	0.04	630.55	15	**0.35**
2	200	1.89	0.05	682.48	18	**0.31**
3	200	1.97	0.08	708.44	15	**0.39**

Table 5: Water loss in different canals

Item	**Water loss** (1/s/100 m)
Improved earthen canal	4.85
Pre-cast canal	3.23
Buried pipe	0.35

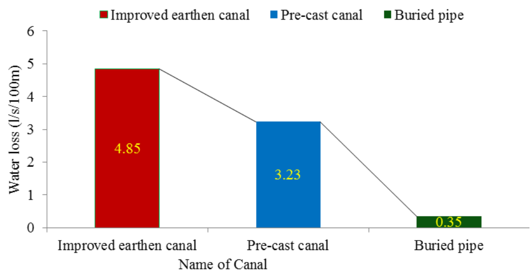

Figure 10: Comparison of Water loss in differen canals

Comparison of command area development in different canals

The cultivable command area of shallow tube well under improved earthen canal, pre-cast canal and buried pip distribution systems were 3.22 hec, 4.6 hec and 6.13 hec respectively. It was observed that command area may be increased by saving canal water without any extra costs.

The command area development by pre-cast canal over the improved earthen canal was 43% and buried pipe distribution systems was 187% respectively. The total area covered by canals increased after pre-cast canal and buried pipe distribution system. Irrigation of this extra land reduces the production cost. Information on command area development by different canal is shown in Table 6.

Table 6: Information on command area development by different canals

Item	**command area (hec)**	**Developing command area over improved earthen canal(%)**
Improved earthen canal	3.22	
Pre-cast canal	4.60	43%
Buried pipe	6.13	187%

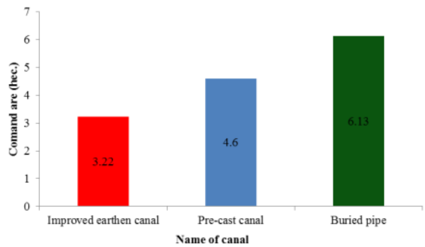

Figure 11: Comparison of comand area in different canal

Cost analysis

The detailed breakups of costs for the construction of different canals are shown in Tables7, 8 and 9. The total cost of the construction of improved earthen canal, pre-cast canal and buried pipe were found to be Tk. 8770, Tk. 57100 and Tk. 118049, for 200 running mater, respectively. The comparisons of costs are presented in Fig. 8. But considering the irrigation cost (fixed cost and variable cost) under different canals as given in Table 10 and 11, the maximum cost was observed for improved earthen canal and minimum for buried pipe distribution system. The fixed costs of improved earthen canal, pre-cast canal and buried pipe system were found to be Tk. 5847, Tk. 3807 and Tk. 2361 per year. The variable costs of these canals were found to be T k. 5625, Tk. 3129 and Tk. 2237 per hec respectively.

Table 7: Detail breakup cost for the construction of improved earthen canal

Name of item	Design Capacity(l/s)	Description of works	Unit of work	Rate of work (Tk)	Amount of work (m)	**Total Cost** (Tk)
Improved earthen canal	14	i)Preparation of map showing command area ii) Construction of canal	Running meter	**43.85/-**	**200**	**8770**

Table 8: Detail breakup cost for the construction of pre-cast canal

Name of item	Design Capacity(l/s)	Description of works	Unit of work	Rate of work (Tk)	Amount of work (m)	**Total Cost** (Tk)
Pre-cast canal	14	i)Preparation of map showing command area ii) Construction of canal	Running meter	**285.5/-**	**200**	**57100**

Table 9: Detail breakup cost for the construction of buried pipe

Item No.	Description of work Item No.	Unite of rate	Quantity	Rate (Tk.)	Cost (Tk.)
01	Earth work in excavation				
	a). Foundation trench				
	b). Under pipe e joints				
	c). Under tree bend etc				
	d). Trench for pump stand				
	Total	**Cum**	**132.47**	**85/-**	**10597.6**
02	Sand filling				
	a) Foundation trench				
	b). Under pipe e joints				
	c). Under tree bend etc				
	d). Trench for pump stand				
	Total	**Cum**	**23.88**	**450**	**10746**
03	Sand filling				
	a). Main line				
	b). Air vent pipe				
	c). Rise pipe (.9+.15+.3)				
	Total	**rm**	**215**	**185**	**39775**
04	Jointing pipe				
	a) Mortar (1:3:6) bonded single flatsoling	sqm	10.45	250	2612.5
	b) cc (1:3:6) at the pipe side along length	cum	10.43	4350	14080.5
	c) Braiding in cement slurry, cc mortar (l :3), Jute, bandage etc	nos	120	35	4200
	Total		**120**	**174.10**	**20893.0**
05	Construction of outlet structure				
	a) Flat soling below tee joint	sqm	0.25	220	55
	b) cc around pipe (out side dimension 25cmx 25cm)	cum	0.22	4350	957
	c) Flatform (.3 x .3m) (l) flat soling	sqm	1.44	220	478.5
	(2) cc (1:3:6) 7.5 mm thick	cum	0.11	4350	478.5
	d) brick work (1.6) 12.5mm wide	sqm	1.08	450	486
	e) Plastering (1:2) with NCF	sqm	2.5	140	350
	Cost per outlet structure each		**4**	**660.425**	**2643.3**
06	Construction of air vent structure				
	a) Flat soling below tee joint	sqm			
	b) cc around pipe (outside dimension (25cm x 25cm)	cum			
	c) double layer FI wirenetting at the top	nos			
	d) Painting air ventpipes with synthetic enamel	sqm			
	e) Plastering (1.2) with NCF	sqm			
	Average cost per air vent structure	**Each**	**5**	**714.36**	**3571.8**
07	Supplying, fixing outlet valve	**nos**	**4**	**1800**	**7200**

08	Construction of Pump stand				
	a) Flat soling	sqm	0.64	220	140.80
	b) 33 (1:3:6)	sqm	0.1	4350	435
	c) cc pipe, dia =.60m, 5mm thick	rm	3.3	1500	4950
	d) making stepping with MS angle (.38mm x .3mm) and MS bar dia 19.06mm	nos	2	1250	2500
	Total cost for structure	**each**	**1**	**8025.8**	**8025.8**
9	Construction of outlet value				
	a) Supplying, fixing 3000mm dia 3mmthick plate	nos	1	500	500
	b) Picing 150mm thick, 400mm dia cc (l :3:6) at the end	cum	1	4350	4350
	Total	**each**	**1**	**4850**	**4850**
10	Back filling				
	a) Main trench	cum	84	65	5460
	b) Trench of pump stand	cum	0.57	65	37.05
	Total	**cum**	**84.57**	**65**	**5497.05**
11	Connection between pump and pump stand				
	a) PVC pipe with socket and necessary fittings, water grade 100 mm dia	rm	5	650	**3250**
12	Commissioning the pipe line with necessary fuel and oil	nos	1	1000	**1000**
Total cost					**118049.55**

Table 10: Irrigation cost (fixed cost)

Sl.N0	Canal condition	Construction cost (Tk.)	Serviceable life (year)	Scrap Value (Tk.)	Cost/year (Tk.)
1	Improved earthen canal	8770	1.5	500	5847
2	Pre-cast canal	57100	15	900	3807
3	Buried pipe system	118049	50	1700	2361

Table 11: Irrigation cost (variable cost)

Sl.N0	Canal condition	Total cost (Tk.)	Command area (hec.)	Rate of irrigation Cost(Tk./hec)
1	Improved earthen canal	18112	3.22	5625
2	Pre-cast canal	14393	4.6	3129
3	Buried pipe system	13709	6.13	2237

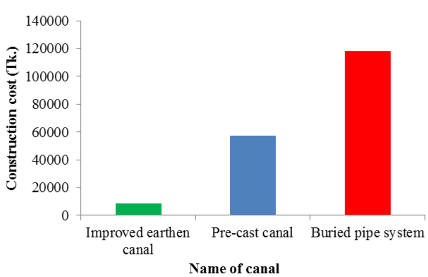

Figure12: Comparison cost of different canals

Comparison of different canals

The water loss through the improved earthen canal was average 4.85 1/s/100m where as through pre-cast canal was found to be average 3.23 l/s/100 m which is 23.57% less of that improved earthen canal and corresponding cost for pre- cast canal is only 6.51 times higher than that of improved earthen canal. Similarly water loss through the Buried pipe system found to be average 0.35 l/s/100 m.

The conveyance efficiency of buried pipe and pre-cast canals were 95% and 72% and the corresponding cost for buried pipe system was only 2.07 times higher than that of pre-cast canal construction.

Although initial cost of earthen canal is low and is performed with unskilled labour, it is considered as temporary structure. On the other hand, in order to construct pre-cast canal and buried pipe needs skilled labour. If properly constructed and maintained, the serviceable life of pre-cast canal may be expected to the 15 years. Pre-cast canal is structurally strong enough to resist external forces like walking animals, earth or hydrostatic pressure. Buried pipe distribution system can be preferred over open canal where poorly cohesive soils would result in high seepage losses or for variation in ground level irrigable land can't be reached by an open canal when water is valuable in terms of crops and limitation of water resource. If it is properly constructed maintained, the serviceable life of buried pipe system may be expected to be 50 years or more.

Considering above points it was observed that the water distribution pattern through buried pipe system was superior to these of conventional irrigation systems for economic aspect, loss reduction and command area development.

CONCLUSIONS

From this study the following conclusions can be made-

- The construction costs of improved earthen canal, pre-cast canal and buried pipe system were Tk. 43.85, Tk. 285.50 and Tk. 590.25 per running meter respectively.
- The command area of a shallow tube-well under improved earthen canal, pre-cast canal and buried pipe distribution system were found to be 3.22 ha, 4.6 ha and 6.13 ha respectively.

- The water loss in improved earthen canal, pre-cast canal and buried pipe distribution systems were found to be 4.85 l/s/100 m, 3.23 l/s/100 m and 0.35 l/s/100 m respectively.
- In this study, the percentage of increased land for pre-cast canal and buried pipe system were 43% and 187% respectively. Thus, command area can be increased by providing pre-cast canal and buried pipe distribution system.
- Considering loss and cost, buried pipe system should be given emphasis to use for irrigation.

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