Cost Effective Water Distribution in Irrigated Crop-Field

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Abstract

In west Bengal irrigation of crop-fields are based on Rainwater, water from lifting rivers/ponds, Shallow/Deep Tube wells, Cannel water from DVC or Kansabati or Tista water. All these stated water are usually over flows naturally over crop-fields; except water lifting from rivers/ponds, Shallow/Deep Tube wells or from different barrages. Water lifting from rivers/ponds, Shallow/Deep Tube wells or from different barrages are usually distributed through cannels. Though no water is less valued; except rain water all types of water are directly cost dependent. So it was essential to develop scientific irrigation system considering topography of the areas where water is been distributed, soil condition and meteorological parameters for minimizing wastage of costly water warranting society's maximum benefits. Here authors have studied the problem with the tools of fluid mechanics for measuring wastage of costly water due to slippage, evaporation and misuse of water in a certain areas of West Bengal for suggesting alternative cost-effective scientific irrigation system. For this study types geographical systems, land mapping concepts and flow characteristic study tools are been utilized.

INTRODUCTION

Water is an essential resource for all life, but the water resources on Earth only three percent of it is fresh of which two-thirds is locked up in ice caps and glaciers. one percent of the remaining, a fifth is in remote, inaccessible areas and much seasonal rainfall in monsoonal deluges and floods cannot easily be used. Day by day water is becoming scarcer and having access to clean, safe. At present only about 0.08 percent of all fresh water in the world[1] is exploited by mankind in ever increasing demand for sanitation, drinking, manufacturing, leisure and agriculture. Due to the small percentage of water remaining, optimizing the fresh water men have left from natural resources has been a continuous difficulty in several locations of different parts of world.

Much effort in water resource management is directed for optimizing the water use and in minimizing the environmental impact for water use on the natural environment. So water is consider as an integral part of the ecosystem is based on integrated water resource management, where the quantity and quality of the ecosystem help to determine the nature of the natural resources.

As water moves in time and space consistent with the hydrological cycle, the term 'water management' covers a variety of activities and disciplines. Broadly speaking, these can be divided into three categories: managing the resource, managing water services, and managing the trade-offs needed to balance supply and demand.

The management of water is not merely a technical issue; it requires a mix of measures including changes in policies, prices and other incentives, as well as infrastructure and physical installations.
Integrated water resources management (IWRM) focuses on the necessary integration of water management across sectors, policies and institutions.

World Water Development Report 2012 emphasized on contemporary water managers have to deal with an increasingly complex picture. Their responsibilities entail managing variable and uncertain supplies to meet rapidly changing and uncertain demands; balancing ever-changing ecological, economic and social values; facing high risks and increasing unknowns; and sometimes needing to adapt to events and trends as they unfold.

IWRM is defined as a process that 'promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. It implies that all the different uses of water resources need be considered together. Though important developments have been made around the world, the preparation by governments of national IWRM plans and the actual implementation rates of these plans remain unsatisfactory and well behind targets.

Furthermore, the complexity of water management, combined with increased uncertainty, both through socio-economic developments and climate change, makes the traditional command-and-control approach less effective. An adaptive approach towards IWRM responds to this: a continuous process of adjustment that attempts to deal with the increasingly rapid changes in our societies, economies, climate and technologies.

In 2002, a diverse group of agencies, individuals and wastewater industry professionals gathered to discuss their frustration with the lack of good public and local government education on rapidly advancing wastewater system technology. To engage in activities which create a climate of informed consent where wise choices can be proposed for appropriately sized wastewater systems which are cost effective to construct, operate and maintain while minimizing environmental footprint and sprawl. For sustainable water use system education it is essential emphasize on two basic commitments:

a) to protect and preserve the watershed, surface and groundwater resources, and the Rivers, Great Lakes Basin, through proactive, comprehensive education and management programs, and
b) to provide free access to a comprehensive resource of information, education and training for individuals, regulators, service providers, schools, communities and local government to enable them to make wise and resilient choices for the future of ever precious and diminishing water sources.

Vast water in the sea is not directly consumable by human being. One of the biggest concerns for our water-based resources in the future is the sustainability of the current and even future water resource allocation.[2] As water becomes scarcer, the importance of how it is managed grows vastly. Finding a balance between what is needed by humans and what is needed in the environment is an important step in the sustainability of water resources. So to increase awareness that water quality is directly linked to the use of appropriate water systems and their management is urgent. To provide access to education which increases public awareness of the link between clean water, safe recreational waters, environmentally sustainable surface and groundwater with watershed based best management practices related to appropriate wastewater sysems, technology, treatment and management. Here have investigated water management presently adopted in cannel water from lifting rivers/ponds, Shallow/Deep Tube wells, Cannel water from DVC or Kansabati or Tista or Mayurakhsi water.

There are six agro-climate zones in West Bengal. Those are i. Hill zone, ii. Terrain zone, iii. Old Alluvium zone, iv. New Alluvium zone, v. Red gravel zone and vi. Coastal zone of which three characteristics soil viz. Old Alluvium zone, New Alluvium zone, Red gravel zone are found in Bhirbhum districts, the areas covered by cannel water from lifting rivers/ponds, Shallow/Deep Tube wells, Cannel water from DVC or Kansabati or Mayurakhsi water. Our focus was to investigate existing irrigation water management especially by open cannels in those areas for quantity as well as quality improvement.

Genesis of the Investigation Methodology

Typical Indian farmer, used for looking up to the skies to see whether the rain gods will favors him this time, irrigation means a wide range of interventions at the farm level, ranging from a couple of support watering(s) (or 'life saving' watering) during the kharif (monsoon) season from a small check dam/ pond/tank/dry well to assured year-round water supply from canals or tube wells to farmers cultivating three crops a year. The method of application has also evolved, from traditional gravity flow and farm flooding to micro-irrigation where water is applied close to the root zone of the plant. Indian farmers gain access to irrigation from two sources— surface water (that is, water from surface flows or water storage reservoirs) and groundwater (that is, water extracted by pumps from the groundwater aquifers through wells, tube wells and so on). Surface irrigation is largely provided through large and small dams and canal networks, run-off from river lift irrigation schemes and small tanks and ponds. Canal networks are largely gravity-fed while lift irrigation schemes require electrical power. Groundwater irrigation is accessed by dug wells, bore wells, tube wells and is powered by electric pumps or diesel engines. To meet the growing needs of irrigation, the government and farmers have largely focused on a supply side approach rather than improve the efficiency of existing irrigation systems.

Irrigation Sector Terminology

The terms used by the Ministry of Water Resources (MoWR), Ministry of Rural Development (MoRD), and the Ministry of Agriculture (MoA), the three ministries within the government responsible for irrigation are as follows:

1. Major irrigation (cultivable command area above 10,000 ha).
2. Medium irrigation (cultivable command area between 2000 ha to 10,000 ha).
3. Minor irrigation (cultivable command area less than 2000 ha)

All these three kinds of irrigation are based on either, a. Surface irrigation or b. Groundwater irrigation and or coupling of both. This classification belongs to an era when all 'irrigation' was largely surface irrigation, promoted and supported by the government. Minor irrigation also includes a large number of small surface irrigation schemes such as village tanks, and ponds, including many which were constructed pre-independence and managed by the local community and have been now handed over to the panchayat administration. Two other terms which are critical to our understanding of irrigation sector are ‘watershed’ and ‘micro-irrigation’. ‘Watershed’ may be defined as an area from where rainwater is drained through a common outlet (lake/river/rivulet) and therefore, can range in size from a few states to a few ha. It is a hydrologic unit which is useful for natural resource planning and management. The watershed programme, funded by the Ministry of Rural Development (MoRD) and Ministry of Agriculture (MoA), focuses on a range of multi-disciplinary interventions (afforestation, soil and water conservation measures, water harvesting and so on) in a watershed which is demarcated so as to be as contiguous to the village boundary as possible. The watershed programme is a key programme of the MoRD and MoA to increase agriculture productivity in areas which are reined and cannot access any surface irrigation scheme (the watershed programme guidelines specifically prohibit work on villages which have more than 30 per cent area already under irrigation). Micro-irrigation encompasses drip and sprinkler technologies. Traditionally, irrigation is provided to crops by flooding the entire farm, largely through gravity-based flow. To get ‘more crop per drop’ two major technologies of drip and sprinkler irrigation have been developed. In both these technologies, water is available in quantities and location more suitable to the plant growth and near the root zone. Use of these technologies improves the efficiency of irrigation. Application of microirrigation devices leads to 30–70 per cent water savings relative to flood irrigation.

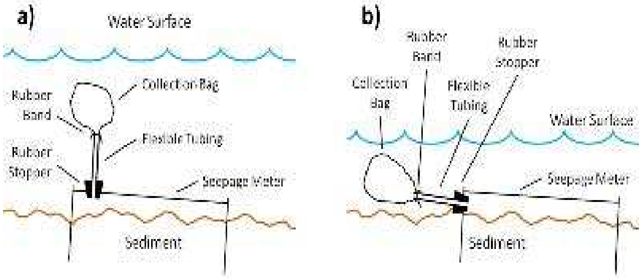


Figure 1: Cross-section view showing a typical installation of a seepage meter at left (a) and for an installation in shallow water (b). (Adapted from Lee and Cherry 1978).

In Birbhum district presently cannel water from lifting rivers/ponds, Shallow/Deep Tube wells, Cannel water from DVC or Kansabati or Maurakhsi water are been distributed thorough open cannels. Soil of those channels is porous. So costly water in cannels used to have downward flows due to seepage through porous soil surrounded the cannels. Seepage meters are instruments for measuring the flow of water between groundwater and a surface water body such as a lake, wetland, estuary, or stream (Figure 1). Seepage meters can be constructed inexpensively from readily available materials and can be custom-built for specific applications[3]. When flow measurements from seepage meters are combined with hydraulic head measurements from mini-piezometers the hydraulic conductivity of the bottom sediment can be calculated. This document is intended to aid those who are engaged in surface water–groundwater exchange studies in cost-effective construction, installation, and use of seepage meters. There is Darcy's Law for calculating seepage which here can be used for calculating seepages from cannels.

Darcy's Law for calculating seepage : An equation that can be used to compute Volume of flow (Q) of water through a porous media using the hydraulic conductivity of the media (K), the hydraulic gradient (dh/dl), and the cross-sectional area of flow (A), I = hydraulic gradient. Seepage from cannels usually is reported in terms of cm 2 of water lost per day, or Q/A Mathematically:

$$Q/A = -K * dh/dl$$

The hydraulic gradient depends not only on the depth of water in a cannel, but also on the soil profiles beneath the cannel and in some cases, depth of the water. Bouwer [4, 5] presented general theoretical models to solve for seepage from canals given K and certain soil profile conditions. Research on the relation between small bodies of water and groundwater was summarized by Hall [6]. Numerous models have been developed to simulate the complexity of seepage flow and its relation to groundwater [7].

Correction coefficient

To determine the actual rate of seepage measured seepage is multiplied by the area. Correction coefficient compensates for inefficiencies in flow in the meter, any restriction to flow through the connection between the bag and the seepage meter, and any resistance to movement of the bag [8].

Non-Flowing Water Applications

If water is not flowing through the cannels for certain period then for non-flowing or very low flow applications the seepage meter is effective to be used. For higher flow conditions, however, additional measures are needed to ensure accurate measurements.

Flowing Water Applications

Seepage meters were originally designed for use in low- or no-flow applications such as lakes and estuaries where issues related to current and scour are generally small. In flowing applications, such as rivers and streams, so for proposed investigation some changes in seepage meters were required.

Figure 2: A streamlined seepage meter with protective housing for the collection piezometers, scaled-down versions bag placed in a low-flow area near the stream bank.

By using more streamlined; low-profile seepage meters effect of scour can be significantly reduced (Figure 2). By isolating the seepage meter collection bag from the flowing current the seepage flow induced by flowing water can be significantly reduced. Streamlined seepage meters can minimize the disturbance of the sediment caused by the flowing water and can allow water and sediment to readily pass over the meter, making the seepage meter more similar to the surrounding streambed. Streamlined seepage meters can be constructed from readily available materials including plastic lids and garbage cans. Locating the collection bag in a protective housing near the stream bank where the current is much lower can minimize seepage induced by the flowing water. Details information of such measured on flowing water applications, has been discussed in the article by Rosenberry and the online document by Rosenberry et al. [9]
For measuring downward seepage Mini-piezometers are usually used [10, 11]. This is simple instruments for measuring the direction of water flow between groundwater and a surface water body like a lake or stream (Figure 1). Often temporarily installed, mini-piezometers are essentially scaled-down versions of Piezometers, scaled-down versions of piezometers, are routinely used to make groundwater level measurements. To determine the direction of water flow, When combined with surface water level measurements it can be used . Mini-piezometers are particularly useful in situations where many measurements are required, cost is a concern, or access to field sites is limited. While mini-piezometers can be purchased commercially, they are easily built using components readily available from hardware and auto parts stores. Person engaged in surface water—groundwater exchange studies want to use those should know about cost-effective construction, installation and use of mini-piezometers [12].
Duly and Domingo [14], looking at water infiltration into soil, found little relation between temperature and rate of water movement. A common correction factor used to adjust measured permeabilities to 20°C is: $K^{20} = Kx\ (Ux/U^{20})$ where K is the hydraulic conductivity, U the viscosity, and x the measured temperature [15]. Thus, the ratio of the relative viscosities can be used to correct for temperature.

Evaporation of Water from open cannels in the fields

Evaporation is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance. The other type of vaporization is boiling, which is characterized by bubbles of saturated vapor forming in the liquid phase. From irrigation cannels evaporation is only vaporization of a liquid that occurs due sun light. **Evaporation** is the process by which water changes from a liquid to a gas or vapor. Water boils at 212 degrees F (100 degrees C), but it actually begins to evaporate at 32 degrees F (0 degrees C); it just occurs extremely slowly. As the temperature increases, the rate of evaporation also increases. The amount of evaporation depends on the temperature, and it also depends on the amount of water there is to evaporate. As it is well known facts that the evaporation rate is influenced by 1) The temperature of the water at the air-water surface, 2) The humidity of the air, 3) The area of the air-water surface, 4) The temperature of the air, 5) water currents convicting heat and the ability to keep the temperature constant at 100 degrees F. and 6) airflow past the water/air surface, moreover evaporation is an endothermic process, in that case heat is absorbed during evaporation all the factors of areas covered by irrigation cannels need be considered and it can be easily calculate by continuity equation.

Cost of water Evaporated and seepages

Cost of total water distributed by irrigation system is usually calculated on the basis of overhead cost of Dam, Barrages and other system associated with irrigation department. Part of which are been charged on cultivators. But wastages due to aforesaid water Evaporated, seepages and other causes not included in cost calculation.

Most important is land uses for cannels are fertile land. Cost of land is not part of water cost. Huge amount of fertile land used for cannels are not directly producing; except its indirect contribution. So lose due non use of those fertile land should be added contribution in the water cost, particularly proceeding for any alternative system(s).

Catchment area of Present Study and it purpose:

On the bank of the River Mayurakshi Masanjor Dam, Kundu Dam and Tilpara Barrage are situated. Mayurakshi-Bakreshwar Main Canal (MBMC) is located between Tilpara Barrage and Bakreshwar River. From Bakreswar River to Kopai River the name of the canal is Bakreswar Kopai Main Canal (BKMC). Along the bank of the river Kopai-Kultore Barrage is the source point of Kopai South Main Canal (KSMC). Details about the canal are bellow.

<u>Canal BKMC:</u>

Length = 9.3km
Width = 24mts
Depth = 2.5mts
Discharge = 2200 cusec

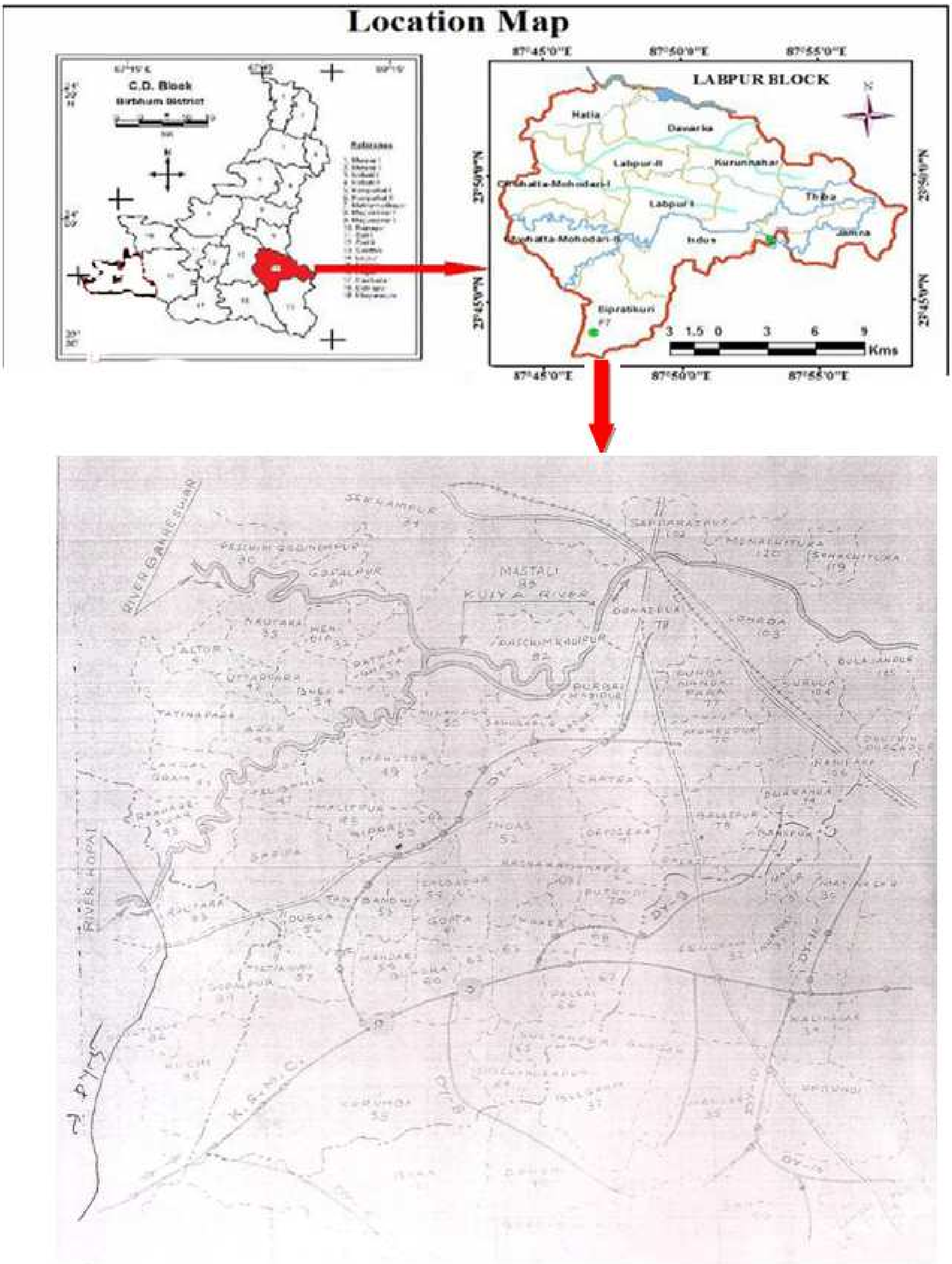
<u>Canal KSMC:</u> (Kultore barrage to Bolpur Div.)

Length=34.38km
Width = 16mts/52 feet
Depth = 7 feet
Discharge = 1230 cusec

Average Silippage and evaporation is about 15%-20%

Canal KSMC in the Lavpur block where it goes through the Mouza Kurumba, Kashiyara, and Feugram Amnahar etc. up to Salar block. In that particular study area the details of KOPAI SOUTH MAIN CANAL are bellow:

Length	6.5km
Width	52feet
Depth	7feet FSD (Full Supply Depth)
Discharge	1230 cusec in Kharif season



Cannels for water distribution in Labpur Block area

Canal BKMC:

Length = 9.3km
Width = 24mts
Depth = 2.5mts
Discharge = 2200 cusec

Canal KSMC: (Kultore barrage to Bolpur Div.)

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Length 6.5km
Width 52feet
Depth 7feet FSD (Full Supply Depth)
Discharge 1230 cusec in Kharif season

Distributary-7;

Length 10km
Width 8feet
Depth 4feet FSD (Full Supply Depth)
Discharge 65 cusec in Kharif season
Cultivated area….4000 acore
Kurumba to Donaipur mouza

Distributary-5:

Length 3.5km
Width 4feet
Depth 2feet FSD (Full Supply Depth)
Discharge 22 cusec in Kharif season
Cultivated area….1500 acore
Sitapur to Amdohara mouza

In present investigation areas under the office of the executive engineer M.S.C. Division, Santiniketan, Birbhum are considered. Blocks of the catchment areas are labpur and Kirnahar. Total length of cannels in catchment areas is 20 km. Average width of those cannels is 21.33 feet and average depth of the cannels is 4.33 feet. From these data firstly areas of land is been calculated. Secondly considering flow of irrigation water i.e. flow velocity, duration of flow quantum of water usually flows over the year is been calculated. Total quantum of water flows through those cannels multiplied by average cost per liter of irrigated water from source one can easily calculate cost of water flows through those channels. Now calculating wastage of water due to evaporation and seepages it is not at all problem for finding cost of wastage water. Adding lose of value for not producing crop of used land for cannels with the wastage calculated earlier real wastage may be calculated.

After having this calculated wastage it is urgent to find out alternative system(s) to stop this wastage or at least for maximum minimization of wastage. Proposed alternative system(s) should be cost effective.

Conclusion

From above discussion it is revealed that water supplied through the cannels are costly due to construction of dams, cannels and for its maintenance. A good amount of men power is been deployed for running dams, groundwater irrigation systems - i.e. shallow-well and deep-well pumps**,** water supply outlets etc and their maintenance. Installation of river irrigation system involves running a power supply to the bed of the river and installing a pump. There pipe is extended from the pump into the river, which is used to draw the water. All these need investments. Therefore it is easy to realize how costly water are been wastage due to seepages and evaporated. Huge lands are been used for cannels construction and not usable for crop production. So cost of crops might be produced is a loss every year. It means in this study cost of lost crops is added factor with the cost of wastage water. Therefore having real wastage of irrigated water on the basis of geographical data of particular zone, if calculated, it may be the basis for thinking cost effective alternative systems. No doubt our present study is a micro level, but having data from number of such micro-level investigation a macro-level investigation can be done. Undoubtedly no cost effective alternative systems can be developed on the basis of such micro level observation of wastage of irrigated water on the basis of geographical data of particular zone, as geographical parameter are not quite enough considered here. This write-up is part of our long time investigation; so with the noted shortcomings we are confident for developing a model for greater perspective. If software can be built then one can be are sure it will be a general study useful in greater perspective.

Also one can think of recent well discussed tools Big Data, IoT Key for Fixing Crumbling Water Infrastructure, Reducing Operating Costs and if it is done then whole water distribution systems in irrigation cannels will be of a revolutionary change.

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