FEASIBILITY ASSESSMENT OF KAPTAI RESERVOIR WATER FOR IRRIGATION PURPOSE AT SELECTED GROSS COMMANDED AREAS OF CHATTOGRAM DISTRICT DEPENDING ON B/C RATIO ANALYSIS

S. Acharya[*1], S. M. F. Ruhani[2], T. B. Khaled[3], A. M . Mithun[4]

[1*] *Assistant Professor , Chittagong University of Engineering and Technology , Bangladesh , e-mail: acharya_shyamal@cuet.ac.bd*
[2] *Undergraduate Student , Chittagong University of Engineering and Technology , Bangladesh , e-mail: u2001055@student.cuet.ac.bd*
[3] *Undergraduate Student , Chittagong University of Engineering and Technology , Bangladesh , e-mail: u2001103@student.cuet.ac.bd*
[4] *Undergraduate Student , Chittagong University of Engineering and Technology , Bangladesh , e-mail: u2001039@student.cuet.ac.bd*

***Corresponding Author**

ABSTRACT

Agriculture constitutes a fundamental pillar of Bangladesh’s economy and national food security framework, contributing approximately 11.2–12% to the country's gross domestic product and engaging around 37–43% of the national workforce, thereby underscoring its critical role in employment generation and economic sustenance. Currently, 80 percent of irrigation water comes from groundwater extraction, a practice that has become increasingly expensive and unsustainable due to rising electricity costs, rapid aquifer depletion, and environmental degradation of surrounding areas. This study explores an innovative solution to Bangladesh's irrigation crisis by investigating the feasibility of developing a gravity-fed irrigation system powered by the Kaptai Reservoir. The reservoir, Bangladesh's largest man-made water body, maintains substantial surplus water beyond its hydroelectric generation needs. Located at a strategic elevation in Chattogram District's mountainous terrain, the reservoir offers a unique natural advantage: water can be conveyed downslope without requiring costly pumping infrastructure. The research focuses on irrigating two primary agricultural zones—Gumai Beel in Rangunia, known as the country's food silo, and cultivable areas in Raozan, totaling 92.08 square kilometers. Through hydrological and hydraulic analysis, a 54.8 kilometers circular lined canal with a 3.5 meters radius was designed to meet the seasonal water demand of 125.504 million cubic meters for paddy cultivation. Financial feasibility assessment reveals a total project investment of 64.5 crores with a payback period of 15.56 years, after which annual benefits of 7.39 crores substantially exceed maintenance costs. By reducing reliance on groundwater extraction, this reservoir-based irrigation initiative provides both economic and environmental benefits for sustainable agricultural development in Chattogram.

Keywords: *Kaptai Reservoir, Gravity-fed irrigation, Canal network Distribution, Feasibility Analysis, Sustainable Agriculture*

1. INTRODUCTION

Bangladesh is a country of huge agricultural opportunities. The economy of this country, it's employment rate, food production depends on agriculture inevitably. The agricultural sector of Bangladesh employs 42.7% of the total labor force and comprises 14.2% of the country's GDP (BBS, 2019). Agriculture plays significant role not only on these sectors. But also supplying raw materials for various manufacturing sectors, such as - tea, jute, textile, leather, fisheries, dairy products etc.

Irrigation is a fundamental element of agriculture, as it directly determines food productivity and food security in Bangladesh (BADC, 2018). At present, in order to collect irrigation water, farmers usually rely on ground water, surface water and rainwater. Currently, in dry season, 80% of irrigation water is collected from groundwater sources (BADC, 2018; World Bank, 2019). Though, groundwater serves as the primary source of irrigation water supply, farmers face several challenges regarding the extraction of water from this source. Such as- high electricity cost, requirement of costly equipment (pumps, deep tube wells), scarcity of water in dry season due to the lowering of ground water table etc. (Mukherji et al., 2020). In some of the areas, farmers might extract surface water by means of pumping using diesel-oriented pumps, electric pumps, tubewell etc. But external energy is must in all these means (Rahman et al., 2018). So, as an alternative solution regarding these problems, a free flow from the upstream to the downstream, might be proven beneficiary from the aspect of cost and energy efficiency (Ali et al., 2021).

The Kaptai reservoir can be a good source for the downstream irrigation project. The geographical location of Kaptai reservoir is ideally suited for this irrigation system. As the reservoir is located at a higher elevation of about 100 ft from MSL, water can flow easily to the downstream agricultural land by gravity force. The Kaptai lake is basically a man-made reservoir built in 1962, with the help of making the dan on the Karnafuli river at Kaptai, for power generation purpose. But for power generation it uses 42 to 46 percent of the available water (Karnafuli Hydropower Station, 2025). The excess water can be directed towards the downstream agricultural land by establishing a canal network system.

Lining of a canal is essential for efficient use of land and water resources. Control of seepage saves water for further extension of the irrigation network as well as reduces the water logging in the adjoining areas. The smooth surface of lining reduces the friction slope, which enables the canal to be laid on a flatter bed slope. This increases the command area of the canal. On the other hand, as the lining permits higher average velocities, the canal can be laid on steeper slopes to save the cost of earthwork in formation. As the lining provides a rigid boundary, it ensures protection against bed and bank erosion (Swamee et al., 2000).

Transportation of water through canal involves some losses such as seepage and evaporation. It is a significant amout of water wastage for canal irrigation system. Such kind of water losses is obviously necessary to minimize. Unless, the requirement of water supply for canal irrigation purpose will be larger. Considering these losses, a circular or a trapezoidal canal system, lined with any lining material, such as soil cement, can prove a better solution in this regard. Because of the lining, the initial cost might have increased, but it saves 40 to 60 percent of water loss while flowing through canal. Other than soil cement lining, the canal can also be lined with earthen material, brick in mortar, fly ash, cement concrete or polythene sheets etc. Each of the measures have different specific seepage loss (Singh et al., 2017).

Comparing these measures, polythene sheets has the lower average seepage loss. Soil cement is the second lowest one considering seepage loss. But the measure of using soil cement can be selected, due to its availability, low seepage loss, low maintenance cost. Using Polyethylene sheets involve a higher risk of being teared and higher maintenance cost. Generally, the canal lined with soil cement has a seepage rate of 8.39 lph per m^2 (Karad et al., 2014). On the other hand, the total amount of evaporated water will be 3 percent of the seepage loss (Saxena et al., 2014**)**. The canal can be of different geometric shape, such as - triangular, trapezoidal, circular. If a channel is a lined canal and the discharge of water flowing through it becomes less than 50 cumec, circular shape of canal can be selected.

For different crops, the required amount of water throughout the base period can be different which is called as the consumptive use of the crop. Depending on this required water and total water loss, the required discharge that has to flow through canal can be calculated. By using that discharge the design parameters of a canal can be determined.

According to these design parameters, the canal needs to be established. For maintaining the proper through the channel by gravity, a certain bed slope is to be maintained for supplying of water. The slope should be a moderate one rather than too mild or too steep. If the slope is too mild, there might not be adequate pressure to supply water to the distant location. In addition, it could cause siltation in the canal. Too much steep slope, also need to be avoided in order to prevent scouring of earth material.

With the aim of maintaining a moderate slope, some cutting and filling needs to be done throughout the total irrigation canal system length. These earth cutting and filling cost are to be considered as initial cost. While establishing this canal network system, some of the obstacles might be encountered such as roads, rivers, canals. To overcome these obstacles some hydraulic structures and cross drainage works need to be introduced.

Comparing to the other methods of irrigation, the irrigation cost might be higher as it involves cutting and filling cost, land requisition cost etc. But during the operational period, there will be only a minimum maintenance cost (Bhattarai et al., 2007). Over the time period, the channel's initial investment will be recouped through its operational revenue. By cost-benefit analysis the break-even point can be determined, after which the project will turn into a profitable one (Gittinger, 1982). The gravity-fed irrigation system is both economically viable and environmentally feasible (Hossain et al., 2019). Within a considerable span of time, the gravity fed irrigation system can be turned into a profitable one without any major harmful effect on environment.

2. METHODOLOGY

2.1 Study Area

Kaptai reservoir was created with the construction of an earth dam across the Karnaphuli River at Kaptai, about 70-km upstream from the estuary of Chittagong, in 1955 for production of hydroelectricity (Islam et al., 2018), which came into operation in January 1962 (BPDB, 1985). It is now the biggest water reservoir in Bangladesh.

The cultivable land is chosen at Gumai Beel (local word, means, cultivable land), located in Rangunia upazilla and another area in Raozan upazilla is considered as the part of study area as irrigation field for water supplying purpose. Gumai Beel is considered the country’s second largest paddy field covering 3450 hectares of land (BADC, 2018) and is known as the ‘food silo of Chattogram’. It is stated locally that, one season’s rice from Gumai Beel could feed Bangladesh for roughly two and a half days. Gumai Beel currently supports large seasonal Aman and Boro cultivation with mixed irrigation sources. Historical context emphasizes that modern irrigation in Gumai Beel has relied on multiple local streams and canalized flows, which remain critical for distributing water during dry-season. In Raozan, Aman and Boro is also produced, of which 33.68 km^2 has been covered by this irrigation project that will facilitate irrigation and ultimately increase production of crops.

This study will investigate the feasibility of the use of water from Kaptai reservoir as irrigation purposes aiming the objectives as, to: (i) investigate the suitability of irrigation canal networks diverting from the reservoir, (ii) to assess and analyse the economic benefit to utilize the water from the reservoir. Along with these objectives, this research study can observe other economic and environmental benefits as well.

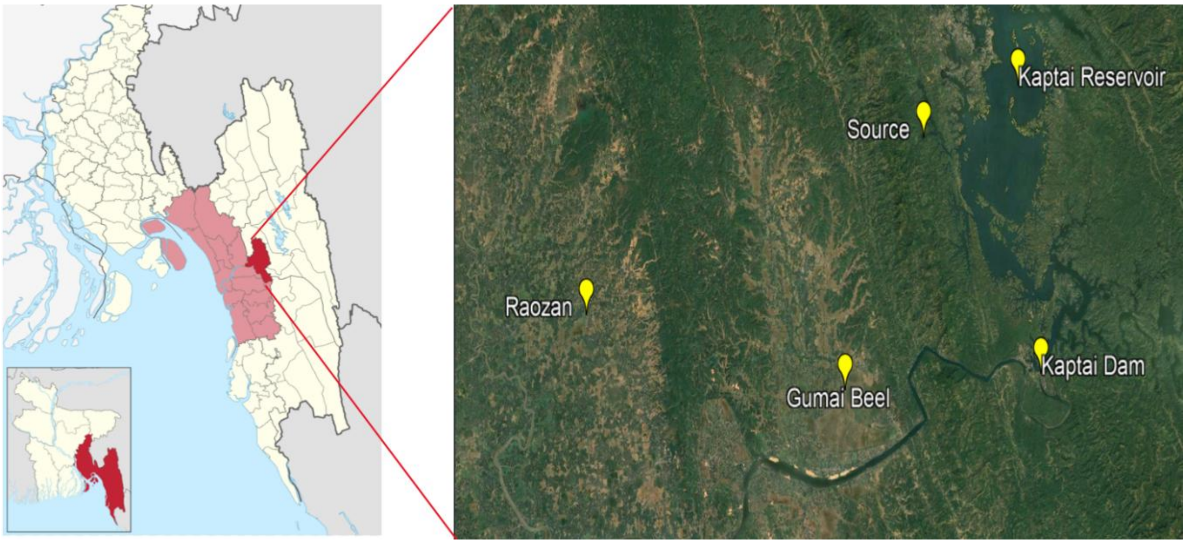

Figure 1: Study Area

2.2 Data Collection

Following table presents the types of data used in the study along with their respective sources.

Table 1: Various data & their sources

Data	Source
Water level data and total volume of water availability	Karnafuli Hydropower Station (Secondary data)
Digital Elevation Model (DEM) of the study area (30 m × 30 m)	USGS Earth Explorer (earthexplorer.usgs.gov), 2025
Canal route KML file (points and line geometry)	Google Earth Pro, Google LLC, 2024

For the purpose of establishment of new irrigation project, a canal network to carry the water the cultivable commandant area would be selected and proposed. In this regard, sizable areas of land are to be proposed for the construction of canal network which should be acquired with suitable compensation package. For this reason, an average local land requisition cost data was collected from Rangunia and Raozan Sub-Register Office to be utilized as the secondary data source for the investigation. Cutting and filling cost of soil were collected from PWD as per 2022 rate chart to be used for the purpose of analysis in the study.

2.3 Calculation of Irrigable Area

From the generated DEM file, the culturable commanded areas are to be fixed up as per the elevation status of the available agricultural fields. The channel bed level as indicated in the previous section, according to that elevation, the culturable commanded areas are fixed up. The agricultural lands those are available lower than the formation or bed level of the selected channel are chosen for the agricultural purpose of the two selected Gross Commanded Area (GCA). Figure-2 shows that the total estimated irrigable area is 92.08 km^2 for this project. Most of the area is of Gumai Beel and some of the area is in Raozan.

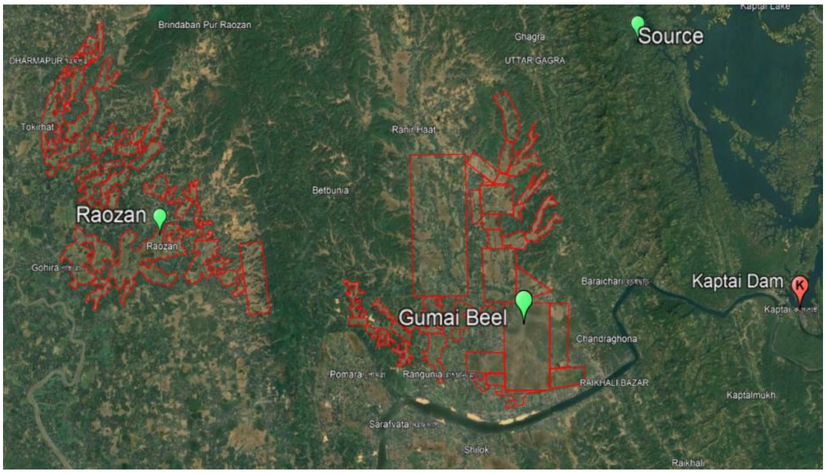

Figure 2: Two Culturable Commanded Areas (CCA) or Irrigable area: Gumai Beel and Raozan

2.4 Calculation of Water Requirement

As the target crop to be produced in the selected irrigable areas is chosen as the paddy. Kung and Atthayodhn, (1968) found that the crop water requirement for rice or paddy in winter season is 800 mm to 1200 mm. As per Bangladesh agricultural standards, the crop water requirement for rice or paddy in winter season is 800 mm to 1800 mm (Prattoyee et al., 2021). So, selecting suitable value of delta in between the indicated range as 1.2 m, the total water requirement for the whole GCA is calculated as 110.5 Mm^3. In this amount of water, no water lost is considered. This is purely consumptive use of the paddy or rice.

2.5 Canal Route Selection with Elevation

By using Google Earth Pro, the canal route has been finalized by maintaining a minimum elevation. The canal is of 54.8 km which serves the irrigable area of 92.08 km^2 (Figure 3). A KML file of the canal route has been extracted. The elevation data along the route is extracted from DEMs using ArcMap (ESRI, 2023) and an 'elevation vs distance' curve was generated using Excel. This curve is used to estimate the initial cost of the project.

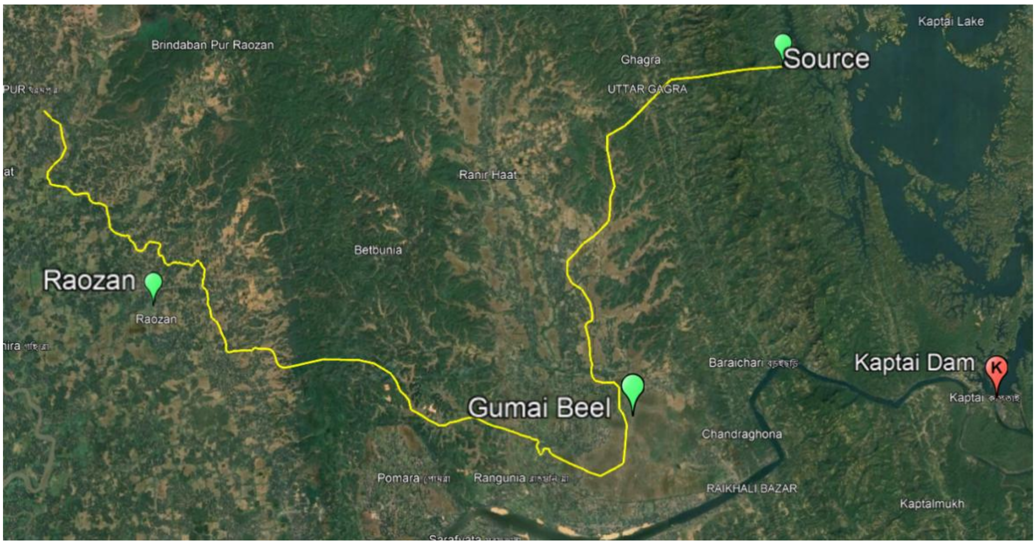

Figure 3: Canal route

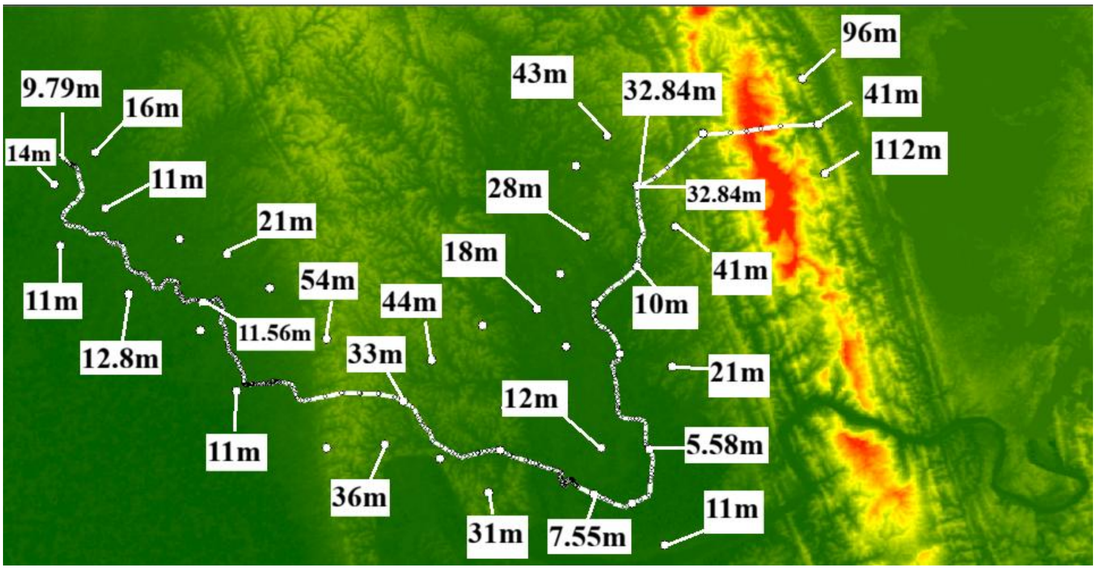

Figure 4: Elevation details on and surrounding of selected route

2.6 Canal Design

A lined canal has been designed to convey the water from Kaptai reservoir, considering a side slope of 1:1 according to the following equations-

$$A = 1.785\ D^2 \tag{1}$$

$$P = 3.57\ D \tag{2}$$

$$R = \frac{A}{P} \tag{3}$$

$$v = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \tag{4}$$

$$Q = A \times v \tag{5}$$

Since the discharge is less than 50 cumecs, circular section has been selected for designing the canal. The calculated radius D was found to be 3.5 m (*Figure 5*).

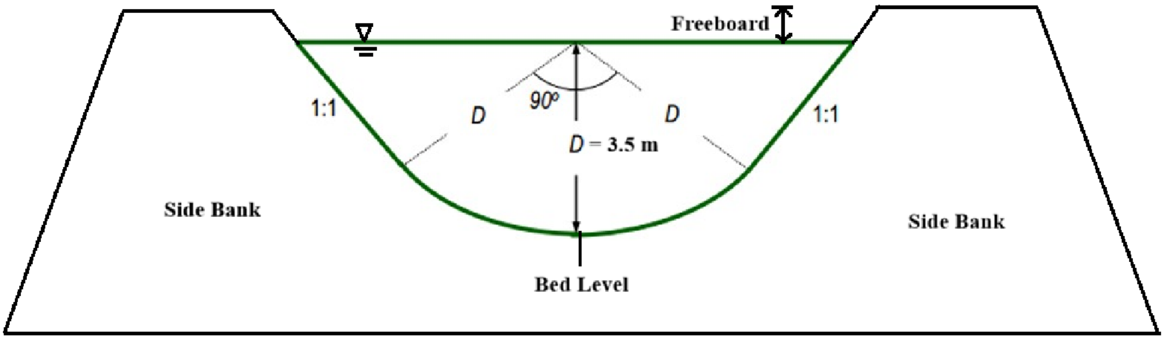

Figure 5: Cross-section of the canal

2.7 Cost Analysis

For the purpose of the benefit-cost ratio, all related costs were considered and calculated depending on the data collected from different offices and organizations.

Land requisition cost for the total area of land to be used for the purpose of establishment of newly proposed irrigation canal network are calculated on the basis of the secondary data collected for land requisition value of Rangunia and Raozan. Along with this cost, a lump sum cost for all fees, taxes and charges were considered.

The cost for cutting and filling cost has been estimated. Along with this cost, a lump sum cost for transportation, mobilization of equipment and other miscellaneous costs were considered. Finally, for the total initial cost, total land requisition cost was added to the cutting and filling cost of the soil for making the canal network.

Same way, total expenditure was calculated with an initial cost and adding the lump sum cost and an operation and maintenance cost.

Annual cost savings = irrigation cost before implementing the project

Break-even point has been determined by following equition-

$$\frac{P}{A} = \frac{(1+i)^n - 1}{i\,(1+i)^n} \quad (6)$$

Here, i = interest rate, n = number of years.

3. RESULT AND DISCUSSION

3.1 Total Water Requirement

For the selected culturable commanded areas (CCA), paddy is taken as the only crop to be grown in the crop fields. Taking paddy or rice as the grown crop in the selected areas, the calculated total water requirement was found as 110.5 Mm^3 depending on the crop requirements for the rice and excluding all other kinds of water losses could be possible for the selected crop fields. The required water was then converted to the discharge rates for the purposes of the channel designed. The channel was designed considering it as a lined canal so that water lost can be minimized.

The calculated discharge required at irrigation field level side of the project is 10.65 cumec. For a circular canal lined with soil-cement, the total calculated seepage loss is 8.39 lph/m^2 (Karad et al., 2014) means in other words, a total of 1.405 cumecs discharge is becoming for this purpose. Using the standard data as per the reference and calculation procedure, the obtained evaporation loss is equal to 0.0422 cumec. Then, the combined seepage and evaporation loss was estimated to be as 1.4472 cumec as discharge. Hence, the total volume of loss becomes to 15.004 Mm^3.

Finally, the total water requirement was obtained or found as 125.504 Mm^3 as the total volumes of waters. From the calculation, it was found that the discharge required just after the intake station for the canal network is 12.10 cumec. Considering other factors regarding water loss, assumed discharge at upstream was 15 cumec. With this calculated value of the water flow through the canal system just after the intake station from the reservoir, using the standard procedure of calculation, it was found that the wetted perimeter of the circular canal was 11 m and the wetted area was 0.6028 Mm^2.for the total section of the channel So, calculated available discharge at downstream is 13.55 cumec, means that with this amount of water discharges though the canal system, the field requirement of water can be fulfilled.

3.2 Channel Design

Depending on the DEM file and the elevation, and the elevation versus distance (*Figure 6*), the suitable assumed bed slope could be 1 in 6000. Using a rugosity co-efficient as 0.0225 for lined canal, the designed radius of the circular channel is 3.5 m. The side slope of the canal was considered as 1:1. The *(Figure 5)* shows the cross section of the designed channel as per the required amount of water to flow up to the farthest part of the selected GCA.

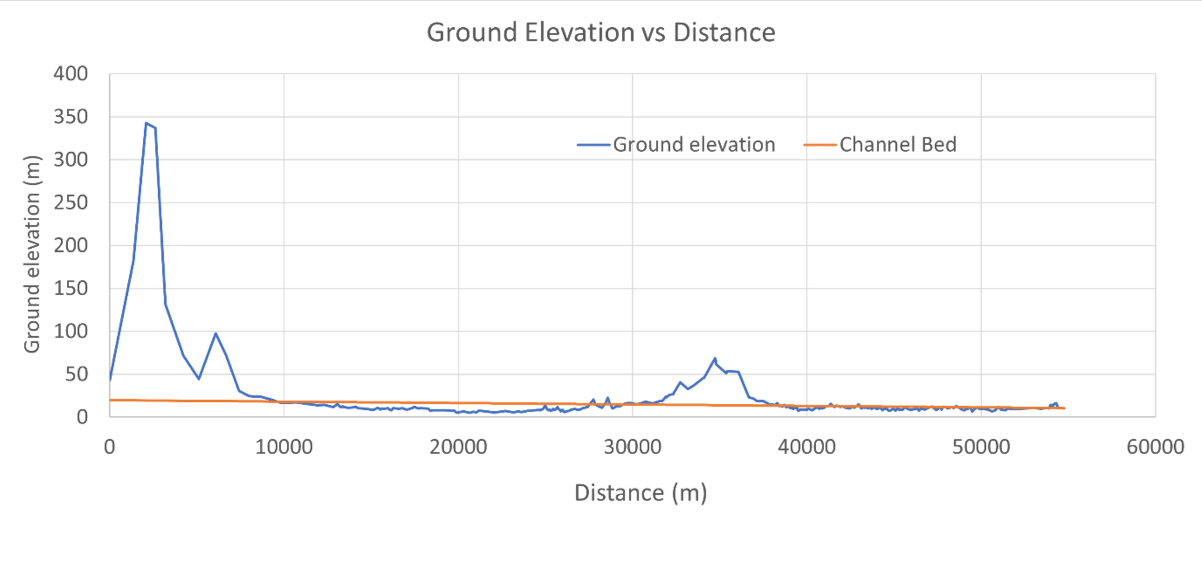

Figure 6: Ground Elevation vs Distance (with channel bed)

3.3 Cutting -Filling Volume

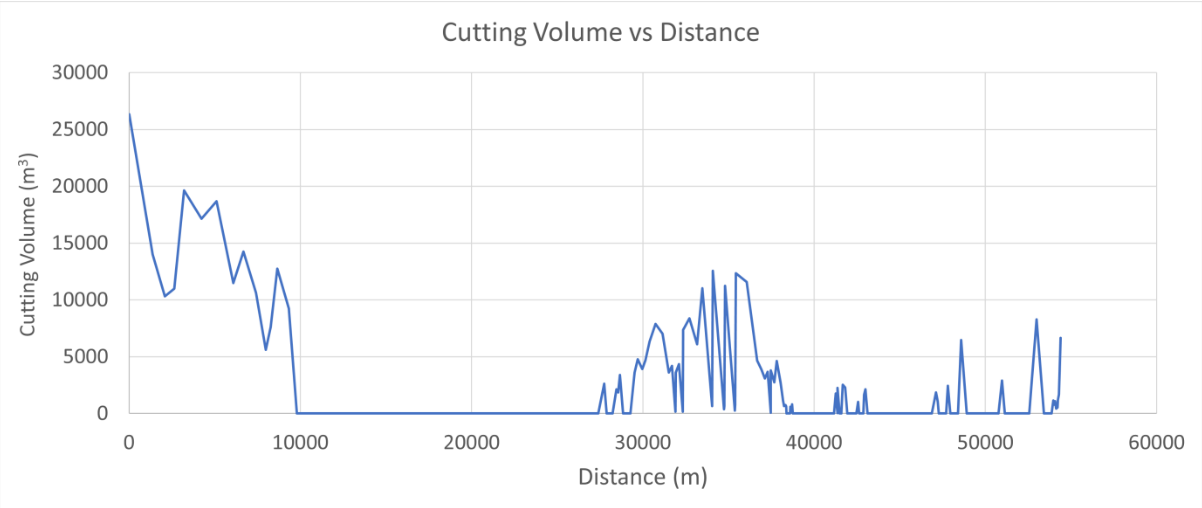

Figure 7: Cutting volume vs Distance

From the elevation data of the route and bed slope of the canal, cutting and filling volumes were calculated by using Excel calculation sheet. In *(Figure 6)* the red line shows the formation or bed level of the channel. The soil of the part of the ground remaining above and below this red line indicates that these are the soil for cutting volume and filling zone volume. The calculated total cutting volume was found to be 423814.6 m^3 which is shown in *Figure 7* and the calculated total filling volume was found to be as 629430.9 m^3 which is shown in *Figure 8*. These values show that the canal network system is more or less an economical one as cutting and filling volume is very close to each other.

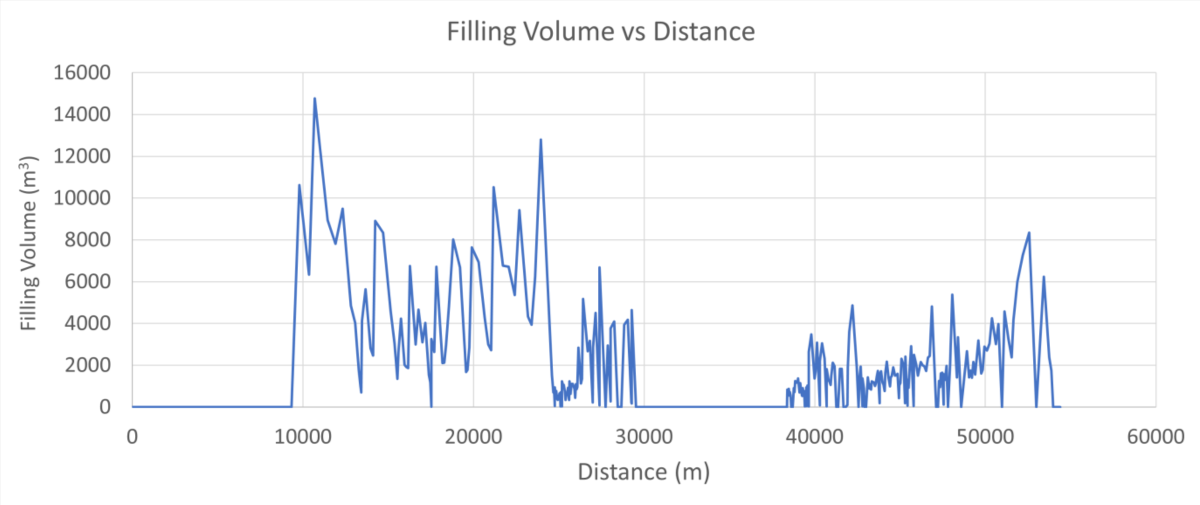

Figure 8: Filling volume vs Distance

3.4 Feasibility Check

Using the collected data from two sub registry offices, total land requisition cost was 18.28 crores. Along with the value, adding a lump sum cost for all fees, taxes and charges, total land requisition cost raised to more or less 20 crores. The cost for cutting and filling was found as approximately 40 crores. With this value and a lump sum cost for the transportation and mobilization of the equipment and other miscellaneous cost, total expenditure raised to around 64.5crores.

Profit was calculated on the basis of getting the advantages of water costs for the gravity-fed irrigation network compared to the early cost for ground water extraction or any other way, before establishing the gravity fed channel network system irrigation scheme. Finally using all costs and benefits the B-C ratio was calculated taking the interest rate as 8%. And the B/C ratio was found as the break-even point basis. And the break-even point time frame was calculated as 15.56 years.

The payback period of the project is 15.56 years, post payback, cumulative cash flow is positive and the project earns profit. Also, annual benefits of was calculated and found as 7.39 crores substantially outweigh operational and maintenance costs was found as 1.29 crores, making this project economically attractive for long-term agricultural development. Furthermore, by reducing dependence on groundwater extraction, this initiative addresses environmental concerns related to aquifer depletion, the system is fruitful as it is a very prominent water recharge option and by that way water table declining would be minimized in a significant amount. The findings suggest that the Kaptai Reservoir irrigation project merits serious consideration as a strategic investment for enhancing food security while promoting sustainable agricultural practices in Chattogram District.

4. CONCLUSION

This study presents a comprehensive feasibility analysis of utilizing Kaptai reservoir as a sustainable irrigation water source for downstream agricultural lands in Chattogram District. The investigation focused on two key irrigable areas – Gumai Beel in Rangunia and culturable commanded areas in Raozan – covering approximately 92.08 km².

The hydraulic analysis indicates that a 54.8 km circular lined canal with a 3.5 m radius can effectively convey water to meet the total requirement of 125.504 million cubic meters for paddy cultivation in one season across the study area. The soil-cement lining reduces seepage losses to a moderate level while maintaining structural integrity. Significantly, the canal's design leverages the higher elevation advantage provided by the reservoir's location, eliminating the need for energy-intensive pumping systems that currently burden for the farmers in the region. This represents a substantial departure from conventional groundwater-dependent irrigation methods that account for 80 percent of current dry-season water supply in Bangladesh.

The financial analysis reveals that despite initial project expenditure of approximately 64.5 crores, the system achieves economic viability within 15.56 years, after which cumulative cash flows become positive and the project generates continuous profit. Annual benefits of 7.39 crores substantially outweigh operational and maintenance costs estimated at 1.29 crores, making this project economically attractive for long-term agricultural development. Furthermore, by reducing dependence on groundwater extraction, this initiative addresses environmental concerns related to aquifer depletion and water table decline. The findings suggest that the Kaptai Reservoir irrigation project merits serious consideration as a strategic investment for enhancing food security while promoting sustainable agricultural practices in Chattogram District.

Through systematic hydrological and hydraulic assessment and engineering design, the research demonstrates that gravity-fed irrigation from the reservoir is both technically viable and economically feasible.

5. REFERENCES

Ali, M. S., Rahman, M. M., & Karim, M. R. (2021). Gravity-fed irrigation potential from Kaptai reservoir for downstream agriculture. Journal of Water Resources Engineering, 45(2), 55–67.

Bangladesh Agricultural Development Corporation. (2018). Irrigation wing annual report 2017–2018. Dhaka, Bangladesh: BADC.

Bangladesh Bureau of Statistics. (2020). Statistical yearbook of Bangladesh 2020. Dhaka, Bangladesh:BBS.

Bhattarai, M., Sakthivadivel, R., & Hussain, I. (2007). Irrigation impacts on income inequality and poverty alleviation: Policy issues and options for improved management of irrigation systems. Irrigation and Drainage, 56(2–3), 255–270.

BBS. (2019). Yearbook of Agricultural Statistics 2019. Bangladesh Bureau of Statistics. Statistics and Informatics Division. Ministry of Planning. Government of the People's Republic of Bangladesh.

Doorenbos, J., & Pruitt, W. O. (1977). Guidelines for predicting crop water requirements (FAO Irrigation and Drainage Paper No. 24). Rome, Italy: FAO.

ESRI. (2023). ArcMap: Advanced geographic information system. ESRI Publications.

Federation of Indian Chambers of Commerce and Industry. (2019). Bangladesh: Unlocking the potential of agriculture. New Delhi, India: FICCI.

Gittinger J. Price (1982). Economic analysis of agricultural projects (2nd ed.). Baltimore, MD: Johns Hopkins University Press.

Google LLC. (2024). Google Earth Pro user manual. Google.

Hossain, M. S., Islam, M. R., & Ahmed, K. (2019). Reservoir-based irrigation systems in South Asia: Feasibility and sustainability. Water Resources Management, 33(12), 4321–433

Islam, M. R., & Khan, M. A. (2018). Kaptai reservoir: Historical development and hydroelectric potential. Bangladesh Journal of Hydropower, 7(3), 187–203.

Karad, M. M., Panke, R. A., & Hangargekar, P. A. (2014). Seepage losses through canals & minors. Dr. B.A.M. University Journal of Engineering,

Khan, A. A., & Hossain, M. S. (2017). Assessment of multipurpose use of Kaptai reservoir water. Bangladesh Journal of Scientific Research, 30(1–2), 23–34.

Mukherji, A., Das, B., Majumdar, N., & Chattopadhyay, N. (2020). Groundwater depletion and energy use in South Asian agriculture. Environmental Research Letters, 15(10), 104012.

Prattoyee, F. T., Hasan, F. R. M. R., Nahid, I. K., & Faruq, M. O. (2021). *Modelling net irrigation water requirements and irrigation scheduling of Boro rice using FAO CROPWAT 8.0 and CLIMWAT 2.0: A case study of Rajshahi region, Bangladesh*. Journal of Global Ecology and Environment, 13(2), 1–11.

PWD. (2022). Unit rates for earthwork and construction. Public Works Department, Bangladesh.

Rangunia Sub-Register Office. (2023). Land survey and agricultural assessment report. Government of Bangladesh.

Rahman, M. M., & Hasan, M. A. (2018). Performance and cost analysis of diesel and electric pumps for irrigation in Bangladesh. Bangladesh Journal of Agricultural Engineering, 29(1), 35–44.

Saxena, A. K., Sahu, P., & Travadi, M. K. (2014). Use of canal lining available materials and its comparative study. IOSR Journal of Civil Engineering (IOSR-JMCE), 11(3), 81-86.

Singh, A. K., Verma, R. K., & Kumar, A. (2017). Canal lining and its effects on seepage control. Indian Journal of Water Resources, 28(2), 145–162.

Swamee, P. K., Mishra, G. C. & Chahar, B. (2000), Minimum Cost Design of Lined Canal Sections, *Water Resources Management* 14: 1–12, 2000. 2000 *Kluwer Academic Publishers. Printed in the Netherlands.*

Tiwari, K. N., & Sharma, J. (2014). Seepage characteristics of different canal lining materials. Irrigation and Drainage, 63(3), 372–379.

USGS Earth Explorer (2025). Digital Elevation Model database. United States Geological Survey.

World Bank. (2019). Groundwater in South Asia: Scaling up sustainable management. Washington, DC: World Bank.