Conjunctive Use of Groundwater and Surface Water for Buri Teesta Irrigation Project

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Abstract

Buri Teesta is basically a surface water irrigation project presently facing problems with the shortage of water from its surface source. In this study a plan for conjunctive use of surface water and groundwater for this project has been formulated. Based on the questionnaire survey, an improved cropping pattern has been developed. The crop water requirement has been estimated to be $26.3x10^6$ m^3 in Rabi season and $18.42x10^6$ m^3 in Kharif-1 for the proposed cropping pattern. The groundwater availability in the project area to meet this requirement has been predicted by applying a numerical model. It has been found that the available groundwater is adequate to meet the irrigation requirement in excess to available surface water. Three options for seasonal irrigation water supply from groundwater and surface water conjunctively have been tested. The use of groundwater for different options would have insignificant environmental impacts in the project area.

Introduction

The Government of Bangladesh has implemented many flood control, irrigation, and drainage projects to increase the food production. Most of the implemented projects were conceived initially as surface water irrigation projects. Some of these projects have areas which do not receive irrigation water because of a shortage of water and as a result, these areas of the projects remain fallow. These projects essentially demand for alternative sources of water during the Rabi season and sometimes also during Kharif II. Many studies and evaluation indicate that there is an opportunity for the use of groundwater along with the surface water in all cropping seasons. A review indicates that there is a great potential for the development of groundwater resources within the Buri Teesta Irrigation Project. It is further believed that the experience in Buri Teesta in respect of conjunctive use of surface water and groundwater will benefit the Teesta project in particular and Bangladesh as a whole. The present paper is an indicative evaluation of using groundwater in conjunction with the surface water.

Project Description

The Buri Teesta Irrigation project is located under Bangladesh water resources planning area 4 (MPO, 1987), about 42 km (26 miles) Northwest of Rangpur Town at about 25^o-45' to 26^o-15' North Latitude and 88^o-50' to 89^o-15' East Longitude. For this project a barrage was constructed over the Buri Teesta River, a distributory of the main Teesta River about 19 km (12 miles) upstream of its confluence, to retain and control monsoon and seepage flow. The project is bounded on the West by Charalkata River, on the East by Dhar Embankment and Buri Teesta River, and on the North and South by high lands and village roads. The project lies on both the banks of Buri Teesta River and covers parts of Jaldhaka, Kishoreganj, and Dimla Upazilas. The project location and the project boundary are shown in Figure 1. The gross command area of the Buri Teesta Irrigation Project as found from the records (EPC and others, 1987) is 11,887 ha (29,344 acres) and the net command area is 7,292 ha (18,000 acres). The irrigation net work has been developed to supplement water to mainly T. Aman crops in an area of 4,050 ha (10,000 acres). Area under A-11, shown in Figure 2 has been proposed to be irrigated from the main canal of the Teesta Barrage Project which is one of the largest irrigation projects of its type in Bangladesh.

After the construction of Teesta barrage in 1990, the original irrigable area under the Buri-Teesta irrigation project is reduced from 10, 117 ha to 2, 232 ha. The downstream part of canal BC-I, BC-II and BC-III are now operating under Teesta Barrage Project (Figure 2). The length of the main canal is almost same (10.94 km). But the length of BC-I, BC-II and BC-III was reduced about 20%, 80% and 67%, respectively. The total reservoir area is 492 ha. But there is a decrease in the bottom level of reservoir as bed level has uplifted about 1 m from 162 PWD to 163 PWD due to the annual sedimentation. Dredging is the only solution left to increase the reservoir capacity.

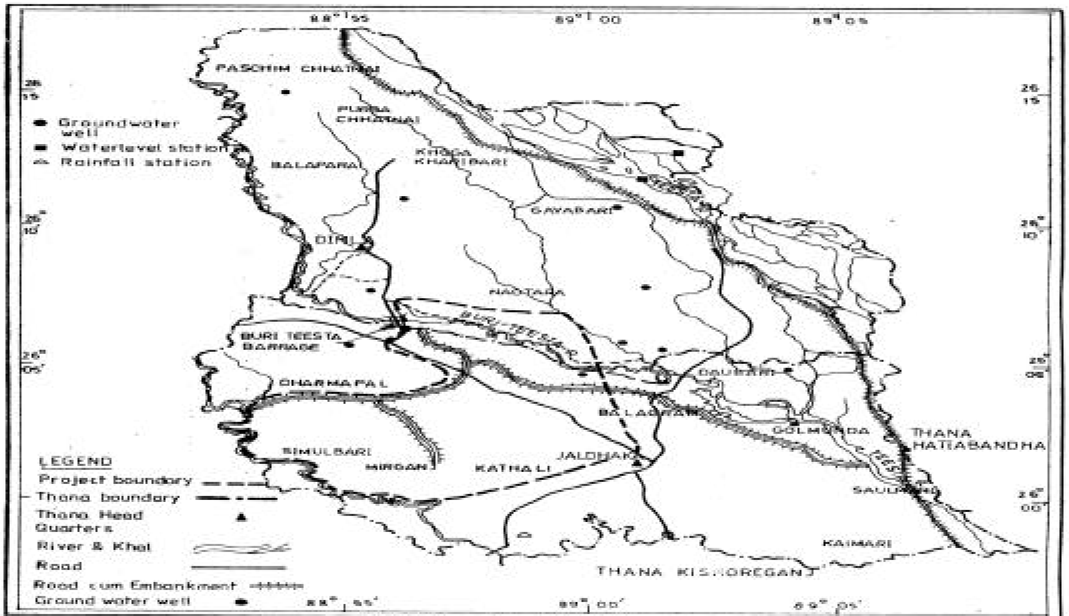

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Figure 1: Project Location with Boundary

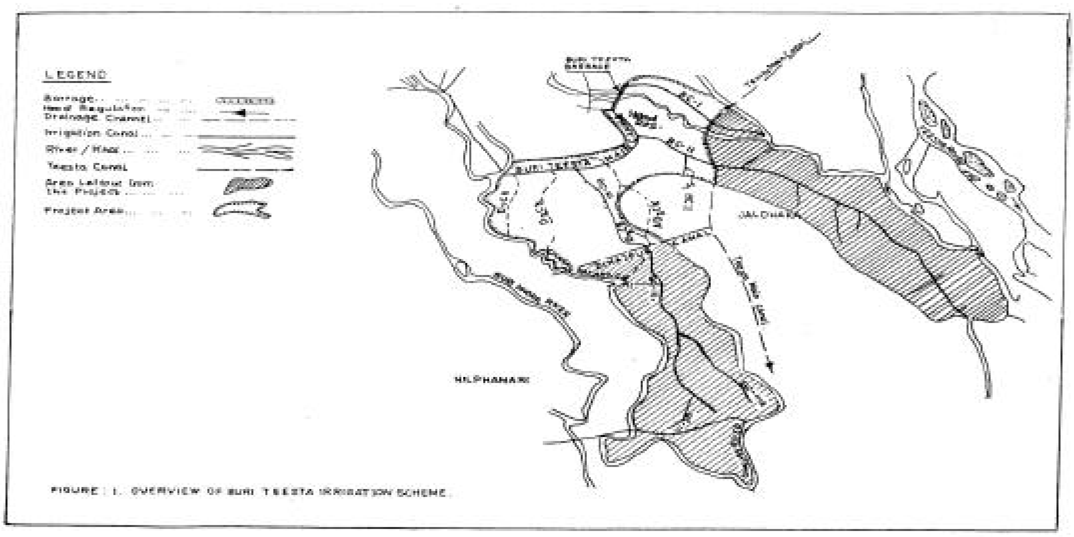

Figure 2. Overview of Buri Teesta Irrigation Project

Proposed Cropping Pattern

The existing cropping pattern data for the project area has been collected from the project office. Based on the questionnaire survey, the future cropping pattern has been developed. The major changes in the cropping patterns has occurred during Kharif-I and Rabi seasons. The cropping pattern for Kharif-II season almost remains same . The questionnaire survey among the farmers of different groups in the project area indicates that there would be 30% of increase of land under cultivation, if water is available for irrigation. Farmers like to change their cropping pattern for more beneficial crop like IRRI (65%). The total irrigable land is not used for crop production in Kharif-I season, only 77% will be used even if water is available because, farmers found that some of the land would not be suitable for IRRI production or for other traditional crop during Kharif-I. At present Jute is growing in 24% of land because it needs almost no irrigation. But, if water is available farmers are willing to go for IRRI production.

Crop Water Requirement

Estimation of crop water requirement is based on the reference crop evapotranspiration and the crop coefficients. There are several methods (FAO, 1977) available for estimating reference evapotranspiration. The applicability of their use have been studied by several authors (FAO, 1977, Hoque, 1978) on the basis of their sensitivity to the climatic factors. Based on the recommendations (Hoque, 1978), the Penman Monteith equation has been used for estimating, ETo, the reference evapotranspiration(Hoque and Islam, 2000) for the present study. The crop water requirement may be estimated as

The crop evapotranspiration (ETcrop) may be estimated as

$$ET_{crop} = ET_o \text{ x } K_c \qquad (1)$$

where K_c is the crop coefficients whose values depend on the type of crops and the stages of plant growth.
The crop net irrigation requirement (I_{net}) depends on the effective rainfall (R_e), water required for land preparation (W_{LP}) for a particular crop, percolation loss (P_L) from the crop field, groundwater contribution (GWc) to the root zone, and irrigation efficiency (Eff).

$$I_{net} = (ET_{crop} + P_L – GW_c – Ref)/ E_{ff} \qquad (2)$$

$$Ireq = Inet + LP \qquad (3)$$

In the present study GW_c has been taken as zero. The effective rainfall has been estimated by the US Soil Conservation Service formula (Dastane, 1978). For Rabi crops water requirement for land preparation (LP) has been taken as zero and for Kharif-I and Kharif-II LP has been taken as 200 mm and 150 mm, respectively (MPO, 1985a). For Teesta Irrigation Project LP has been taken as 170 mm (WRE and IFCDR,1996). The irrigation conveyance efficiency has been taken as 70% (MPO, 1985b). Net irrigation requirement as estimated is presented in Table 1.

Model Preparation

A three-dimensional finite difference groundwater model MODFLOW has been selected for this study. The MODFLOW model (McDonald and Harbough, 1988) has been developed by the United States Geological Survey(USGS). The model may be described by the following partial-differential equation:

$$((\partial/\partial x(k_{xx} * \partial h/\partial x) + \partial/\partial y(k_{yy} * \partial h/\partial y) + \partial/\partial z(k_{zz} * \partial h/\partial z) - W = Ss * \partial h/\partial t \qquad (4)$$

Where, k_{xx} , k_{yy} , k_{zz} are values of hydraulic conductivity along the x, y and z coordinates, which are assumed to be parallel to the major axes of hydraulic conductivity (Lt^{-1}); h is the potentiometric head (L); W is a volumetric flux per unit volume and represents sources and sinks of water (t^{-1}); S_s is the specific storage of the porous material (L^{-1}) ; and t is the time (t). In general, S_s, k_{xx}, k_{yy}, and k_{zz} may be functions of space such as $S_s = S_s(x, y, z)$, $k_{xx}=k_{xx}(x,y,z)$, etc. and W may be a function of space and time (W=W(x,y,z)).

Table 1: Cropwater requirement for proposed cropping pattern in Rabi

Week	Net Irrigation Kharif-1 (mm)	Net Irrigation Kharif-2 (mm)	Net Irrigation Robi (mm)
1	24.5	0	9
2	33	0	37.2
3	33.7	0	52
4	34.3	0	70.3
5	34.8	36.5	78.1
6	35.7	29.6	81.7
7	36.8	28.8	96.9
8	37.6	28.4	104.8
9	38.4	28	112.7
10	38.5	27.4	119
11	38.5	27	121..3
12	38.5	26.1	108.4
13	37.9	25.2	113.6
14	37	24.2	114.2
15	33.7	23.4	101.5
16	17.7	22.5	86.8
17		21.3	59
18		20.3	
19		13.9	

Model Schematization and Calibration

The model area is bounded by Teesta river on side and other side is partly by Buri Teesta river and partly by Thana boundary. The Buri-Teesta project area is located well within the model boundary. The total area within the model boundary is 637 sq.km. where the total project area is only 110 sq.km. The time variant river water level would be used as boundary conditions of the model where possible, however, the time variant groundwater level would also be used for the area where river does not make the boundary. To facilitate the schematization process, the model area has been first considered as a regular rectangular area of about 40 km in length and 27 km in width. The whole model area is divided into a set of rectangular grids of 17 columns and 22 rows. The grid size is 1.8 km x 1.6 km. The upper left corner grid is considered as (0,0) node. The initial model run has considered the whole layer as a homogeneous unconfined aquifer of a depth of 80 m from ground surface. The ground surface slope has been ignored when considered aquifer thickness, but for groundwater table, the slope has been taken into account.
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The model calibration and verification have been performed with the data of 1994 Rabi-season due to the availability of all the data required by the model.

Conjunctive Use of Groundwater and Surface Water

The total demand for Rabi is about 1500 mm, for Kharif-I is 1050 mm, and for Kharif-II is 800 mm. For land preparations, Kharif-I and Kharif-II require 200 and 150 mm of water, respectively. The cropping pattern of the project area during Rabi season does not require any water for land preparation. The total requirement, therefore, for whole year is about 3250 mm. The surface area of the Buri-Teesta reservoir is about 492 ha and the total irrigable area is 1750 ha which is almost 3 times of the reservoir surface area. Therefore, considering regular vertical side of the reservoir, withdrawal for 1 mm of irrigation over the irrigable land causes the reservoir water level fall by about 3 mm.

Figure 3 shows the conditions of Buri-Teesta reservoir water level during Rabi and the Kharif-I seasons for different conditions of irrigation. At the beginning of Rabi season, the reservoir water level is 51.75 m PWD and the limiting water level is about 49.35 m PWD. The limiting water line shown in Figures 3, 4, and 5 indicate that if the reservoir water level goes below this level, the field distribution canals would not receive any water from the reservoir. Figure 3 shows that 50% of total demand for Rabi can be met from the reservoir water until the 4th week of February which covers almost first 67% of the growing season and then the water level falls below the limiting water level and continues to be there during rest of the Rabi and total Kharif-I seasons. So, the reservoir can meet the demand for 50% of the irrigable land during the first 13 weeks of the Rabi season. The other 50% of irrigable land, during the first 13 weeks of Rabi irrigation, depends on groundwater. Rest of the Rabi and the total of Kharif-I seasons fully depend on groundwater. Figure 3 further shows that when 25% or 20% irrigation water is withdrawn from the reservoir, and 75% or 80% from groundwater, the reservoir water is available until the end of March and the first week of April, respectively and afterwards the reservoir level remains at or below the limiting water level. When 10% of irrigation requirements are met from reservoir and 90% from groundwater the reservoir supply is available for this amount for both Rabi and Kharif-1 seasons except for 3 weeks of Kharif-1 which starts from the second week of May and continues there to the end of May.

Figure 4 shows the conditions when reservoir water supply is considered for Rabi season irrigation only. From the analysis it is found that at least 25% of irrigation for total growing season can be safely done by reservoir water and rest 75% should be done by groundwater. But in Kharif-I, at least for some time of the irrigation season total water to be supplied from the groundwater source. As a result, the groundwater development provision must include the capability of covering the whole irrigable land of the project. Figure 4 also shows when 50% of water is supplied from reservoir and 50% from groundwater conjunctively from the beginning of the season, the reservoir water is available for 13 weeks of the growing season and for rest of the season, the irrigation is fully dependent on groundwater. But with the options of 25% from reservoir and 75% from the groundwater, the reservoir water is available for the whole Rabi season. In this options, no water will be available in the reservoir for Kharif-I season. So, the Kharif-1 will be fully dependent on the groundwater. Figure 5 shows if total water is kept for Kharif-I, even then the reservoir water is not enough for the irrigation requirement throughout the season. It is found from the figure that during the first four weeks of irrigation the reservoir level goes below the limiting line for two times altogether almost for a week. So, when reservoir water is not available, the irrigation is fully dependant on groundwater.

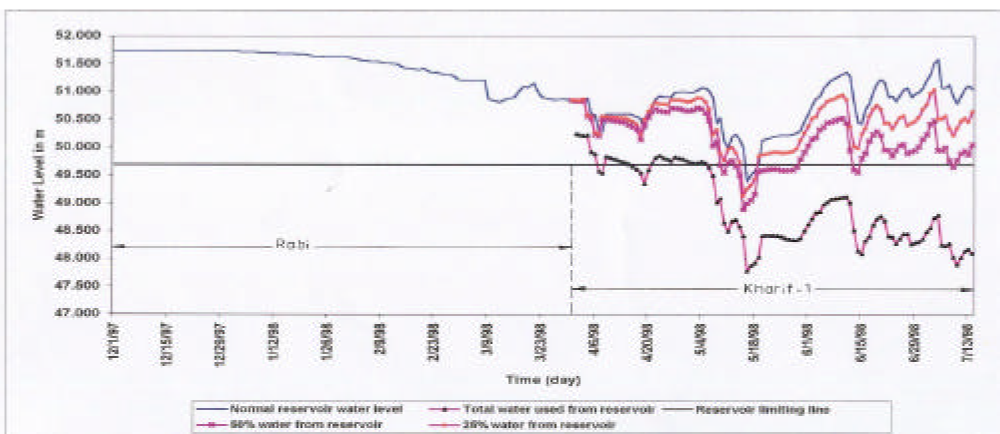

Figure 3 : Reservoir Water Level at Different Conditions of Water Withdrawal for both Rabi and Kharif-1 Seasons

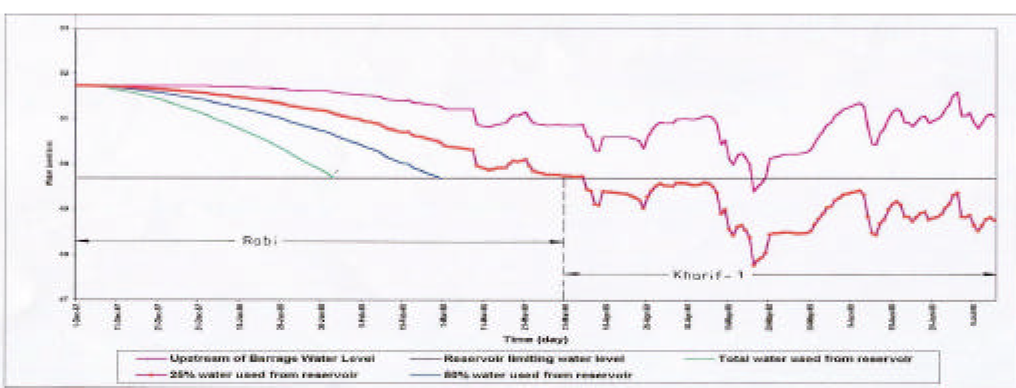

Figure 4 : Reservoir Level at Different Conditions of Water Withdrawal for Rabi Crops.

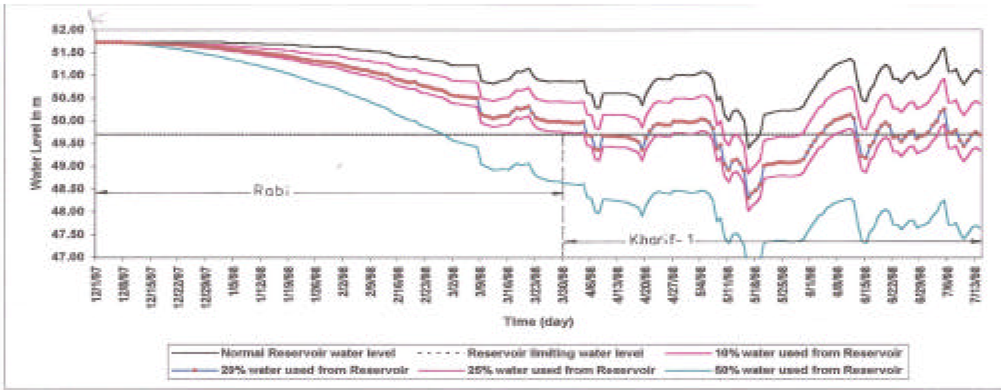

Figure 5 : Reservoir Level at Different Conditions of Water Withdrawal for Kharif-1 Crops.

For supply of 50% of reservoir water and 50% of groundwater the reservoir water is available for 8 weeks and to supply 25% from reservoir water and 75% from groundwater, reservoir water is available for about 10 weeks. Figure 5 also shows that the reservoir water levels falls below the limiting line even the reservoir water is not used at all for the irrigation.

The conditions described above indicate that Rabi is partially and Kharif-1 is fully, at least for sometime of the season, dependent on groundwater for total coverage of irrigation. Therefore, planning for tube wells to extract groundwater should be done to a maximum supply up to full irrigation from groundwater alone. Based on the situations discussed above the following three options has been analyzed in terms of groundwater availibility:

1) To supply 50% of irrigation water from reservoir and 50% from groundwater during the first 13 weeks of Rabi season and total requirement from groundwater for rest of the Rabi and for full Kharif-1 seasons.
2) To supply 25% of irrigation water from reservoir and 75% from groundwater during Rabi season and total requirement of Kharif-1 from groundwater.
3) To supply 10% of irrigation water from reservoir and 90% from groundwater during Rabi season and first 5 weeks of Kharif-1 and total requirement for rest of Kharif-1 from groundwater.

To meet the irrigation requirement of Buri Teesta Project with option for full coverage from groundwater as many as 75 tube wells would be required considering average capacity of the tube well is 2 cusec and the coverage by each tube well is about 24 ha. The position of groundwater table due its withdrawal to supply irrigation water for options 1, 2, and 3 described earlier in the Rabi and Kharif-I seasons is simulated using the MODFLOW model.

Impacts of Groundwater Use

The withdrawal of groundwater for irrigation and other purposes has negative impacts on environment and it is necessary to assess this impact while planning for withdrawal. In the present study such impacts in terms of effect on drinking water tube wells have been evaluated. Information about the water level of drinking water tube wells has been collected from the Department of Public Health Engineering (DPHE) by personal communication. Based on the collected data from DPHE, the average limiting level of drinking water well is set to 33.6 m, PWD. To evaluate the impacts of groundwater withdrawal for different options of irrigation as set earlier to analyses, this limiting water table has been considered as base line. Then the conditions of groundwater table, for 3 options has been compared with the limiting conditions. Earlier, simulation of the conditions of groundwater table after withdrawal for each of 3 options has been described. Groundwater tables after withdrawal as per option 1 has fallen to a minimum level of 40 m and 42.5 m PWD at two nodes. In other nodes of the modeled area, the water table for option 1 remain above that of those two nodes. So the option 1 would not create any problem for drinking water supply by shallow tube well. Using groundwater as per option 2, water level has fallen to its minimum at a level below the limiting line at 33.6m, PWD in one node and in other nodes the water table is higher than 33.6 m which is the limiting level for drinking water tube well to remain in operation. This would create problems for drinking water tube wells in the area close to two nodes of the project area. When groundwater is used as per option 3, the level again goes below the limiting condition at those two nodes. So, the option 2 and 3 are causing the water table fall below the drinking water limiting level during April-May in some are of the project. This will create problems for drinking water tube wells of this area to supply water to the people.

It has been observed that only 2 nodes out of 374 are affected by groundwater withdrawal for irrigation with the options 2 and 3. To avoid of this problem, deep set shallow tube well (DSSTW) can be used for drinking water purpose. Depending on this analysis it is suggested that option 1 to be followed for irrigation in the Buri Teesta Project area, if shallow tube well are not replaced by the Deep Set Shallow tube wells.

Conclusions

Based on the study, the following conclusions may be made:

1. Availability of surface water in the Buri-Teesta Reservoir has been found inadequate to meet the project requirement both in Rabi and Kharif-I seasons. Therefore, groundwater must be developed for Buri Teesta irrigation during Rabi and Kharif-I seasons.
2. The model study shows that the Buri Teesta project has potential for groundwater irrigation during Rabi and Kharif-I seasons. The model study further shows that during May to July, the natural recharge in the project area is more than the proposed withdrawal for irrigation.
3. The groundwater use has environmental impact in the area in terms of effects on the shallow or drinking water well.
4. The results of the present study supports the use of groundwater for overall economic development of the project area.

References

1. Dastane, N. G.(1978), Effective Rainfall in Irrigated Agriculture, FAO Irrigation and Drainage paper 25, Food and Agriculture Organization of the United Nations, Rome, Italy, pp62

2. EPC and others (1987a), Rehabilitation of Water Development Project, Draft Feasibility Report, Buri-Teesta Irrigation Project (Sub-Project-1),Dhaka, Bangladesh.

3. FAO (1977), Crop Water Requirements, Guide lines for Predicting Crop water Requirements, Food and Agriculture Organizations of the United Nations , Paper No.24 (revised), Rome, Italy.

4. Hoque, M.M. (1978), Evapotranspiration and its Sensitivity to Meteorological Factors, M.Sc. Thesis, University of Southampton, Southampton, U.K.

5. Hoque, M. M. and S. Islam (2000), Conjunctive Use of Groundwater and Surface Water for Irrigation in Buri Teesta Irrigation Project, Final Report, R03/2000, Institute of Flood Control and Drainage Research, Bangladesh University of Engineering and Technology, Dhaka.

6. McDonald, M.G. and Harbough, A.W. (1988), A Modular Three-Dimensional Finite Difference Groundwater Flow Model, Techniques for Water Resources Investigation of the United States Geological Survey, USA, Book 6, Chapter 4.

7. MPO (1987), Surface Water Availability, Technical Report No.10, Ministry of Irrigation, Water Development and Flood Control, Government of the People Republic of Bangladesh, Dhaka, Bangladesh.

8. MPO (1985a), Improvement of Irrigation Water Management, Technical Report No.3 Master Plan Organization, Ministry of Irrigation Water Development and Flood Control, Government of the People’s Republic of Bangladesh, Dhaka, Bangladesh.

9. MPO (1985b), Irrigation Water Requirements, Technical Report No. 2, Master Plan Organization, Ministry of Irrigation Water Development and Flood Control, The Government of the People’s Republic of Bangladesh, Dhaka, Bangladesh.

10. WRE and IFCDR (1996), Review and Optimization of Planning and Design of Irrigation and Drainage System of Teesta Barrage Project, Preliminary Review Report, Bureau of Research, Testing and Consultation, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.