IRRIGATION SCHEDULING IN A CANAL COMMAND AREA
A CASE STUDY

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in thesis entitled "Irrigation Scheduling in A Canal Command Area A case study", in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Irrigation Water management, submitted in the Department of Water Resources Development Management, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period from July 2004 to June 2005 under the supervision of Dr. Deepak Khare, Associate Professor Department of Water Resources Development Management, Indian Institute of Technology Roorkee, and Dr. S.K. Mishra Assistant Professor Department of Water Resources Development Management, Indian Institute of Technology Roorkee.

I have not submitted the matter embodied in this thesis for the award of any other degree.

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Roorkee, ..26... June 2005

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ABSTRACT

Irrigation is important for agricultural production, specifically in arid and semi arid regions where rainfall is inadequate to sustain crop growth. Now a day, it has become essential for increasing and stabilizing the production to feed the ever increasing world population. The world has experienced a large investment in irrigation sector, more particularly in the past few decades, and irrigated areas almost doubled. Since the water resources have become increasingly scarce, more water is likely to be diverted from agriculture to meet human and urban consumption requirements in near future.

The frequent water shortages, farmers often facing deficiencies in water deliveries due to poor management of available water have resulted in reduced yields and incomes. Both at the system and farm levels, there exist a range of problems that abate reduce the benefits of irrigation investments significantly. On the other hand, the excessive use of water has also led to a range of environmental problems such as waterlogging, leaching of agro-chemical, and consequent groundwater pollution.

Irrigation scheduling is a basic tool to improve water use efficiency, and enhance yields, and to maintain the quality of soils and ground water as well. The research results over the past decade have led to enhanced knowledge on plant-water relations useful for judicious irrigation management and, in turn, the improved water use efficiency.

This study is primarily aimed at to determine crop water requirements and irrigation water requirements to suggest a suitable cropping pattern for command area of Way Sekampung Irrigation Project, an agricultural improvement scheme. To this end, the available CROPWAT program which is a decision support system developed by the land and water development Division of FAO was employed. This program is able to compute reference evapotranspiration, crop water requirement, and crop irrigation requirement; to develop irrigation schedules under various management conditions and scheme water supply; and to evaluate rainfed production and drought effects and efficiency of irrigation practices. The present analysis however attempted to study the effect of various governing factors, such as stipulated irrigation efficiency, staggering of planting date, irrigation scheduling option, maximum infiltration to soil, maximum rooting depth, on field water supply (FWS). The last three factors were found to have insignificant influence on the computed field water supply. The sensitivity analysis showed FWS to decrease with increase in irrigation efficiency. The rate of decay of FWS increased significantly as the date of plantation shifted from November 15 to October 15. Since both the factors equally affected the FWS, the judicious consideration of either or both of these can lead to enhancement of irrigation output with reduced water supply.

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CHAPTER I

INTRODUCTION

1.1 . GENERAL

Irrigation is essential for agricultural production in arid and semi arid regions where rainfall is inadequate to sustain crop growth. Indeed, in more humid areas irrigation has now become the primary tool to increase and stabilize agricultural production in view of uncertainties of rainfall and frequent droughts, and to feed the ever increasing world population.

Worldwide, large investments in irrigation engineering works have been made over the past decades and irrigated areas have almost doubled. Water resources have, however, become increasingly scarce and the competition for good quality water is forecast to divert more water from agriculture to human and urban consumption.

Water shortages have become more frequent and farmers often face deficiencies in water deliveries, resulting in reduced yields and incomes. Furthermore poor management of available water for irrigation, both at system and farm level, has led to a range of problems and further aggravated water availability, and has reduced the benefits of irrigation investments.

Excessive use of water has also led to a range of environmental problems such as waterlogging, leaching of agro-chemical and consequent groundwater pollution. Salinization of soil and ground water resources due to inappropriate water use is threatening large areas of productive irrigated land.

Irrigation scheduling is the primary tool to improve water use efficiency and raise yields and it will in turn lead to higher incomes and greater availability of water resources, and provokes a positive effect on the quality of soils and ground water. Research results over the past decade have importantly improved our knowledge on plant-water relations and provided a large number of tools which can potentially enhance irrigation management and substantially improve irrigated crop production and water use efficiency. Despite considerable efforts to promote the introduction of modern irrigation scheduling tools, their application in practice has so far fallen well below expectations.

1.2. NEED OF IRRIGATION SCHEDULING

Irrigation is essential for food production to overcome deficiencies in rainfall and to stabilize agricultural production especially in arid and semi-arid areas. The food requirements of an ever-increasing world population necessitate higher agricultural production, a large share of which comes from irrigated lands. The availability of water resources for irrigation has become a severely limiting factor, leading to reduction in irrigated agriculture.

Extensive engineering programmer have been undertaken worldwide not only to make available the large amount of water required for irrigation but also for other purposes, such as urban and industrial use. At present approximately 80 % of all the available fresh water supply is used for agricultural and food production. The demand for water of good quality has accordingly increased tremendously in the last decade.

The efficiency of water in agricultural production is, however, low. Only 40 to 60% of the water is effectively used by the crop, the remaining water is lost in the system in the farms and on the field, either through runoff to the drainage system or by percolation into the groundwater. Part of the lost water can perhaps be recovered, but additional cost will be incurred.

Poor management of irrigation water is one principal reason for this low water use efficiency in irrigation. The inadequate and often unreliable water deliveries in the main system cause farmers to face regular shortages in water supply, resulting in reduced yield and incomes as well as in much smaller areas being irrigated than originally planned. At field level, inappropriate field layout and mismanagement leads to further water losses and reduced yields.

Irrigation scheduling is the process to decide when to irrigate the crop and how much to apply. It forms the sole means for optimizing agricultural production and for conserving water and is the key to improving performance and sustainability of the irrigation system. It requires good knowledge of the crop water requirement and of the soil water characteristic that determine when to irrigate, while the adequacy of the irrigation method determine the accuracy of how much water to apply. In most cases, the skill of farmers determines the effectiveness of the irrigation scheduling at field level. As such the appropriate irrigation scheduling should lead to improvements in yield and incomes, result in water saving and, in turn, increase the availability of water resources and should have a positive impact on the quality of soils and ground water.

1.3. OBJECTIVE OF THE STUDY

The main objective of the study is to determine crop water requirements and irrigation water requirements, suggest a suitable cropping pattern, and schedule irrigation for the command area.

1.4. SCOPE OF THE STUDY

The basic components of the proposed study area are:

1. It deals with introduction of the issues and statement of the objective, scope and study area.
2. Analysis of crop water and irrigation water requirement for the command area of Way Sekampung Irrigation Project.
3. Study of irrigation practiced with the existing cropping patterns in the command area of Way Sekampung Irrigation Project.
4. Application of computer software "CROPWAT" for irrigation scheduling.
5. Analysis for different irrigation scenarios with varying cropping pattern and other governing parameters.

1.5. ORGANIZATION OF DISSERTATION

This thesis is composed of the following six chapters:

Chapter I:	Introduces the need for irrigation scheduling, objective of irrigation scheduling study, scope of study and organization of dissertation.
Chapter II:	Deals with literature review of the approaches available for improvement of irrigation scheduling.

Chapter III:	Bounds description of the Project Area and outlines the present conditions of Way Sekampung Irrigation system.
Chapter IV:	Deals with the methodology adopted for irrigation scheduling.
Chapter V:	Presents the analysis and discusses the results of derived from "CROPWAT"application
Chapter VI:	Summaries and Concludes the study.

CHAPTER II

LITERATURE REVIEW

2.1 GENERAL

Irrigation scheduling is a part of water distribution planning in the command area of an irrigation project. It is an important aspect of irrigation project planning but generally ignored in project preparation stage. While analyzing irrigation development during the project life, it is important to consider likely water deficit condition, resulting in yield reduction, and plan for irrigation scheduling to manage water deficits at micro field and macro project level.

During operation stage, conventional procedure of water distribution planning is to prepare a roster of regulation for canal network specifying discharge and running days for each segment of canal network. It is prepared at the beginning of a crop season and published for the information of farmers. Modification in the roster is made if there is unexpected rain or other reason beyond control.

During project preparation stage irrigation scheduling is accounted for in terms crop type, number of watering and depth of irrigation. Thus, there is a lot of subjectivity in assessment of demand and the procedure for meeting the spatially distributed irrigation demand. With availability of software such as CROPWAT and others, it is possible to carry out irrigation scheduling and water distribution planning in more scientific manner.

2.2 CROP PLANNING

The objective of crop planning is to evolve a cropping pattern, which maximizes the socio-economic benefits of irrigation. Cropping pattern means the proportion of area under different crops at a particular period of time. A change in cropping pattern means a change in the proportion of area under different crop. Canal operation schedule is based on cropping pattern and crop water demand. Development of a realistic cropping pattern needs no emphasis. With introduction of irrigation water, farmers go for their own selection of crops.

Correct evaluation of economic, social and ecological factors (rainfall, temperature, soil etc) is necessary to make the crop planning realistic. A designed cropping pattern should have a fair chance of being implemented in field. A too ambitious or pessimistic design can throw the planning machinery into disarray and cause lot of confusion and manipulations at the implementation stage. Factor influencing a cropping pattern and source of information are briefly explained in table 2.1

2.2.1 Cropping Pattern

With assured irrigation, farmers tend to adopt commercial crop (cash crop). Wide discrepancies have been observed in design cropping pattern and actual cropping pattern.

Irrigation demand, planning and design of irrigation facilities and economic feasibility of the project as a whole depend upon the designed cropping pattern. Actual cropping patterns are drastically different from the designed cropping patterns for several project commands in Indonesia indicating serious deficiencies in socio-economic survey/investigations during the planning stage. Economic considerations, unreliability and inadequacy of water supply and lack of on-farm development work have mainly influenced adoption of particular cropping patterns by the farmers in these project commands. Several other input and support services are needed for realization of design pattern.

2.2.2. Contingency Planning

In the economic analysis of irrigation project, assume data on cropping pattern, crops prices etc., are pressured to be know with certainty. They are, however, not in the real world. Price and yields change, causing risk and uncertainty in the crop planning.

Risk: Future outcome is not known with certainty, however, it is known what the future outcomes could be and probabilities associated with them. Examples of risk causing factors are hail, rain draught and floods and one can insure against these risks.

Table 2. 1. Factors & Source of Information for Crop Planning

ITEM	REFERENCE	ITEM WHICH IS INFLUNCED
Rainfall	National Commision on Agriculture's Report on State Rainfall and Cropping Pattern	a. Type of crops b. Sowing dates and harvesting dates
Sunshine hours Pan evaporation Relative Humidity, Wind Velocity	1. Metrology Departement 2. Agriculture University/Research Stations 3. Major Project Stations	Crop Water Requirement of different crops in different forthnight
Soil and Topography	1. National Bureau of Soil Survey & Land Use Planning 2. State Agriculture Departement	1. Type of Crops 2. Frequency of Irrigation 3. Method of Irrigation
Communications Cultivated area, cash and tenant Ethnographic descripition)	Socio-economis survey report	Farmer's choice orientatsation of crop will be based on Socio-cultural factors.
Communications cultivated area, cash and credit, availablity of farmyard manure, bullock power, holding size, education	Socio-economis survey report	Farmer's choice of crops
Support price and market price of ceops	Radio, Television, Newpaper and market survey's	Farmer's choice of cash crops supplemental to his consumption need
Marketablity-means of communication	District Planning Reports	1. Farmer's choice of crops which produce marketable surplus 2. Choice of perishable crops
Locaton of Agro Industries	District Planning Reports	Crops required by and supported by the Industry will be preferred by farmers
	Agricultural & Animal husbandry Dept., Socio-economic survey	Choice and extent of fodder crops

Uncertainty: Manager is not aware of different outcomes and cannot assign any probabilities to these items. One cannot reasonably ensure against uncertainty (fire, wind, war, and political change).

In every business there are risks but farming probably has more than its share. Heavy rains may damage some or all of the crops; a severe drought may burn them up. Right up to the day of harvest, a hailstorm may destroy them. Insects or diseases of crops may reduce the crop yields seriously or wipe it out entirely; likewise a disease of epidemic proportions may attack certain livestock and cause heavy losses. The magnitude of risks and uncertainties to which a farmer's fortune exposed is very large. Change of agricultural technology may make fixed assets become obsolete rapidly when whole new production systems are adopted. The government and other institutions can change tax laws, credit program and other factors relating to rain field/irrigated farming, causing, and uncertainty in crop planning.

2.3 WATER REQUIREMENT

Crop water requirement is defined as the quantity of water utilized by the plant during its lifetime; this water may be supplied either entirely by rainfall, entirely by irrigation or by a combination of both. The water requirement of a chosen cropping pattern is compared with the available water resources to determine the maximum cropping intensity and extent of irrigable areaThe consecutive steps involved in calculating net crop water requirement and the irrigation supply to supplement rainfall are given in Fig 2.1 and discussed below:

2.3.1 Reference Crop Evapotranspiration (ETo)

Reference Crop Evapotranspiration (ETo) represents the rate of evapotransiration of an extended surface of an 8 to 15 cm tall green grass cover, actively growing, completely shading the ground and short of water.

There are several methods of calculating ETo, the best review of these is provided by FAO Irrigation and Drainage paper No.24 "Crop Water Requirement". mean daily climatic data for 30 or 10 day periods. ETo is expressed in mm/day and represents the mean value over that period. The reported four methods, Blaney – Criddle, Radiation, Penman and Pan evaporation method, are modified to calculate ETo using the Primarily the choice of method must be based on the type of climatic data available and on the accuracy required in determining water needs.

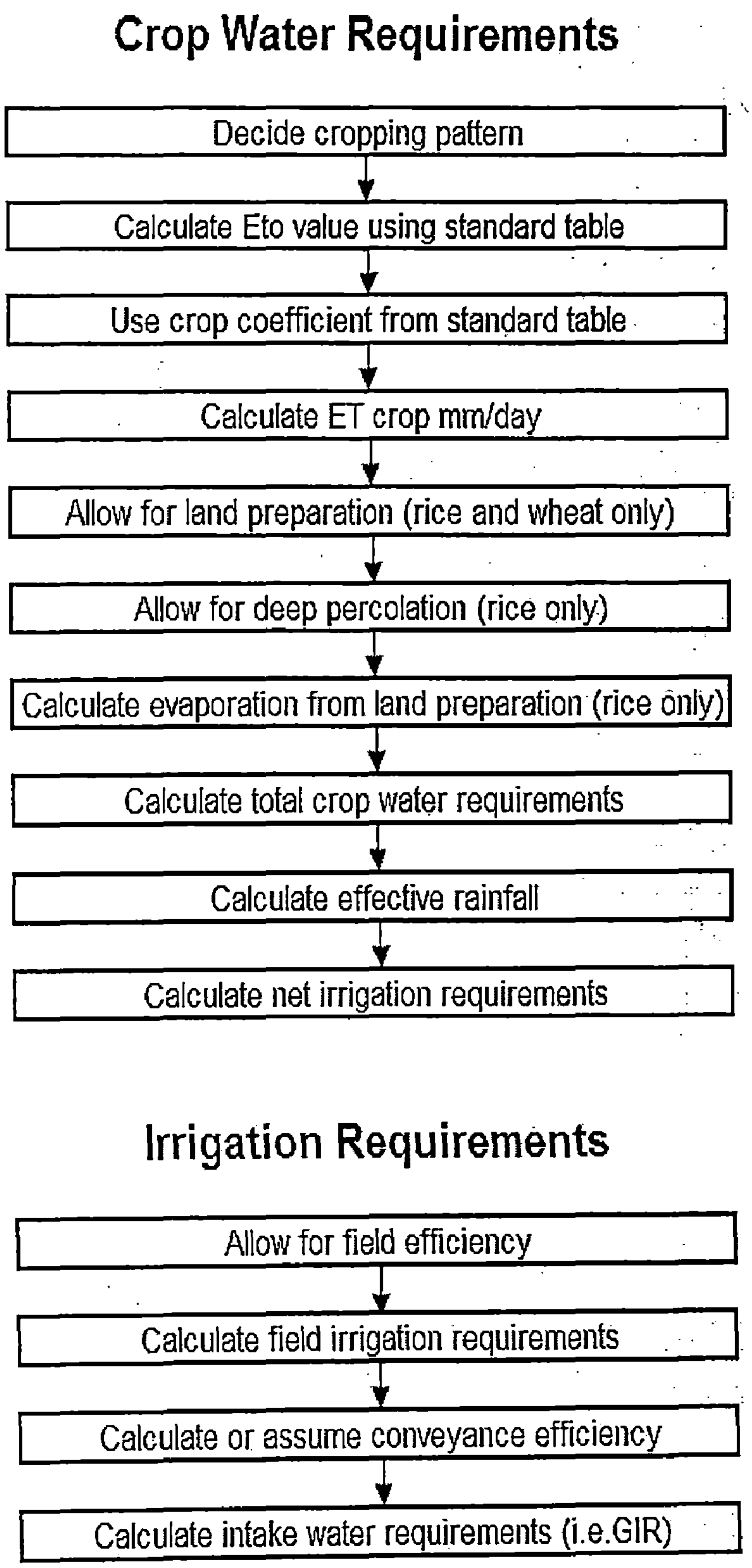


Fig.2.1. Flowchart Showing Crop Water Requirement and Irrigation Requirement

Climatic data needed for the different methods are:

Method	Temperature	Humidity	Wind	Sunshine	Radiation	Evaporation
Blaney-Criddle	*	0	0	0		
Radiation	*	0	0	*	(*)	
Penman	*	*	*	*	(*)	
Pan evaporation		0	0			*

* Measured data; 0 estimated data; (*) if available, but not essential

Concerning accuracy, only approximate possible errors can be given since no base-line type of climate exists.

The modified Penman method offers the best result with minimum possible error of plus or minus 10 percent in summer, and up to 20 percent under low The Pan method can be graded next with possible error of 15 percent, depending on the location of the pan. The radiation method, in extreme conditions, involves a possible error of up to 20 percent in summer. The Blaney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter condition an over, and under prediction of up to 25 percent has been noted. The Penman method is recommended for crop water requirements in Indonesia. The form of the modified Penman method is:

$$ETo = \{W.Rn + (1-W).f(u).(ea-ed)\} \quad (2.1)$$

Where:

ETo = Reference Crop Evapotranspiration.

e_a = saturation vapour pressure at mean temperature in m/bar (FAO, No 33, Table 9) (Appendix D).

e_d = actual vapour pressure e_a x RH_{mean} / 100 (m bar).

f(u) = Wind function

f(u) = 0.27 (1+U/100) where, U is 24 hour wind run in km/day at 2 m height

W = Temperature and altitude dependent weighting

R_n = Total net radiation in mm/day or

R_n = Rs – Rnl where,

Rs = Incoming short wave radiation in mm/day either measured or obtained From:

Rs = (0.25 + 0.50 n/N) Ra

Ra = extra – terrestrial radiation in mm/day (Table 10, Appendix D)

n = mean actual sunshine duration in mm/day

N = maximum possible sunshine duration in hour/day (Table 11, Appendix D)

Rnl = net long wave radiation in mm/day and

Rnl = f(T) . f(n/N) . f(e_d) where,

f(T) = function of temperature (Table 12, Appendix D)

f(e_d) = function of actual vapour pressure (Table 13, Appendix D)

f(n/N) = function of the ratio of sunshine duration (Table 14, Appendix D)

W = temperature and altitude dependent weighting (Table 15, Appendix D)

C = adjustment factor for ratio U day/U night, for RH_{max}

2.3.2 Crop Coefficient (Kc)

To account for the effect of the crop characteristics on crop water requirements, crop coefficients (Kc) are presented to relate ETo to crop evapotranspiration (ET crop). The Kc value rates to evapotranspitration of a disease-free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment. ET crop can be found by : Etc = Kc.ETo.

Crop coefficients are given Table 2.2 for a range of crop length and planting dates for suitable varieties of most commonly irrigated crops in Indonesia. The crop coefficients are based on those provided in FAO Irrigation and Drainage Paper No.24 adjusted for length of season where necessary.

2.3.3 Land Preparation Requirement

For estimation of land preparation water requirement, "Irrigation Design Standard" prepared by Directorate General of Water Resources Development, Ministry of Public Works, were referred to. A supporting report for these standard, "Irrigation Design Manual" Stipulates the procedure of estimation of land preparation water requirement as follows:

$$LP = M\,e^k / (e^k - 1) \qquad (2.2)$$

Where,

LP : land preparation water requirement (mm/day)

M: Water requirement to compensate for evaporation and percolation of the fields already saturated, M = Eo + P.

Eo : open water evaporation during land preparation, Eo = 1.1 x Eto

k = M.T/ S

T : land preparation period, 30 days

S : presaturation requirement added with 50 mm water layer, 250 mm

P : percolation : 3.5 mm/day in the rainy season and 4.0 mm/day in dry season.

Table 2.2. Crop Coefficient

Crop	Crop Development Stage					Total Growing Period
	Initial	Crop Development	Mid-Season	Late Season	At Harvest	
Banana						
Tropical	0.4-0.5	0.7-0.85	1.0-1.1	0.9-1.0	0.75-0.85	0.7-0.8
Sub Tropical	0.5-0.65	0.8-0.9	1.0-1.2	1.0-1.15	1.0-1.15	0.85-0.95
Bean						
Green	0.3-0.4	0.65-0.75	0.95-1.05	0.9-0.95	0.85-0.95	0.85-0.9
Dry	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.25-0.3	0.7-0.8
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0	0.8-0.95	0.7-0.8
Cotton	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9	0.65-0.7	0.8-0.9
Grape	0.35-0.55	0.7-0.8	0.7-0.9	0.6-0.8	0.55-0.7	0.55-0.75
Groundnut	0.4-0.5	0.7-0.8	0.95-1.1	0.75-0.85	0.55-0.6	0.75-0.8
Maize						
Sweet	0.3-0.5	0.7-0.9	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
Grain	0.3-0.5	0.7-0.85	1.05-1.2	0.8-0.95	0.55-0.6	0.75-0.9
Onion						
Dry	0.4-0.6	0.7-0.8	0.95-1.1	0.85-0.9	0.75-0.85	0.8-0.9
Green	0.4-0.6	0.6-0.75	0.95-1.05	0.95-1.05	0.95-1.05	0.65-0.8
Pea, fresh	0.4-0.5	0.7-0.85	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
Paper, fresh	0.3-0.4	0.6-0.75	1.95-1.1	0.85-1.0	0.8-0.9	0.7-0.8
Potato	0.4-0.5	0.7-0.8	1.05-1.2	1.85-0.95	0.7-0.75	0.75-0.9
Rice	1.1-1.15	1.1-1.5	1.1-1.3	0.95-1.05	0.95-1.05	1.05-1.2
Safflower	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.7	0.2-0.25	0.65-0.7
Sorghum	0.3-0.4	0.7-0.75	1.0-1.15	0.75-0.8	0.5-0.55	0.75-0.85
Soybean	0.3-0.4	0.7-0.8	1.0-1.15	0.7-0.8	0.4-0.5	0.75-0.9
Sugar beet	0.4-0.5	0.75-0.85	1.05-1.2	0.9-1.0	0.6-0.7	0.8-0.9
Sugarcane	0.4-0.5	0.7-1.0	1.0-1.3	0.75-0.8	0.5-0.6	0.85-1.05
Sunflower	0.3-0.4	0.7-0.8	1.05-1.2	0.7-0.8	0.35-0.45	0.75-0.85
Tobacco	0.3-0.4	0.7-0.8	1.0-1.2	0.9-1.0	0.75-0.85	0.85-0.95
Tomato	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.95	0.6-0.65	0.75-0.9
Watermelon	0.4-0.5	0.7-0.8	0.95-1.05	0.8-0.9	0.65-0.75	0.75-0.85
Wheat	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.2-0.25	0.8-0.9

2.3.4 Deep Percolation Losses

Deep percolation losses are only explicitly considered in the calculation of requirements for paddy rice. In the case of dry-foot crop deep percolation is indirectly allowed for in the field efficiency factor.

The estimate of deep percolation losses for rice can have major impact on the overall calculation of irrigation requirements, and field measurements are desirable whenever possible.

Percolation loss in the paddy field varies from place to place; the same values as in definite plan were applied in this study: i.e 3.5 mm/day in the rainy season and 4.0 mm/day in the dry season. Rainy and dry season are defined as the periods from October through March and from April though September, respectively.

2.3.5 Net Irrigation Requirement

The elements in the calculation of the net irrigation requirement are:

Paddy Rice:

Net irrigation requirement (NIR) = Crop evapotranspiration + land preparation + deep percolation – effective rainfall ....(2.4)

Dry-foot Crops:

Net irrigation requirement (NIR) = Crop evapotranspiratio(+Land preparation for maize, etc.) - Effective rainfall .... (2.5)

2.3.6 Irrigation Requirement at the Headworks

Assumptions on field and conveyance efficiencies are critical to the calculation of irrigation requirements. There has been considerable variation in estimates of these key parameters in past studies in Indonesia, with overall efficiencies ranging from 15 to 65%.

2.3.7 Field Irrigation Requirement

Basin irrigation for dry-foot crops can be reasonably efficient given good management. However, it is still difficult to apply the desired amount of irrigation to the furthest corner of the field without considerable over-supply to the crop closest to the supply point. This over-supply is regarded as loss from the system and is expressed as field irrigation efficiency. This efficiency depends on several factors including basin size, soil type, size of irrigation stream, the skill of the farmers and so on.

Generally, application efficiency ranging 50 – 70%, i.e. water stored in root zone/ water applied to field, is taken for the calculation of field irrigation requirement (FIR).

FIR = NIR / Field Irrigation Efficiency (0.75)..(2.6)

2.3.8 Gross Irrigation Requirement

Conveyance efficiency relates to the main and secondary canals and is dependent on seepage losses, management efficiencies and losses due to the rotation. Gross irrigation requirement (GIR)at the headworks or at the point of diversion, which include all field, conveyance and operational losses are worked out assuming the conveyance efficiency ranging between 70 – 80% (i.e. water received at field gate / water released at project head).

GIR = FIR / 0.80..(2.7)

2.4 IRRIGATION SCHEDULING

2.4.1 Factors Influencing Irrigation Scheduling

Scheduling and hence water distribution planning is influenced by factors such as depth of root zone, extraction pattern, relation between moisture content, stress and crop yield. These are briefly described below:

Development of root zone

Effective root zone is the depth from which the roots of an average plant are capable of extracting soil moisture, which needs to be replaced by irrigation.

The rooting depth depends on the nature of the crop, but can be influenced by restricting conditions e.q. shallow soil layer, or high water table. The effective root zone depths of some of the more common crops are given below:

Table 2.3. Effective root zone depths (on full development).

Shallow rooted 60 cms	**Moderately deep 90 cms**	**Deep rooted 120 cms**	**Very deep rooted 180 cms**
Rice	Wheat	Maize	Sugar cane
Potato	Tobacco	Cotton	Citrus
Cauliflower	Groundnut	Soybean	Apples
Cabbage	Carrots	Sugar beat	Coffee
Onion	Beans	Tomato	Grape Vines
	Chilies		Safflower

The rate of development of root zone depth depends on the crop subject to the influence of soil-moisture and nutrients. Measurements at demonstration farm of IIT Roorkee showed the development of effective root zone for wheat by almost 1 cm/day for the first 90 days, and negligible growth afterward (Singh, 1994). For all crops the general pattern is faster growth of root zone up to the flowing stage and considerably slower afterwards.

Extraction pattern:

When to irrigate and how much to apply are affected considerably by where and when water is removed from the soil by the plant root zone. A shallow rooted crop will require more frequent irrigation than deep-rooted crops, rooting data from irrigated crops grown in semi humid regions show considerably more water removed from the top 30 cm of soil than any succeeding depth while data of hot arid regions generally show less water removed from the first 30 cm than from the next lower 30 cm. For normal irrigated soils the average patterns is given in Fig.2.2.

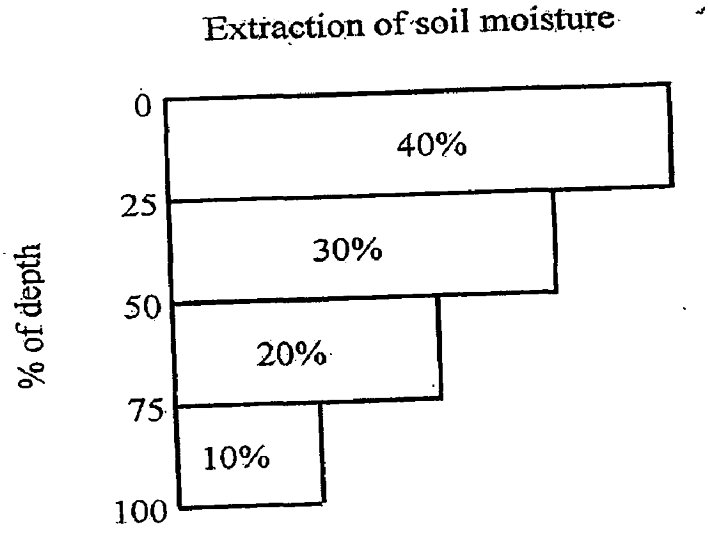


Figure 2.2 Average extraction of soil moisture by plant roots

Influence of stage of growth

The growth of all plants can be divided into three stages with regard to irrigation practice, vegetative, flowering and fruiting. During vegetative stage, consumptive use continues to increase. Flowering occurs near and during the peak of consumptive use. The fruiting stage may be further subdivided into parts; the wet fruit stage which follows flowering and the dry fruit stage. Dry fruiting is accompanied by a decrease in consumptive use until transpiration ceases and the plant is dead. Different crops are harvested at different stages depending on their utilization e.q. green fodder-and leafy vegetables at the vegetative stage, cauliflower at the flowering stage, tomatoes, green peas, sugarcane and other fruits at wet fruit stage and cereals, pulses, and cotton at the dry fruit stage. The amount of water applied and the frequency of irrigation must be adjusted to the actual consumptive use of the crop, water holding capacity of the soil and depth of rooting since consumptive use is at or near maximum during the flowering stage, care must be exercised to ensure adequate moisture in the root zone. The increased consumptive use is offset by increased depth of root zone, and frequency normally does not need to be increased.

The root system is essentially extended to its maximum depth by the time fruiting occurs and the consumptive use has begun to decrease, reducing the water requirements of the crops and the frequency of irrigation. Adequate supply of phosphorus and potash fertilizers should be present in the soil at this stage. During production of dry fruit, irrigation essentially ceases; the slight water requirements of the crop are met usually from the stored water in the soil. The last watering is normally given during the wet fruiting stage.

Relationship between soil moisture content (SMC) and stress

Soil moisture content is related to the soil moisture stress by the soil moisture retention function. A decrease in SMC generally results in an increase in stress. Soil moisture stress can be plotted against moisture content or against available water deficiency. The latter mode of plotting is more meaningful. Typical curves for different soils are plotted in fig 2.3. It can be seen that for the same soil moisture deficiency, the stress is higher in clayey soils and less in sandy soil.

Effect of soil moisture stress on yield

To obtain optimal yield, the soil moisture should be so maintained that the plant is not under stress, particularly at the sensitive growth stages. The results in this respect are based on experimental data. Data for a few crops based on the work done in U.S.A. by Peri and Skogerboe is given below:

Crop	Maximum Soil Section (bars)
Beans	0.75 to 2.0
Sugarcane	0.25 to 0.30
Potatoes	0.3 to 0.50
Oranges	0.20 to 1.00
Tomatoes	0.80 to 1.50

It is generally accepted that up to 50 percent depletion of available capacity, the stress level is such that it does not have appreciable effect on yield. Also up to this much soil moisture depletion the actual evapotranspiration is only marginally less than potential maximum evapotranspiration. In the dry fruiting stage depletion up to 75 percent is acceptable. Table 2.4 show the loss of yield of the wheat crop with delay in irrigation.

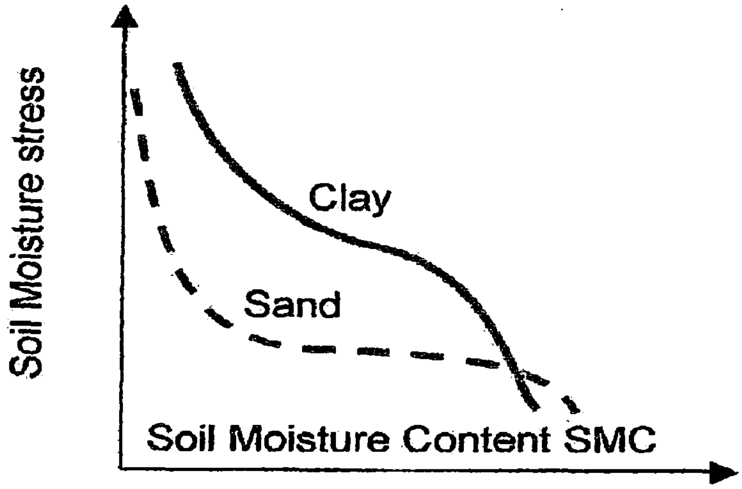


Fig 2.3 Retention curve for various types of soils

Table 2.4 : Soil-clay loam-crop wheat. Zero stress yield 40 ql/ha

Stage	Crown Rooting		Flowering	
Delay (days)	5	8	5	8
Yield (ql/ha)	37.5	31.8	38.5	32.7
% loss of yield	6.25	20.5	3.75	19

Soil Moisture Content

The moisture deficiency Δ at a particular time is given by

$\Delta = (W_f - W) * Z * \gamma ds$ ....(2.8)

Where, Δ is the required water depth

Wf is moisture content at field capacity as proportion of dry soil Weight.

W is moisture content at the time in question

Z is effective root zone depth and

γds is specify dry unit weight of the soil.

If W is the moisture content at wilting point, the deficiency is expressed as a percentage, P as below;

$$\frac{P}{100} = (W_f - W) = (W_f - W_p)\left\{1 - \frac{W - W_p}{W_f - W_p}\right\} \quad (2.9)$$

Equations (2.8) and (2.9) give the moisture deficiency to be made up by irrigation. Knowing soil properties, Wf, Wp and γds, the effective root zone depth Z, and permissible stress or permissible depletion, the depth of irrigation watering can be computed. Slight variations in actual technique are possible as follows:

- Continuously monitor soil moisture content or soil moisture stress in the root zone. Irrigate when moisture deficiency or stress reaches the maximum permissible limit.
- Time interval to next irrigation, T, is estimated by,

  $T = \Delta / Eta$ ....(2.10)

  Here Eta is the actual evapotranspiration per unit of time to be determined from pan evaporation measurement and crop factor at the stage of growth or any other method. Assuming that last irrigation left the soil moisture at field capacity, daily loss can be computed by daily Eta, and irrigation applied when permissible deficiency is estimated to have reached by such computation.

Physiological growth stages

Certain stages of plant growth are more sensitive to water requirement than others. As far as possible, there should be no stress as sowing stage. As an example for wheat, the critical stages and days after showing are as below:

Stage for Wheat	No. of days from sowing	Order of priority
Crown rooting	20 – 25	1
Tillering	40 – 45	4
Jointing	60 – 65	3
Flowering	75 – 85	2
Milking	100 – 105	5
Dough formation	115 - 120	6

Thus, optimally six waterings are needed. As far as possible watering should be made to coincide with the more important critical growth stages, e.g. Crown rooting and flowering for wheat.

2.4.2 Framework for Irrigation Scheduling

2.4.2.1. Irrigation Scheduling Concept

Burt (1996) suggested two concepts of irrigation scheduling: the agronomic concept and the water delivery engineer's concept. The agronomic concept of irrigation scheduling is to apply water to the crop in the correct amount and at the proper times to maximize crop production and/ or profit, while maintaining reasonably high irrigation efficiency. Maximum flexibility in delivery is required. Ideally, irrigators should have direct access to water so they can react adequately to change in the soil moisture situation, optimize their irrigation schedules and synchronize them with other on- and off-farm activities. However, this is not the case in most irrigation schemes. The often limited amount of available water has to be shared with others irrigators. Elected farmers, a water users association or an irrigation agency entrusted with the task of managing this limited amount of water for an equitable and efficient delivery. To plan under such circumstances for effective and efficient use of water, the irrigator and supplier require information on the actual irrigation needs and the time and amount of water to be supplied in terms of flow size, duration and interval.

The water delivery engineers' concept of irrigation scheduling is to develop and implement a schedule of water deliveries which is compatible with the water delivery system's capabilities and constraints with the least amount of trouble. This means simple operation rules and procedures and results in limited flexibility.

Whatever concept is applied, the success or failure of the irrigation system is determined by the supply of water to the individual farmers at the farm gate. This requires good communication between supplier and irrigator and a clear understanding of rules and regulations for acquisition, conveyance, delivery and distribution of water. Moreover, an accountability mechanism needs to be in place to ensure that these rules are obeyed. These rules are made in different forums. The irrigation agency develops a set of rules related to water allocation and delivery to the users or users groups. The users develop their own set of rules for distribution of water among themselves. A water users association (WUA) performs this function at the tertiary unit level in smallholder schemes where the number of farmers is large.

Often the field staff and farmers develop their own informal rules for water supply from the main system.

The institutional concept of irrigation scheduling is to develop and implement a schedule of water delivery and distribution, which is based on a set of rules accepted and adopted by the supplier, the distributor and the user. These rules reflect the social and power arrangements among and within farming communities, their water right and capability to adjust the distribution of water to their socio-cultural situation. It is desirable to combine these concepts by developing water delivery and water distribution policies which are accepted and adopted by suppliers, distributors and users, and which extract the most flexible and reliable performance available from the water delivery system. The resulting rules will restrict the flexibility of water supply to the individual users and, hence, is the potential for flexible irrigation scheduling.

2.4.2.2 The Framework

In Fig 2.4. Showing an irrigation scheduling framework, three levels of operation are distinguished: the main system for water acquisition, conveyance and delivery to the tertiary units; the tertiary system for water distribution among farmers; and the field system for water application. Each of these levels has its own management authority: formal or informal group of organized farmers or water users; and the individual farmers, respectively water is delivered by the irrigation authority to a group of farmers who distribute this water among themselves or with accepted outside assistance. The scheduling practice thus completely depends on when, how and how much water is delivered by the authority and distributed by the farmer group.

Irrigation development, especially in large schemes, is usually the responsibility of government agencies as part of an overall development plan with specific objectives. Within the framework of development, irrigation agencies are assigned to develop a physical and management infrastructure to deliver water at the interface with the users. Policy choices made at this planning level are on water rights, cropping arrangements, water delivery arrangements, cost recovery, and system management. The group of water users will decide on their water distribution arrangements, how cost will be recovered and how they will manage their system. Individual farmers will decide on crop selection, use of agro-input and labor, irrigation method, water application system and irrigation scheduling method. This choice is not made in isolation but an interaction will occur between various levels regarding their choice. Based on these options, an infrastructure will be chosen that fits their purpose and is accessible to them. Overall choice is based on the management environment, which includes legal, social, economic and institutional components.

The policy choices of government, irrigation agency, farmers group and individual farmers are the first set of limitations on the potential of flexible irrigation scheduling. A second set of limitations is the translation of these choices into infrastructure, organization and rules and procedures to manage the infrastructure. The actual implementation can deviate considerably within the infrastructure, operation, maintenance and management rules, this demonstrates the rules-in-use and forms the third set of limitations.

Policy choices are usually made at the beginning of irrigation development. Changes in policies usually require changes in infrastructure and organization. Here, a compromise has to be often made between the requirements posed by the new policies and the capability of the infrastructure posing an additional set of limitations.

2.4.3 Application of Irrigation Scheduling

2.4.3.1 Planning

Application of irrigation scheduling start with a process of planning of what is desired and possible on both user supplier system levels. It decides upon which procedures and technologies are suitable given the aim and objectives formulated in the irrigation policies.

Successful irrigation scheduling must be simple to understand and implement and acceptable from both the farmer and management personnel standpoints **(Burt, 1996; Horst, 1996; Mangano, 1996; Hill and Allen; 1996; Tollesfson et al.,1996).**

and soil conditions are variable and dynamic. Irrigation scheduling programmers must be strong enough to withstand physical and human uncertainties **(Burt, 1996).**

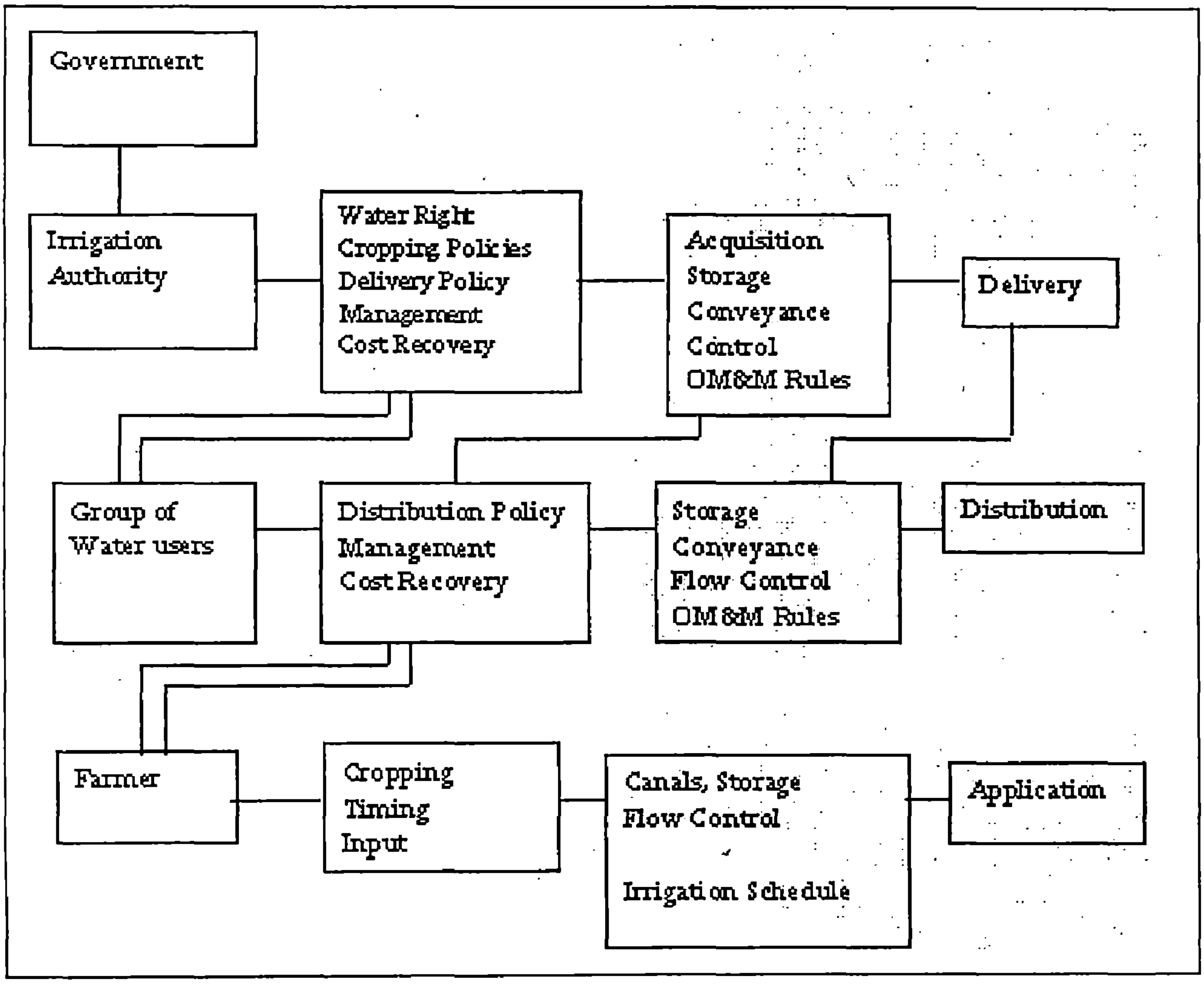


Fig. 2.4 A Frame Work for Irrigation Scheduling

Application of irrigation scheduling methods depends on irrigation policy choices, the level of acceptance of the planned methods by the operator and the farmers and the capability of the infrastructure.

The main constraining factors in irrigation scheduling are water delivery and water distribution. Water delivery from the main system to the group of users is based on a set of policy choice, which relate to water rights, crop regulation, cost recovery and management. Based on these choices, an irrigation infrastructure is developed which consists of the hydraulic system, the management, organization and the rules and regulations of operation.

Van Hofwegen et al. (1996) provided a description of the policy choice made in the water scarce Triffa Scheme in Morocco and their impact on the flexibility of on-farm irrigation scheduling. The possibility for flexible water delivery required for water-saving irrigation scheduling in the Triffa scheme is constrained by several policy choices. The first policy choice is payment of water based on volume consumed. Farmers receive and agreed volume of water per irrigation cycle, released at affixed rate (20 or 30 l/s) through an agency managed turnout. Usually there are a number of farmers below one turnout. They take the flow in turn and for duration according to the schedule as agreed with the master delivered at their turnout.

The second policy choice is to have the scarce amount of water distributed by the agency in an equitable, efficient and effective (=productive) way. Depending on the water availability and requirement, management decides on the implementation of an irrigation cycle, its duration and the volume per hectare to be applied for the various crops. This requires farmers to follow the established schedules, which have been prepared in different degrees of participation depending on the water availability.

The third policy choice is to have a gravity scheme with a mixed automatic flow control system in the main canal and a manual upstream control system in the laterals. More flexible delivery to the farmers might result in a more efficient use of water at the on-farm level but probably increase operational losses in the main system considerably. Moreover, the irrigation fees do not allow increased staffing levels for more flexible delivery. Increased fees are said to present a problem for the competitiveness of the produce on local and international markets. It is unlikely that farmers will ever be willing or be able to pay for such extra service, since there is already a considerable level of government subsidies. For irrigation development in Pakistan **(Bandaragoda, (1996)**, the irrigation network is designed to give 'protective' irrigation extensively over a large gross command area. The reason for keeping the 'water allowance' relatively low was to maximize the number of settlers on newly irrigated land, but the original design also assumed a cropping intensity of about 75 %. Water delivery was arranged in warabandi rotation schedule which aims to apportion on water shortage equitably, allowing farmers to respond to the available water with appropriate cropping pattern. These supply driven rotation schedules leave little room for flexibility in irrigation scheduling.

In watershort region of Tamil Nadu (India), **Pundarikanthan and Santhi (1996)** proposed a localization policy for cropping. It is applied where command areas are localized as 'wet' (for water intensive crops like paddy rice, sugar cane, banana) and 'irrigated dry' (for crops such or groundnuts, onions and cotton) leaving crop choice to farmers. The consequent diversified cropping system under the same sluice makes irrigation scheduling a difficult task in the field, considering the control available in the field. Main system schedules and on-farm schedules do not match, especially because distribution below sluice is on the rotational basis. Moreover, planning and design concepts are based on duty (expressed in acres per cubic feet per second). Delivery of water according to the crop water requirement needs interventions in the physical infrastructure to match demand and supply. A systematic scheduling based on a service agreement is very important and has been successfully experimented with community organizers.

Irrigation scheduling is important for optimizing the use of water resources where irrigated agriculture has a long tradition (**Mangano, 1996**). However, in new schemes this should be deferred to a later stage when farmers have fully accepted the irrigation practice and are ready to follow more flexible rules.

That planning for irrigation scheduling not only requires a sound hydraulic and operational bases but also well functioning irrigation authorities (institutions) with shared responsibilities and a high level of mutual accountability. This can probably be achieved by the introduction of service oriented irrigation management. Clear agreements between users and suppliers, like the cases of Morocco and India, indicate that scheduling becomes possible and delivery performance improves. These aspects have to be included in the preparation of the irrigation policy during planning stage.

2.4.3.2. Implementation

In implementation, discrepancy arises between irrigation scheduling following soil-water-plant relationships and water delivery (**Horst, 1996**) because of which an irrigation scheduling approach often fails. The reasons are:

- Planners and designers aim at full regulation throughout the system. Inappropriate structures, however, are often chosen.

- Operation office staff made complicated schedules: excessive data collection, processing and dissemination combined with lack of staff and measuring capability result in just a paper exercise only.
- Operation staffs, often poorly trained, are confronted with an impossible task. Real cropping patterns differ from those assumed in irrigation scheduling. Moreover, the loyalty of field staff lies primarily with farmers, and they are often used to accommodating the wishes of various groups of farmers.

Though the high level of professionalism in terms of design and construction of water conveyance facilities has been achieved, the on-farm water management is not as satisfactory as it should be **(Cheng, 1996)**. Farmers are generally dissatisfied with the irrigation service because the system is designed and operated in a top-down, centralized manner by engineers at their convenience. It delivers water on a fixed rotation schedule with limited attention to the needs, skill and wishes of the farmers, resulting in low efficiencies, water wastage and reduction (to 80% of potential) of the irrigated area.

Vermillion and Brewer (1996) described the problems due to the above discrepancy for two cases in Indonesia and India. In Indonesia, inequitable and inefficient water distribution is caused by inefficient and cumbersome gate operation requirements and lack of control and communication, unreliable supplies due to unauthorized tapping by farmers in the upstream reaches, a lack of farmers involvement and an erratic presence of staff in the area.

In Pakistan the reason for this discrepancy is the erosion and collapse of the condition that made the Warabandi function well **(Bandaragoda, 1996)**. The collapse of the Warabandi attribute to the combined effect of a change in the value system and a general breakdown in the overall institutional responsibility for the management of irrigation systems. The system became dysfunctional, and a vicious circle set in with the physical and human sub-system acting on each other to cause a rapid performance decline.

2.4.3.3. Changing Irrigation Schedules

Steenbergen (1996) studied three cases of changing traditional irrigation schedules in small-scale locally managed irrigation system in Pakistan. The reason for the changes was to increase irrigated area by increasing efficiency through a process of farmer's consultation and participation. These cases show that although farmers acknowledge the potential for improvement, a very rigid and system specific irrigation schedule will not be easily changed; instead of a revision, the schedule will be kept acceptable by 'muddling through', primarily through inter-individual adjustments, such as exchanges and transfer of water turns between two users or within a subgroup of users. The step from local economic opportunities to local institutional change is not always obvious. Non-economic considerations, conflicting interest and the question of who takes the initiative may stand in the way.

Due to gradually changing operational objectives, a mismatch with the flow control method is often met **(Ankum, 1996)**. The supply-based system (such as in India and Pakistan) cannot be easily shaped into 'crop based system 'since the relative capacities must be increased and water availability ensured. Moreover, upstream control for a semi-demand allocation must rely on strong central management. Problems encountered with such changes are illustrated in study by **Bandaragoda** (1996). To arrest the erosion of warabandi, attempts have been made to inject the ailing systems with technological inputs. They became increasingly ineffective when confronted by low accountability and policy inertia regarding institutional reform. The cardinal mistake of the planners was their failure to anticipate the required institutional change for coping with the new irrigation management technologies they hoped to introduce. The design was based on broad assumptions for a shift from the traditional irrigation options:

- The presence of institutional capacity or adaptability to undertake this shift;
- The flexibility of the users to adjust to a pattern of variable supply;
- Harmony and uniformity of the social background to resolve disputes and develop rules and methods for water distribution.

2.4.4 Approaches for Improvement

The problems mentioned refer to overly complex irrigation scheduling systems for managing institutions. They are often insufficiently equipped to carry out their task satisfactorily. A first approach is to simplify the irrigation scheduling method. A second one is the use of farmer participatory approaches in the improvement of system operations. A third approach lies in improvement of the capability of managing institutions. A final approach suggests the acceptance of rigid delivery and the introduction of flexibility at the farm level.

2.4.4.1. Simplification

Horst, (1996) argued that improvements of present approaches, such as the introduction of new irrigation scheduling techniques, training, organizing water users groups, etc., will remain cosmetic surgery as long as the fundamental problem of over-complicated irrigation schedules requiring over-complicated water division structures resulting in cumbersome operation are not addressed properly. Automation will result in fewer but very highly skilled operation and maintenance staff requirements. He therefore advocates a simplified approach based on the 'Additional Operation Requirements' (AOR) concept. Apart from crop requirement water is needed to facilitate a fair and simple water distribution; 'you need water to save water'. A constant discharge over the whole growing period for rice or stepwise variation for non-rice crops. Fixed proportional distribution might provide an adequate technological solution if AOR is taken into account. The loss of AOR will be compensated for increased overall efficiencies and unequal distribution will decrease. In this concept no allowance is made for variable rainfall. Moreover, a strong institution is required that sees to the proper implementation of the proportional distribution.

Mangano, (1996) confirms the finding of **Horst, (1996)**. The farmers proposes to start new schemes with simple irrigation and defer scheduling to a later stage when farmers have fully accepted the irrigation practices and are ready for more flexible rules. He counters the argument that 'modification of acquired bad habits is an impossible task'.

Burt, (1996) proposes allocation of known and reasonable volumes of water to minimize water wastage. When the volume is used up, there is no more water forthcoming unless the farmers can purchase water from other farmers. There must be an ability to withhold water from farmers once they have utilized their allotment. Moreover, the water volume must be provided in a fashion that it is usable and beneficial. If a volume is allocated, but that volume is only available in an unreliable or untimely manner, the programmer will fail. **(Panoras and Mavroudis, 1996)** show in their study that introduction of volume-based irrigation charging in users operating pump irrigation schemes reduced the consumption of water and supported water saving scheduling practices.

2.4.4.2. Participatory Approaches

Vermillion and Brewer, (1996) described two cases of participatory action research (PAR) involving farmers, agency staff and researchers which facilitated a change in irrigation operations and produced significant improvements in performance. The first case is an innovation in dry season rotational irrigation in the Maneugteung Irrigation System in West Java, Indonesia. The second case involves the creation of a farmers' distributary's canal committee and the introduction of new operational procedures for enhancing equity and management control in the Paliganj Distrubutary Canal of Sone Command in Bihar, India. It showed that if planned change did not involve both sound technical analysis and participation of key stakeholders in decision-making, the outcome would probably be neither optimal nor capable of mobilizing the needed support of farmers and agency staff. The communications between farmers, agency staff and the PAR team revealed a common interest between farmers and agency staff in altering the configuration of rotation blocks, changing the timing of rotations and expanding the role of farmers in a new rotational arrangement. The option was selected on the basis that it would provide the best for improvement in equity efficiency and control through farmer participation. Participants recognized that an attempt to maximize any single performance dimension would seriously compromise another dimension, hence optimization was needed.

According to **Cheng (1996)** farmers' involvement in irrigation management is an important means for people to become aware of and select solutions for their own problems. It contributes much to the improvement of irrigation service. It is very important for the implementation and success of water saving irrigation scheduling. The success of any measure (intervention) to save irrigation water depends on the understanding and acceptance of the beneficiaries. In order to be effectively involved in the implementation process of saving irrigation schedules, farmers should be well organized.

2.4.4.3. Institutional Development (Capacity Building)

For capacity building, **Bandaragoda. (1996)** suggested that the introduction of irrigation scheduling should to be preceded by a change in the attitudes, policies, awareness and the institutional framework of irrigation management. This change would not occur easily or quickly. A strong vested interest among influential individuals to keep existing institutional arrangements intact is the greatest obstacle to change. Yet, alternative strategies need to be developed for introducing new technologies to replace or modify the traditional water delivery systems which are crumbing under the stress of changing socio-economic conditions. These strategies should ensure that the benefits of new technologies of water delivery and irrigation scheduling reach the more disadvantaged group among the water users. Encouragingly, there are some efforts in both policy and research, currently underway in Pakistan, to develop viable institutional strategies for more productive and sustained irrigated agriculture.

Than, for establishing irrigation policies, (**Burts. (1996)** the agency should be cognizant of the fact that their responsibility is to provide a service, not to dictate schedule or the only way this concept of service can work is if the water delivery system is broken down into levels of service'. When the concept of service is wholeheartedly adopted by the project staff, amazing agronomic and social improvements can be achieved.

2.5. CROPWAT PROGRAM FOR IIRIGATION SCHEDULING

"Cropwat for Windows" is software developed by **Derek Clark, Martin Smith** and **Khaled El-Askari (Clark et al. 1998).** It uses **Penman-Monteith method** for calculating reference crop evapotranspiration. These estimates are used in crop water requirements and irrigation scheduling calculations. The software can deal with multiple crops (up to 30 crops) in a cropping pattern. Complex cropping patterns can be designed with several crops with staggered planting dates. Irrigation schedules can be calculated for individual block of each crop. Time base can be daily, weekly, and/or monthly. This program uses monthly climatic data only. The program allows user defined irrigation events and has option to add adjustments to the calculated soil moisture deficit. This provides a flexible tool for managing soil moisture during the growing season. An important drawback of the program is that, in the present version, it does not compute crop water requirements for rice, and therefore, these are determined separately and given as input data to the program.

2.6 WATER DELIVERY AND DISTRIBUTION PLANNING

2.6.1 Aim of Delivery and Distribution Planning

Due to lack of proper planning in distribution and delivery system the whole project will be badly affected. While planning an Irrigation System the following four aspects are to be kept in mind to achieve them as far as possible :

i) **Adequacy:** Delivery of water as per crop requirement.

ii) **Efficiency :** Maximum possible saving of irrigation

iii) **Reliability :** Confirmation of uniform water as per the design irrigation schedule.

iv) **Equity :** Proportionate distribution of water as per the land holding size but not necessarily be the equality.

2.6.2 Delivery and Distribution Schedule

Although water delivery and distribution involves complex technical institutional and investment questions, the potential pay-off from improving irrigation system is large.

The delivery system of irrigation water is to be properly managed and schedule for the proper distribution of water. The scheduled can be classified as:

a) Demand Schedule

In this method the users can take water when they desire. The rate of flow can be controlled by the hydraulic structures provided at the entry of the field or tertiary canal. So in this schedule the users have complete flexibility frequency, rate and duration of delivery. The main defect of this schedule is that heavy investment in control structure is to be made for water control. Water consumption is usually maintained and paid for by volume.

(b) Arranged Schedule

In this schedule the users have control over water and they request the rate and duration in advance. The main advantages of this system are the adequacy, equity and reliability which are achieved to some extent if the system is properly managed. But this schedule needs great communication deal and management. Many dhalpas (gate keepers) are required in case if automation is not maintained.

c) Rotational Schedule

This method is applied during winter, because of low water supply in source. In this method the timing of taking water is prearranged in order to allow the users take water in turn as per water availability. The frequency, rate and duration are controlled by the central level policy.

In this method, though some extent of equity and reliability is achieved, the central level authority is suffered from the problem such as to meet supply and demand for the crop. The reliability and equality is affected by the fluctuation of water supply at source. However this schedule is advantageous because it is simple to manage and not many controls and measuring structure are required.

d) Continuous Flow

In monsoon it is not difficult to manage water in the canal and continuous flow can be provided in the network of canal. In this method the water flows continuously in the canal throughout the irrigation season and users can get water in proportion to how much land they hold. As the flow is continuous, no matter the quantity be very small, it meets at least the daily crop evapotranspiration requirements. This method is suitable for rice and equity can be maintained. The land where paddy can not be grown i.e. on high level lands, adequacy may suffer.

e) Combined Schedule

The combination of the above schedules (all or partial) can be used when it is difficult to apply any of the single schedule in any irrigation project. For example main canal could operate with continuous flow, while there could be rotational flow along the branches. It may be possible to have arranged in a schedule below canals where continuous flow or rotation method is practiced.

2.7 IRRIGATION EFFICIENCY

There are two aspects involved in water use efficiency. One concerns input that is application of irrigation water with minimum losses of various kinds and the other concern the output that is the crop yield. The losses in storage, conveyance and application depend on the engineering structures and regulation of delivery and application. The output depends on one hand on season, crop and variety; and on the other on various agronomic practices adopted for raising the crops. The objective of the efficiency concept is show where improvements can be made which will result in more efficient irrigation. Irrigation efficiencies are expressed in different ways. Some of them are listed below.

(1) Conveyance efficiency E_c : It is defined as the ratio of irrigation water supplied at outles to the field W_f and the irrigation water supplied at diversion (river or reservoir W_r).

$$E_c = \frac{Wf}{Wr} \times 100 \quad \text{.......... (2.11)}$$

(2) Water application efficiency E_a : It is defined as the ratio of amount of irrigation water stored in the root zone of the soil during irrigation by the crop Ws to the amount of water supplied to the field W_f.

$$E_a = \frac{Wa}{Wf} \times 100 \quad \text{.......... (212)}$$

Where E_a is the water application efficiency.

Normal surface irrigation practices has the water application efficiency of the range 60% while a well designed sprinkler irrigation system is generally considered to be 75% efficient.

R_f and D_f respectively being surface runoff from the farm and deep percolation from the farm below root zone and if evaporation losses during and after irrigation water application is neglected. It follows that

$$W_f = W_s + R_f + D_f \quad \text{.......... (2.13)}$$

There water application efficiency E_a can also be expressed as

$$E_a = \frac{Wf - (Rf + Df)}{Wf} \times 100 \quad \text{.......... (2.14)}$$

(3) Consumptive use efficiency E_{cu} : It may be defined as the ratio between normal consumptive use of water W_{cu} to the net amount of water depleted from the root zone of the soil.

$$E_{cu} = \frac{Wcu}{Wd} \times 100 \quad \text{.......... (2.15)}$$

If the better irrigation practice is followed consumptive use efficiency increases. This concept also involves the efficiency with which roots are able to utilize moisture stored in the soil during irrigation. It is affected by soil texture amount and distribution of vegetation, profile of the soil surface, distribution of roots within the soil and variation of soil moisture within root zone.

(4) Water storage efficiency E_s : It may be defined as the ratio of amount of water stored in the root zone during irrigation Ws to the amount of water needed in the root zone for irrigation W_n.

$$E_s = \frac{Ws}{Wn} \times 100 \quad \text{.......... (2.16)}$$

Water storage efficiency is important where water is scarce and high priced and value of irrigation is realized.

Researches have shown that improved storage efficiency may result double and some time triple production.

(5) Water distribution efficiency E_d : More the uniformity of water distribution in the field would be, better would be the crop response. Uneven distribution may cause

patch of drought areas in the field requiring excess irrigation. These areas are also prone to high salt accumulation.

Water distribution efficiency may be expressed mathematically as:

$$E_d = (1\text{-}y/d) \times 100 \quad \text{......} \quad (2.17)$$

Where,

E_d = Water distribution efficiency.

y = average numerical deviation in depth of water stored from average depth stored during the irrigation.

d = average depth of water stored during the irrigation.

(6) Project efficiency or overall efficiency E_o: It may be defined as the ratio of irrigation water evapotranspired by the crop W_{cu} to the irrigation supplied at the diversion point W_r.

$$E_o = \frac{Wcu}{Wr} \times 100 \quad \text{......} \quad (2.18)$$

Overall efficiency is the product of all efficiencies and takes into account total amount of losses incurred.

CHAPTER III

STUDY AREA AND DATA AVAILABILITY

3.1. STUDY AREA

3.1.1. General

The study area is located in Lampung Province, which is the most southern province of the island of the Sumatra, the western largest island of the Indonesia archipelago. This province, with a land area of 34,000 km^2, is bounded on the north and northwest by the Sumatra and Bengkulu provinces, on the south east by the Java sea, on the west by the Indian Ocean, and on the south by the Sunda strains.

The Way Sekampung Irrigation area covers a gross area of around 124,780 ha. The service area actually lies in both the Sekampung and Seputih Rivers. The service area is show in Fig. 3.1 and relevant data in Table 3.1. The Way Sekampung Irrigation area receives water at Argoguruh weir and the irrigation water is conveyed though Feeder-I and feeder-II canals and distributed by primary, secondary and tertiary/quaternary canals. In Batanghari and Raman Utara irrigation scheme, irrigation water is diverted from feeder-I canal to natural streams and taken at weirs located downstream. At present some area (6900 ha) receives return flow from other irrigation schemes, as schematically shown in Fig. 3.2 (Appendix B).

The Project Area is basically an agricultural improvement scheme attained though an increase in production of irrigated rice within the study area. An increase in the infrastructure development within the area is also used as an incentive to promote and encourage further transmigration into the area from the move densely populated areas of Indonesia.

3.1.2. Location

Geographically, the irrigation command area of Way Sekampung Project is bounded as follows: The Northern extreme ties approximately follow latitude 4°45' South; the Southern extreme ties 5°40'; the Western extreme ties longitude 104°40' East; and the Eastern extreme ties 105°35' east.

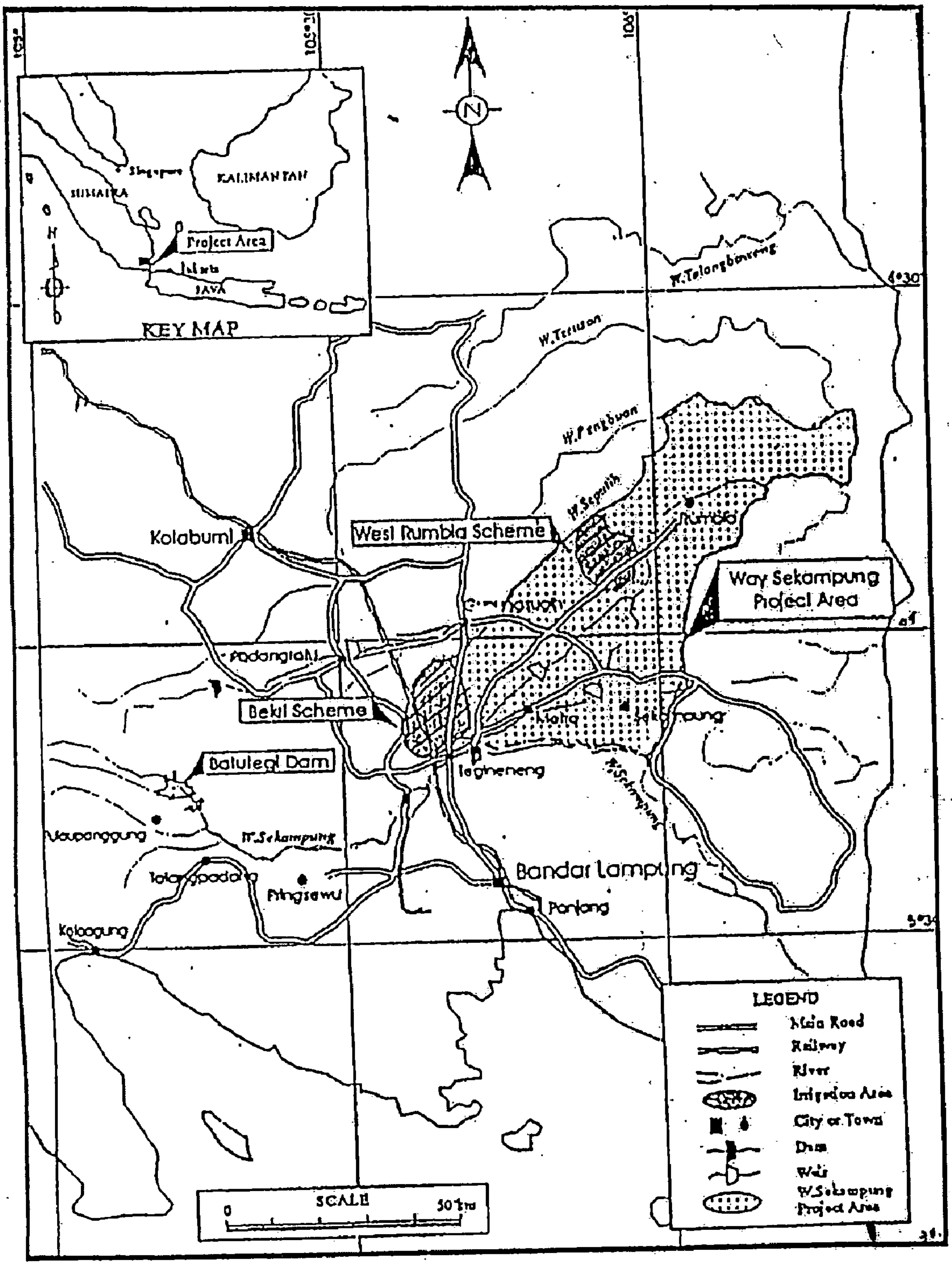


Fig. 3.1 Location Map of Batutegi Dam & way sekampung irrigation

Table. 3.1 Way Sekampung Irrigation Area

Irrigation Scheme	Present Irrigable Area (Ha)		Potential Irrigable Area (Ha)	
	Direct Diversion	Return Flow	Direct Diversion	Return Flow
Feeder-I Canal	420	-	463	-
Batanghari	7,600	-	11,562	-
Bunut	4,980	-	7,233	-
Punggur Utara	14,500	-	31,500	-
Raman Utara	-	3,000	2,565	3,950
Batanghari Utara	-	3,900	3,176	4,050
Bekri	-	-	6,500	-
West Rumbia	-	-	5,790	-
Rumbia II	-	-	4,566	-
Rumbia III	-	-	4,427	-
Rumbia IV	-	-	5,558	2,783
Total	27,500	6,900	83,340	10,783

3.1.3. TOPOGRAPHY

The physiographic setting of the study area is briefly described as follows. The Lampung province is composed of narrow coastal plain on the west coast which borders on the Indian Ocean; the Barisan Mountains, which from the southern spine of Sumatra; and wide pen plain sloping gently form the foothills of the Barisan Mountains east to the control plain swamps bordering the Java Sea.

The topographical information is given in Table.3.2

Table. 3.2. Land Classification Criteria, West Rumbia of Way Sekempung Irrigation

Soil Factors	Land Classification						
	Diversion Crop				Rice Paddy		
	1	2	3	4	1R	2R	3R
1. Soil							
a. Texture :							
Upper layer:	Clay To stiff sandy clay	Clay to sandy Clay to sandy	Sandy clay to clay	Clayey sand to clay	Silt clay, very fine clay stiff silty clay	Stiff silty clay, silty clay, clay	Silty clay to clay
b. Depth							
P to:							
- sand, gravel, stone, plinthite	> 90 cm	> 60-90 cm	30-60 cm	< 30 cm	> 90 cm	60-90 cm	30-60 cm
- impermiable stiff layer	> 150 cm	120-150 cm	100-120 cm	< 100 cm	> 50 cm	30-50 cm	< 30 cm
2. Topography							
- slope	0-2%	2-5% ordinary	5-10% or 8-15%, if depth of gravel, etc. > 90 cm	15%	0-2% 2-5% Wavy	2-5% 5-8% ordinary wavy	5-8% ordinary 8-15%, if depth is 60 cm
3. Drainage							
- flood / inundated	no	no	no	no	no	inundation within 6-12 hours	inundated water gone in 12-24 hours
- drainage	good	good	rather good	rather bad to bad	-	-	-
- permeability speed	-	-	-	-	very slow (0.1 m/day)	slow (0.1 - 0.5 m/day)	medium (0.1-1.0 m/day)

3.2 Data Availability

3.2.1 Climate

The tropical climate of the project area is characterized by a rainy season lasting from the later part of October to April, a transition period during the months of the May and June, and relatively dry period from July to September. This wet-dry pattern is not always consistent. For instance, higher monthly rainfall has been recorded in the dry-season than the wet-season. This climatologically regime has led to the adoption of 1 November until 31 October as the hydrologic year, also called the water year. Average annual rainfall in the irrigation area of the project ranges from about 1800 mm to 2500 mm. Annual rainfall

in the project area is seldom less than 1400 mm. In the upland catchments areas of the project, annual rainfall generally varies from 2000 mm to 3000 mm, while value rainfall in excess of 3250 mm is rare. Climate data are given in Table. 3.3.

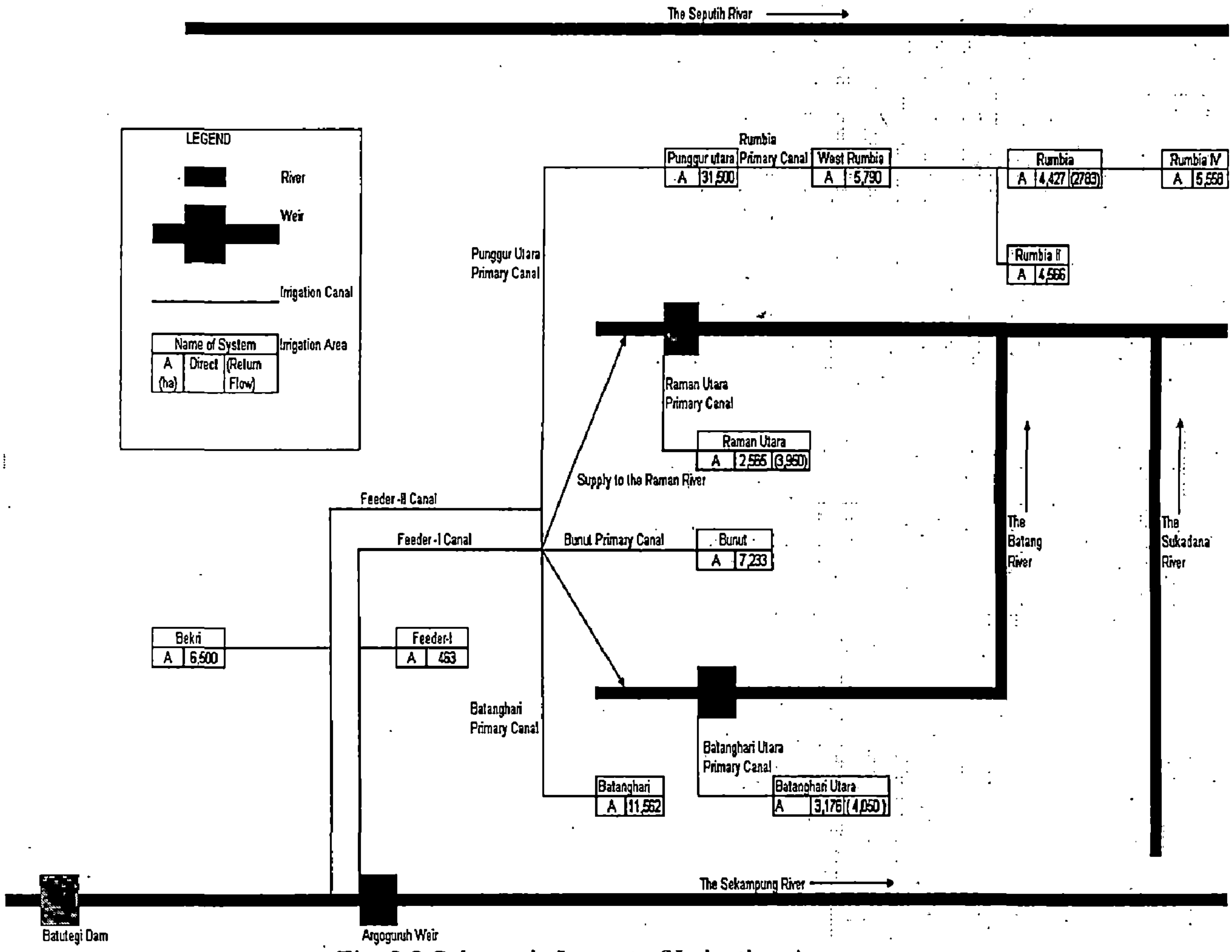


Fig. 3.2 Schematic Layout of Irrigation Area

3.2.2. Humidity

Mean monthly temperature and relative humidity do not vary significantly, rather nearly constant. Mean monthly temperature normally varies between 26°C and 28°C, with a mean annual temperature of about 27°. Maximum diurnal variation of temperature occurs during the dry-season when cloud coverage is less than other times. Mean monthly relative humidity generally varies from 80 to 88 percent, with an annual value of 85 percent. Diurnal variations in relative humidity indicate that early morning values approach 100 percent. The daily minimum, generally ranging from 55 to 65 percent, occurs in the early afternoon.

Humidity data are given in Table.3.3.

Table 3.3. Climatic Data - Branti Airport

	RH	Temperature (C)			Wind Run	Radiation	Sunshine	Rainfall	Atm. Pressure
	(%)	Max.	Min.	Ave	(km/day)	(cal/cm2)			
January	84.6	30.51	22.54	25.87	80.61		6.26	357.8	1,029
February	85.31	30.95	22.51	26.02	76.05		6.92	308.1	1,030
March	85.07	31.57	22.57	26.18	64.2		7.6	243.9	1,012
April	84.48	31.85	22.71	26.47	62.01		7.75	158.8	1,010
May	84.39	31.86	22.58	26.44	69.41		8.24	97.6	1,010
June	83.64	31.57	22.12	26.06	69.74		8.28	94.6	1,028
July	82.14	31.26	21.42	25.61	85.84		8.43	70.2	1,045
August	80.45	31.72	21.55	25.65	84.72		8.57	64.6	1,026
September	79.42	32.27	21.3	25.97	83.7		8.04	92.1	1,028
October	78.4	32.58	21.93	26.51	76.16	109.9	7.86	76	1,011
November	81.82	31.99	22.29	26.38	66.25		6.94	200.1	1,027
December	83.6	31.19	22.54	26.18	69.61		6.63	243	1,011
Ave / Total	82.78	31.61	22.17	26.11	74.03	359	7.63	2,006.90	1,022
Max.	85.31	32.58	22.71	26.51	85.84		8.57	357.8	1,045
Min.	78.4	30.95	21.3	25.61	62.01		6.63	64.6	1,010

(January 1976 - January 1994)

3.2.3. Wind

Seasonal changes in wind direction and velocity are closely associated with the change from the southerly monsoon of the dry season to the northerly monsoon of the rainy season. A prevailing wind from the south or southeast occurs during the dry season. As the wet season begins, the wind gradually shifts in a clockwise direction until the prevailing wind is generally from the north. Near the coast, the wind directions and velocities are influenced by diurnal land and sea breezes. Wind data are given in Table. 3.3.

3.2.4 Soil

Sufficient data to establish the feasibility of the area, particularly with respect to soils and land classification. The basic soil criteria for mapping are presented in Tables 3.2 and 3.4.

3.2.5. Effective Rainfall

Precipitation falling during the growing period of a crop that is available to meet the evapotranspiration needs of crop is called effective rainfall. It does not include precipitation lost through deep percolation below the root zone or the water lost as surface runoff. Since there are no records of effective rainfall available, it is necessary to estimates the portion of total rainfall that can be effective. An approximate procedure for arriving at effective rainfall is given as follow:

Pe = Effective rainfall (mm)

Pe = 0.8P – 24 if P> 70 mm

Pe = 0.6P – 10 if P< 70 mm.

Table 3.4 Soil Mapping Criteria

1. Texture

Upper layer	Lower layer
S_0 = clay to sandy clay	clay to permeable clay
S_1 = clay to sandy clay	sandy clay to permeable clay
S_2 = sandy clay to clay	sandy clay to clay
S_3 = sandy clay to clay	sandy clay to clay

2. Depth

Up to sand, gravel, stone, or plinthite

S_0 = very deep (over 90 cm)
S_1 = deep (60 – 90 cm)
S_2 = medium (30 – 60 cm)
S_3 = shallow (less than 30 cm)

Depth to impermeable layer

Diversified Crops	Rice field Paddy
S_0 = very deep (over 150 cm)	S_0 = over 50 cm
S_1 = deep (120 – 150 cm)	S_1 = 30 -50 cm
S_2 = medium (100 – 120 cm)	S_2 = less than 30 cm
S_3 = shallow (less than 100 cm)	

3. Topography

Slope

t_o = 0 – 2%
t_1 = 2 – 5% (ordinary or wavy)
t_2 = 5 – 8% (ordinary or wavy)
t_3 = 8 – 15%
t_4 = over 15%

4. Drainage Classification

d_o = good
d_1 = rather good
d2 = rather slow
d_3 = slow
d_4 = very slow (inundated)

For the crop, other than rice, USDA method is used.

To establish irrigation planning 80 % assurance is required. In other words, rainfall of 5 year drought return periods is assumed for irrigation planning. The semimonthly rainfalls at Bekri for 45 years are presented in Table 3.5. The rainfall consumed by the paddy effectively is estimated 70 % in the land preparation period and 30 % in the growing period.

Table 3.5 Probable Rainfall with 1/5 Drought

(mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
75.58	87.40	57.89	48	34	14.96	6	0	0	5	27.27	56.93
69.79	60.40	78.96	25.68	23.86	8.89	0	0	1	13.93	45.40	86

The upper row shows the probable rainfall during the first half of the month and second row the second half

3.2.6 Inflow to Batutegi Dam

In 1981, runoff at Batutegi dam site was estimated using COSSARR model which convents rainfall to runoff because runoff observation period was not long enough for water balance simulation. Now data for 26 years are available. The discharge at Batutegi dam site is converted from the discharge at kunyir as follows;

$$Qb = Cb/Ck \times Qk$$

Where, Qb : discharge at Batutegi (m^3/s)

Qk : discharge qt kunyir (m^3/s)

Cb : discharge area at Batutegi (424 km^2)

Ck : discharge area at kunyir (438 km^2)

The estimated runoff at Batutegi dam site is summarized below and presented in Table 3.6.

Table. 3.6. Estimated Runoff at Batutegi

(m/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30.65	34.25	31.57	30.70	27.30	21.13	17.25	14.94	14.68	12.71	16.69	22.62
29.49	29.91	30.96	28.01	23.61	17.76	17.12	14.76	14.59	13.93	18.29	24.34

The upper row shows the runoff during the first half of the month and the second half.

3.2.7 Discharge from Residual Basin between Batutegi Dam and Argoguruh Weir.

After the contrustruction of Batutegi dam, the discharge from the catchment's area excluding that at Batutegi dam site was converted as follows:

Qa' = Qa – Q

Where, Qa : discharge at Argoguruh from the catchments area after Batutegi dam (m^3/s)

Qa : discharge at Argoguruh from the whole catchment area (m^3/s)

Qb : discharge at Batutegi dam site (m^3/s)

The estimated discharge at Argoguruh from the catchments area after Batutegi dam is summarized below and shown in Table 3.7.

Table. 3.7. Estimated Runoff at Argoguruh Weir

(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
183.87	209.46	181.38	132.24	109.27	65.87	47.74	32.39	67.01	43.23	52.39	83.33
188.05	167.83	165.73	120.25	83.10	40.83	37.91	48.85	52.63	54.17	56.38	105.05

The upper row shows the runoff during the first half of the month and second row the second half

3.2.8 Capacity of Batutegi Dam Reservoir

Though the area-capacity relation of Batutegi reservoir was measured in definite plan study on 1:10,000 scale maps, it was resource-measured using 1:5,000 scale aerial photo maps.

The estimated area-capacity curve of Batutegi reservoir is presented in Table. 3.8

The life of the reservoir expected to be 100 years, and effective storage volume after 100 year sedimentation about 578.8 x 10^6 m^3.

Fig. 3.8 Area-Capacity relation of Batutegi Reservoir (with sedimentation)

	Water level (El.m)	Water Surface (km^2)	Storage Volume (10^6 m^3)
Design Flood	28.5	25.0	751.3
Normal High Water	274.0	21.1	578.8
Low Water	208.0	0.7	2.0

3.2.9 River Maintenance Flow

After construction of a reservoir dam, the environmental situation change especially for aquatic life. In the environmental and ecological viewpoints, dam operation should be made so that negative effect to them is as little as possible.

In general, the river maintenance flow (called also duty flow, compensation flow or minimum flow) just after dam is determined to be 10-year probable drought discharge. Annual minimum daily mean discharges at Batutegi were analyzed and the river maintenance flow was set at 2.0 m^3. This means that even if no irrigation water is required, diversion of the discharge of 2.0 m^3 to the Sekampung river is obligatory on Batutegi dam.

3.2.10 Power Generation

The irrigation water will be diverted from Batutegi reservoir to the Sekampung River through irrigation/power waterway. This waterway will be circular tunnel with diameter of 3.5 m in the first portion and it branches into two penstocks; for irrigation release and for power house. Both the irrigation penstock and power penstock further branch into two penstock, respectively. In the power house, two units of generators will be installed with capacity of 12 MW each. In the water balance study, irrigation water is to be released through power tunnel as much as allowed and the excess water flows through irrigation outlet.

3.2.11 Water Balance Simulation

With river discharge data for 25 years from 1968 to 1993, water balance simulation was carried out in the conditions described below:

- Water level in the Batu tegi reservoir may not exceed El. 274.0 m nor be lower than El 208.0 m.
- Evaporation from reservoir water surface is below :

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(mm)	110	121	128	126	120	112	112	112	128	124	124	116
(mm/day)	3.55	4.28	4.13	4.20	3.87	3.73	3.61	3.62	4.27	4.00	4.13	3.74

(Final Report Hydrology Page IV-38)

- Conveyance efficiency from Batutegi dam to Argoguruh weir is set 0.95
- Irrigation areas of golongan -1,-2 and -3 are the same.
- Six (6) golongan are introduced at present of three (3) double cropping and three (3) single cropping patterns. As after the construction of Batutegi dam, double cropping area is expected to extend, only one (1) single cropping pattern is applied. That is, golongan-1, -2, -3 and -4 are employed in the simulation.
- Simulation is made semimonthly using:

$$V_{i+1} = V_i + Qb - DWR - Evp \qquad (3.1)$$

DWR = (IDWR – Qa)/e, if DWR turns negative, DWR is set at zero.

Where, V_{i+1} : Storage volume in the next period (m^3).

V_i : Storage volume in Batutegi reservoir (m^3)

Qb : Inflow to Batutegi Reservoir.

DWR: Diversion water demand from Batutegi dam (m^3)

Evp : Evaporation from the reservoir surface (m^3)

IDWR : Irrigation diversion water requirement at Argoguruh Weir (m3)

Qa : Runoff at Argoguruh (m^3)

e : Conveyance efficiency from Batutegi dam to Argoguruh Weir (0.95)

- If storage volume exceeds 578.8 x 10^6 m^3 (Vmax, storage volume at normal high water level), the excess water is split out through spillway and storage volume is reset at Vmax.
- In the same sense, in the case of that storage volume becomes less than 2.0 x 10^6 m^3 (Vmin, storage volume at low water level), it means water shortage occurs and storage volume is reset at Vmin.

The evaluation criteria for the water balance simulation are as follows:

- Irrigation water shortage less than 10 % is allowable.
- Irrigation water shortage more than 10 % may occur in not more than 5 years for the simulation period of 25 years.

Simulation was carried out considering the following options:

1. Irrigation area of 70,999 ha (excluding rumbia areas) is assured.
2. The following areas are simulated:

   76,789 ha (70,999 ha + West Rumbia)

   81,355 ha (the above + Rumbia II)

   88,565 ha (the above + Rumbia III)

   94,123 ha (the above + Rumbia IV)
3. The cropping intensity of 100 % in the rainy season is fixed.
4. The cropping intensities of 60%, 70%, 80%, 90% and 100% in the dry season are simulated.

The results are summarized in Table 3.9. The water balance simulation results reveal the following:

1. The water is sufficient to irrigate West Rumbia (the total irrigation area of 76,789 ha, with 190 % cropping intensity).
2. Dry season paddy cropping for 80 % of the total area (the overall cropping intensity 180 %) allows the irrigation for 81,355 ha including Rumbia II.
3. If dry season paddy cropping be as low as 70 % (the overall cropping intensity 170 %), Rumbia III could be irrigated, and if 60 % (the overall cropping intensity 160 %), as far as Rumbia IV could be irrigated.

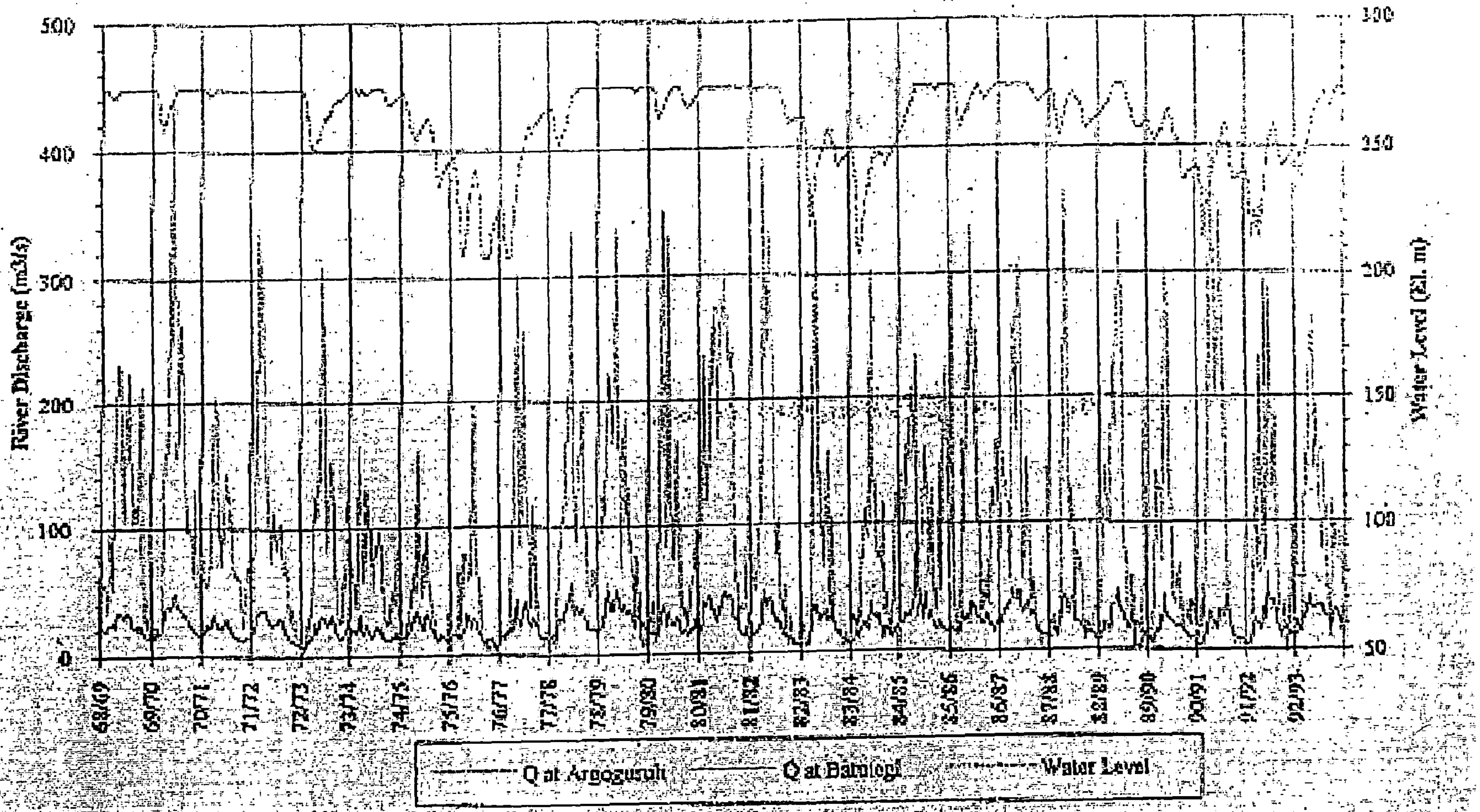
The simulation result for the following case (the maximum irrigation area under the cropping intensity 180 %, which is common for irrigation project in Indonesia) is presented in Table 3.9 and in Fig. 3.4

Table 3.9 Water Balance Simulation Result Summary

River Maintenance Flow : 2.00 m3/s
Muncipal Water : 0.00 m3/s

Total Irrigation Area (ha)	Crop Intensity	Ranny Season		Dry Season		Water Shortage Occurance (years)	Annual Power Generation (Gwh)	Remark
		Direct Diversion (ha)	Return Flow (ha)	Direct Diversion (ha)	Return Flow (ha)			
76,789	160%	68,789	8,000	41,273	4,800	0	127	Upto West Rumbia
	170%			48,152	5,600	0	117.9	
	180%			55,031	6,400	2	106.9	
	190%			**61,910**	**7,200**	**5**	**94.8**	
	200%			68,789	8,000	8	84.4	
81,355	160%	73,355	8,000	44,013	4,800	0	121	Upto Rumbia II
	170%			51,349	5,600	2	111.2	
	180%			**58,684**	**6,400**	**3**	**97.8**	
	190%			66,020	7,200	8	87.4	
	200%			73,355	8,000	11	75.7	
88,565	160%	77,782	10,783	46,669	4,800	1	115	Upto Rumbia III
	170%			54,447	5,600	3	103.6	
	180%			**62,226**	**6,400**	**8**	**90.8**	
	190%			70,004	7,200	11	78.9	
	200%			77,782	8,000	13	68.5	
94,123	**160%**	**83,340**	**10,783**	**50,004**	**4,800**	**2**	**106**	Upto Rumbia IV
	170%			58,338	5,600	6	93.8	
	180%			66,672	6,400	8	81.4	
	190%			75,006	7,200	13	70.3	
	200%			83,340	8,000	14	59.5	

Figure 3.3 Water Balance Simulation Result



CHAPTER IV

METHODOLOGY

4.1 GENERAL

Irrigation scheduling primarily described when to and how much irrigate. Despite its seeming importance, a relatively small proportion of produces utilize scientific scheduling practices. Competition for agricultural water is rapidly increasing through urban expansion, industrial and recreational uses. Efficient irrigation scheduling based on sound methodology must be emphasized as water supplies become scarce and the price of water increases.

The biggest challenge for irrigation scheduling is to develop methodology specific to various crop and environments. Without economic or social incentives for scientific scheduling, adoption of technical and real time procedures have been slow or non-existent. Consequently, most irrigators do not use real time procedures despite technological advancements. Techniques must be developed and disseminated effectively so that producers can use them. Otherwise, research and demonstration efforts are wasted **(Martin et al., 1990).** The challenge to researchers is to develop economically viable technology that is readily adaptable to rural society. To be effective, agricultural research must be directed to producer needs and results made available to producers readily and conveniently **(Seegers and Kaiomowitz, 1990).**

4.2. IRRIGATION SCHEDULING METHODS

There are various methods available for scheduling irrigation. In principle, irrigation can be scheduled by monitoring the soil, plant and/or micro climate interactions **(Hillel, 1990).** These methods involve:

- All aspects of irrigation management, and especially irrigation scheduling, require an understanding of the soil water balance. Using the balance, the amount of water in the root zone at any given time is estimated.

  Soil water affect plant growth directly by influencing plant water potential and indirectly through its influence on soil aeration, soil temperature and nutrient

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mobility **(Phene et al., 1990).** Traditionally, irrigation scheduling is based on soil moisture levels. Soil moisture can be measured using: gravimetric determination, neutron probe, time domain reflectometry, tensiometer, and/or gypsum block techniques **(Swartwood and Remer, 1992).** These measurements are site specific and, therefore, need many observations to properly characterize a field moisture status. This however is a laborious and expensive procedure. In addition, some of these methods require tedious calibration procedures, frequent servicing and constant supervision.

- Plant-based Measurement

Plant responds interactively to soil and environmental conditions. Hence, they are a logical indicator for irrigation scheduling. Plants can be used to schedule irrigation through visual observations. There are also numerous destructive and non-destructive techniques. These methods are labour intensive. They require many samples for testing. Measurement must be normalized with well-watered fields for accurate estimations **(Phene et al., 1990).** Visual indicators of plant stress are often an after-the-affect method of scheduling. More recently, plant canopy temperature relative to air temperature using infrared thermometer has been used for irrigation scheduling with varying degrees of success (Council for Agricultural Science and Technology, 1988).

- Weather

The method based on Evapotranspiration (ET) for scheduling irrigation follows a meteorological imposed evapotranspirational demand as it varies over time, and irrigation requirements determined accordingly **(Hillel, 1990).** ET is used in combination with the soil water balance equation to schedule irrigation.

The estimation of potential evapotranspiration, as defined by the Penman and other formulae, can serve as irrigation scheduling criteria. Evaporation pans are widely used all over the world, despite having differences in energy balance, aerodynamic, and vegetative surfaces **(Phene et al., 1990).** This requires data from well-equipped meteorological stations. Lysimeters and atmometer are also used to measure ET.

4.3. PROBLEMS WITH IRRIGATION SCHEDULING

In the Way Sekampung Irrigation Project, approximately 80% of the total water is used for agricultural purposes. Presently domestic and industrial needs are relatively low. However demand for water is expected to increase in all sectors and this will require considerable improvements in efficiency. Major improvement must come from dominant user, irrigation **(Hennessy, 1993)**. Numerous methods, as previously discussed, are available to facilitate irrigation scheduling. Despite this, the overall use of scheduling methodology is very limited. In this study, CROPWAT program is used for irrigation scheduling, a description of which follows

4.4. THE CROPWAT PROGRAM

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for determination of the functions summarized in Table 4.1

Table 4.1 : Summary of CROPWAT functions

To calculate:	To develop:	To evaluate:
• Reference evapotranspirationon • Crop water requirement • Crop irrigation requirements	• Irrigation schedules under various management conditions. • Scheme water supply	• Rain fed production and Drought effects. • Efficiency of irrigation practices

CROPWAT is meant as a practical tool to help agro-meteorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain-fed conditions or deficit irrigation.

Prediction methods for crop water requirements (CWR) are used owing to the difficulty of obtaining accurate field measurement. The methods often need to be applied under climatic and agronomic conditions very different from those under which they were originally developed. Testing the accuracy of the method under a new set of conditions is laborious, time-consuming and costly, and yet CWR data are frequently needed at short notice for project planning.

Thus amongst other, CROPWAT version 4.3 performs calculations of crop water requirements and irrigation requirements, which are carried out with inputs of climatic and crop data. Standard crop data are included in the program. The development of irrigation schedules and evaluation of rain fed and irrigation practices are based on a daily soil-water balance using various options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern provided.

Procedures for calculation of the crop water requirements and irrigation requirement are based on methodologies presented in FAO Irrigation and Drainage Papers No 24 'Crop water requirements' and No. 33 'Yield response to water', many of which are summarized in FAO Irrigation and Drainage Paper No.56 'Crop Evapotranspiration'. CROPWAT uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration. The methods supersede the older FAO 24 procedures published in 1977, which are no longer recommended as they overestimate evapotranspiration. The CROPWAT version 4.3, currently used for all simulations, calculates the following:

- Crop Water Requirements (CWR)
- Irrigation Scheduling

4.4.1 Input Data

The following Table 4.2 lists the input data required for CWR and irrigation scheduling calculations:

Table 4.2 CROPWAT version 4.3 input data requirements

Data Item	CWR	Irrigation Scheduling
Climate	Optional	Optional
Reference Evapotranspiration	Required	Required
Rainfall	Optional	Optional
Crop Data	Optional	Optional
Cropping Pattern	Required	Required
Soil Data	Not required	Required
Scheduling Criteria	Not required	Required

4.4.2 Crop Water Requirements

Crop water requirement have already been defined as ETm. To calculate CWR, measured values of the reference evapotranspiration (ETo) can be directly entered. In the case, any other climatic data can be omitted. Hence, the data item ' climate' in Table 3.3. is optional. If however, no measured values of reference evapotranspiration exist, then CROPWAT calculates it from the climate data using the revised FAO Penman Monteith equation.

(a) Cropping Pattern

A cropping pattern is necessary, because CropWat calculates the CWR for each crop planted as a function of the total area available (%) upon which the crop is grown for that period as:

$$CWR = ETo . Kc . Area\_Planted \quad (3.2)$$

The following cropping pattern was entered for all simulations:

Table 4.3: Cropping Pattern

S. No	Variable	Value used
1	Percentage of total area planted to crop	100% (because only one crop was planted thought the year on one specific plot of land)
2	First Planting Day	15 October

(b) Monthly Rainfall Data

Rainfall data is not necessary but it should be used if rain falls in the growing season. Hence it is listed as an 'optional' data item. The effective rainfall was calculated by selecting the 'dependable' option, which is an empirical formula developed by FAO based on analysis for different arid and sub humid climates. This formula is as follows:

$$P_{eff} = 0.6\, P_{Tot} - 10 \; (P_{Tot} < 70 \text{ mm}) \quad (3.3\text{ a})$$

$$Peff = 0.8\, P_{Tot} - 10 \; (P_{Tot} > 70 \text{ mm}) \quad (3.3\text{ b})$$

Where,

Peff is the effective rainfall (mm $month^{-1}$),

P_{Tot} is the total rainfall (mm $month^{-1}$)

(c) Soil Data

CROPWAT requires soil data to calculate the Total Available Moisture, TAM. As the water content above field capacity cannot be held against the forces of gravity and will drain, and as plant roots cannot extract the water content below wilting point, the total available water in the root zone is the difference between the water content at field capacity and wilting point (FAO Irrigation and Drainage Paper No.56, 1998):

$$TAW = 1000(\theta_{FC} - \theta_{WP})Z_r \quad \text{...(3.4)}$$

Where:

TAW is the total available soil water in the root zone, equal to TAM in the case (mm m^{-1} depth);

θ_{FC} is the soil water content at field capacity ($m^3\ m^{-3}$) equal to θ (volumetric water content)

θ_{WP} is the volumetric water contents at wilting point ($m^3\ m^{-3}$), equal to θ_{res} (Residual Water Content)

Z_r the rooting depth (m), equal to Maximum Rooting Depth.

TAM is the amount of water that a crop can extract from the root zone, and its magnitude depends on the type of soil and the rooting depth.

4.4.3 Scheduling Criteria

Before any irrigation requirements can be carried out a scheduling criteria must be defined. The table below lists the scheduling criteria used for simulating the current scenario:

Table.4 .4 Scheduling criteria input data

Criteria	Calculation method
References Evapotranspiration (ETo) as per Penman Monteith	ETo Distribution Model: Fit a curve to monthly averages
	Angstrom's Coefficients (default Values): a = 0.25 b = 0.5
Rainfall	Rainfall Distribution Model: Fit a curve to monthly averages
	Aggregate Interpolated daily rainfall into individual strom every 5 days (Default Value)
Effective Rainfall	Effective rainfall calculation method: Dependable rain
	Application Timing: Irrigate when a specified % of Total Available Soil Moisture Depletion occurs (90% entered)
	Application Depth: Refill to a specified % of Readily Available Soil Moisture (100%)
	Start of Scheduling: First Planting Date of Each Crop (15 th Oct. in the case)

From the above, it is evident that calculations of the crop water requirements and irrigation requirements are carried out with input of climatic, crop and soil data. For the estimation crop water requirements (CWR) the model requires:

a) Reference Crop Evapotranspiration (ETo) value measured or calculated using the FAO Penman-Monteith equation based on the decade/monthly climatic data: minimum and maximum air temperature, relative humidity, sunshine duration and win speed;
b) Rainfall data (daily/decade/monthly data); monthly rainfall is divided into a number of rain storm each month;
c) A Cropping Pattern consisting of the planting date, crop coefficient data files (including Kc value, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area); a set of typical crop coefficient data files are provided in the program.

In addition, for Irrigation Scheduling the model requires information on:

d) Soil Type: total available soil moisture, maximum rooting depth, initial soil moisture depletion (5 of total available moisture);
e) Scheduling Criteria – several options can be selected regarding the calculation of application timing and application depth (e.g. 80 mm every 14 days, or irrigate to return the soil back to field capacity when all the easily available moisture has been used).

- Total Available Moisture – TAM (mm); Readily Available Moisture – RAM (mm);
- Actual Crop Evapotranspiration – ETc (mm);
- Ratio of Actual Crop Evapotranspiration to the maximum Crop Evapotranspiration – ETc/E Tm (%);
- Daily Soil Moisture Deficit (mm);
- Irrigation Interval (days) and Irrigation Depth Applied (mm);
- Lost Irrigation (mm) – irrigation water that is not stored in the soil (i.e. either – surface runoff or percolation);
- Estimated Yield Reduction due to crop stress (when Etc/Etm falls below 100%);
- Field Water Supply (l/s/ha).

4.5 COMPUTATIONAL PROCEDURE

The flowchart (Fig.4.1) describes the computational procedure, which is self explanatory:

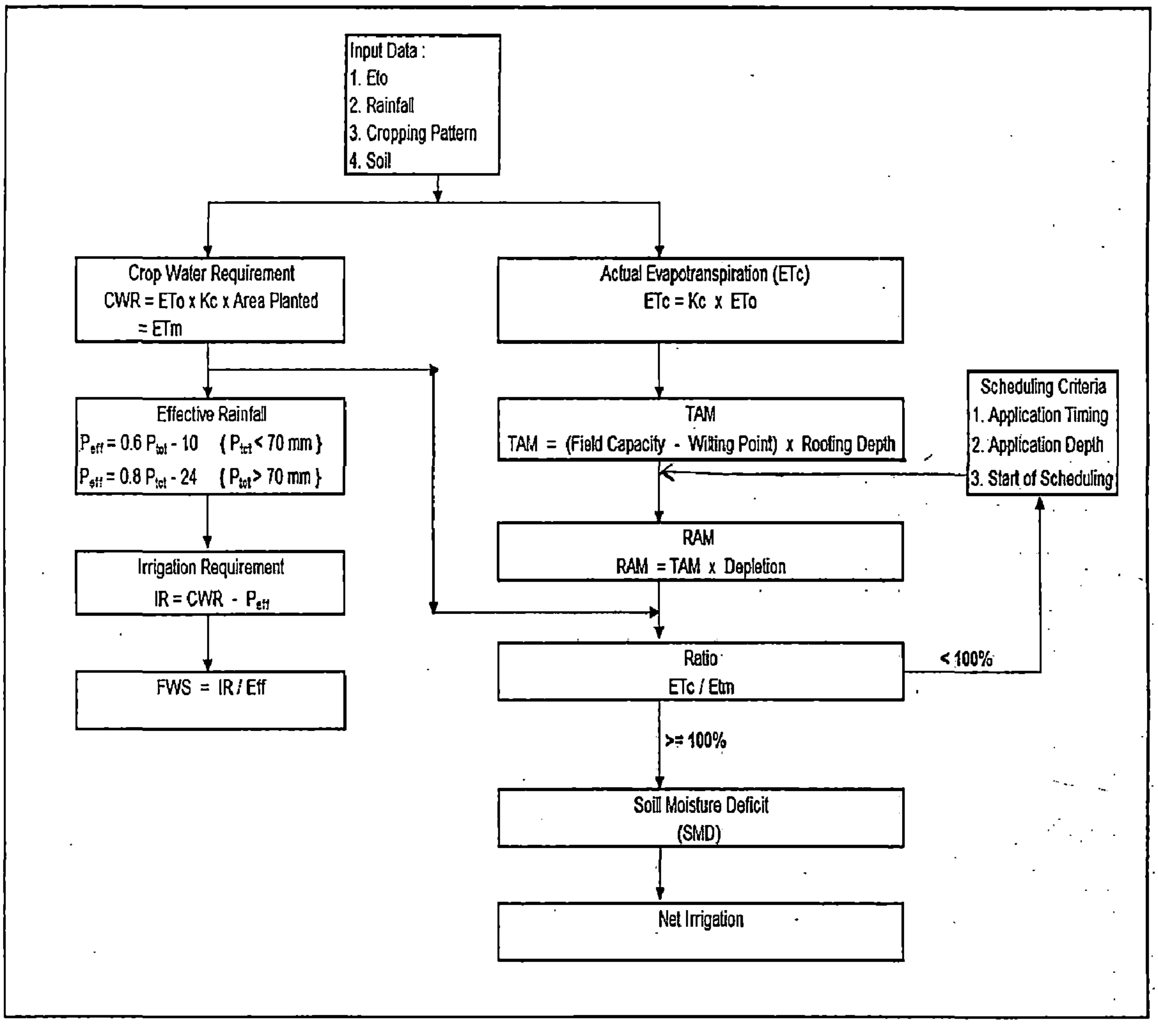


Fig. 4.1 Computational Procedure of CROPWAT Program

The value of decade or monthly Reference Crop Evapotranspiration (ETo) are converted into daily using four distribution models (the default is a polynomial curve fitting).

The models calculate the Crop Water Requirements using the equation: CWR=ETo*Kc*area planted. This means that the peak CWR in mm/day can be less than the peak ETo value when less than 100% of the area is planted in the cropping pattern. The average values of crop coefficient for each time step are estimated by linear interpolation between the Kc values of each crop development stage. The "Crop Kc" values are calculated as Kc*Crop Area. So if the crop covers only 50% of the area, the "Crop Kc" values will be half of the Kc values in the crop coefficient data file. For crop water requirements and scheduling purposes, the monthly total rainfall has to be distributed into equivalent daily values. CropWat does this in two steps. First the rainfall from month to month is smoothed into continuous curve (the default curve is a polynomial curve, but can be selected other smoothing methods available in the program e.g. linear interpolation between monthly values). Next the model assumes that the monthly rain fall in 6 separate rainstorms, one every 5 days or 10 days (the number of the rainstorms can be changed). The model can compute the effective rainfall using any of the four methods. The assumed in field irrigation efficiencies, which affect the calculated the field water supply (FWS).

For the Irrigation Scheduling criteria option shows the status of the soil moisture every time new water enters the soil, either by rainfall or a calculated irrigation application. Calculated irrigation events would be find result net irrigation.

Total Available Moisture (TAM) in the soil for the crop during the growing season is calculated as Field Capacity minus the Wilting Point times the current rooting depth of the crop. Readily Available Moisture (RAM) is calculated as TAM*P, where P is the depletion fraction as defined in the crop coefficient (Kc) file. To avoid crop stress, the calculated soil moisture deficit should not fall bellow the readily available moisture.

Ratio of actual crop ET to be maximum crop ET. This defined irrigation schedules should be 100% for an unstressed crop, if the less than 100% called stressed crop and should be review of scheduling criteria (application timing, application depth, and start of scheduling) repeat calculation of readily soil moisture (RAM) until satisfy with ratio of ratio of actual crop ET (ETc) to be maximum crop ET (ETm) more than or equal to 100%.

4.6 OUTPUT

Once all the data are supplied, CropWat Windows version 4.3 automatically calculates the results as tables or plots the graphs. The time step of the result can vary as: daily, weekly, decade or monthly. The output parameters for each crop in the cropping pattern are:

- reference crop evapotranspiration – ETo (mm/period);
- Crop Kc – average of crop coefficient for each time step;
- Effective rain (mm/period) – the amount of water that enters the soil;
- Crop water requirement – CWR or ETm (mm/period);
- Irrigation Water Requirement – IWR (mm/period);

4.7 POTENTIAL USES OF SOFWARE

The software can be used for the following:

- Can calculate the potential evapotranspiration (ETo) by Penman Monteith method (which is standard method) and field irrigation requirement.
- Can be used to study the practice of actual irrigation in field vs the scientific irrigation. This can give data on water going as wastage and its effect on yield and salinity due to over-irrigation.
- Given the field water supply (liter/sec/ha), it can be useful for water distribution planning. Effect of different application efficiencies for different crops can be analyzed.
- It is useful in irrigation planning for complete project area to decide following:
  - Different cropping patterns and related irrigation water demand
  - Plantation if each crop in a set of blocks staggered in time for example paddy crop area staggered into four blocks and planted at ten days interval. Its effect on peak irrigation water demand can be analyzed to reduce the peak demand and thus canal capacity can be scientifically fixed.

CHAPTER V

ANALYSIS AND DISCUSSION OF RESULTS

CROPWAT (Chapter 4), which is a decision support system and developed by the Land Water Development Division of Food and Agricultural Organization (FAO) for planning and management of irrigation, was used as a tool to carry out calculations for reference evapotranspiration, crop water requirement, and crop irrigation requirement, more specifically for the design and management of irrigation schemes. It allows the development of improved irrigation practices, and the assessment of crop production under rain-fed conditions or deficit irrigation. In this Chapter, CROPWAT was employed for scheduling of irrigation in the command area of Way Sekampung Irrigation Project, Indonesia. To this end, the information is required on crop water requirements, irrigation demands, cropping pattern, soil type, etc.. The employment of CROPWAT helps derive a suitable (optimal) cropping pattern which requires minimum irrigation, but meets the crop water requirement. A sensitivity analysis was also carried out to investigate the impact of varying the governing factors affecting the scheduling of irrigation.

5.1 CROP WATER REQUIREMENT

For estimation of crop water requirement, modified Penman method was applied, which is widely used in the world and is quite popular in Indonesia. The procedure is used to estimate i) reference crop evapotrnspiration (ETo) from climatic data, ii) crop coefficient (Kc), and iii) consumptive use (ETc). ETo is obtained from climatic data such as mean temperature, relative humidity, wind run and sunshine hours. Climatic data at Branti (Table 3.3) was used for estimation. The reference crop water requirement was estimated as given in Table 5.1 following the computational procedure presented in Table B.1. (Appendix B).

Table 5.1 Reference Crop Evapotranspiration (ETo) (mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.58	4.81	4.93	4.76	4.51	4.76	4.49	5.09	5.10	5.28	4.85	4.66

In accordance with the FAO guidelines, the Crop coefficient (Kc) was set for paddy as below:

For every half a month after transplanting: 1.00, 1.00, 1.15, 1.15, and 1.15.

Thus, Crop Water Requirement is obtained as follows:

$$ETc = Kc \times ETo \quad \text{(5.1)}$$

Where, ETc : Consumptive Use (mm/day)

Kc: Crop Coefficient

ETo: Reference Crop Evapotranspiration (mm/day)

5.2 IRRIGATION DEMAND

Monthly irrigation demands are based on (i) crop calendar, area and golongan (rotational groups); (ii) crop water requirement; (iii) consideration of water requirement for land preparation, percolation losses, effective rainfall etc; and (iv) conveyance efficiencies.

5.2.1 Different Scenarios of Irrigation Development

The simulation (Appendix A) considers the following scenarios of irrigation development (Report, 1994)

- Irrigation area of 70,999 ha (excluding Rumbia areas) is assured
- The following irrigation scenarios are simulated:

  Scenarios I : 76,789 ha (70,999 ha + West Rumbia)

  Scenarios II : 81,355 ha (Scenarios I + Rumbia II)

  Scenarios III : 88,565 ha (Scenarios II + Rumbia III)

  Scenarios IV : 94,123 ha (Scenarios III + Rumbia IV)
- The cropping intensity of 100% in the rainy season is fixed.
- The cropping intensities of 60%, 70%, 80%, 90% and 100% in the dry season are considered for each of the above scenarios. Thus, there are twenty conditions of simulations analysis and different scenarios of irrigation development as shown in

Table 5.2. The simulation result for the following case (the maximum irrigation area under the cropping intensity 180%, which is typical for an irrigation project in Indonesia) is presented below:

Total Irrigation Area	: 81,355 ha (including up to Rumbia II)
Direct Diversion Area	: 73,355 ha
Rainy Season	: 73,355 ha
Dry Season	: 58,684 ha (80%)
Golongan – 1	: 19,561 ha
Golongan – 2	: 19,561 ha
Golongan - 3	: 19,561 ha
Golongan – 4	: 14,671 ha

5.2.2 Cropping Pattern and Golongans

The cropping pattern shows the kind of crops, their starting, and cultivation time in general for a certain command area. Generally there are 3 types of cropping patterns which are adopted in Indonesia, and these are:

(i) Paddy-Paddy Pattern

In certain command area paddy is cultivated twice a year.

(ii) Paddy-Paddy-Palawija Pattern

In a certain command area paddy is cultivated twice and Palawija once a year. It is usually performed in case there is plenty of water available throughout the year and by using the high yielding varieties (paddy which has life time duration less than 140 days).

(iii) Paddy – Palawija – Palawija Pattern

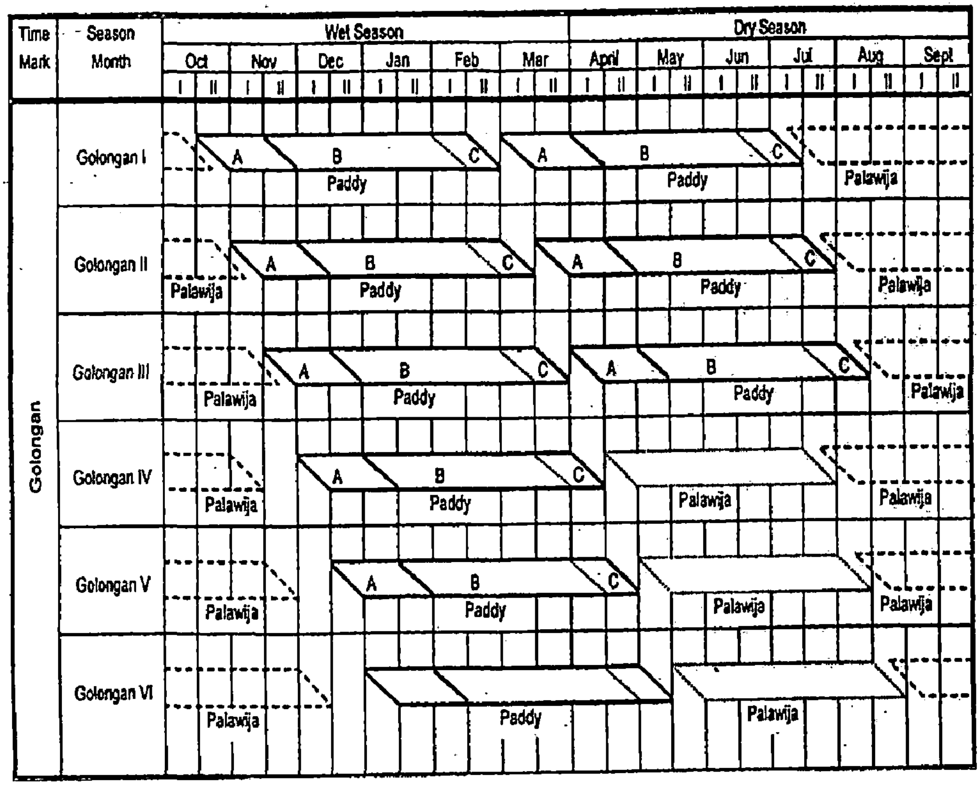
In a certain command area paddy is cultivatied once and Palawija twice a year. It is usually performed in some part of a certain command area which gets insufficient water due to limited water being available in dry season.

Table 5.2. Different Scenarios of Irrigation Development

Condition	Zone	Total Irrigation Area (Ha)	Crop Intensity	Irrigation Area			
				Rainy Season		Dry Season	
				Direct Diversion	Return Flow	Direct Diversion	Return Flow
I	Up to West Rumbia	76789	160	68789	8000	41273	4800
II	Up to West Rumbia	76789	170	68789	8000	48152	5600
III	Up to West Rumbia	76789	180	68789	8000	55031	6400
IV	Up to West Rumbia	76789	190	68789	8000	61910	7200
V	Up to West Rumbia	76789	200	68789	8000	68789	8000
VI	Up to Rumbia II	81355	160	73355	8000	44013	4800
VII	Up to Rumbia II	81355	170	73355	8000	51349	5600
VIII	Up to Rumbia II	81355	180	73355	8000	58684	6400
IX	Up to Rumbia II	81355	190	73355	8000	66020	7200
X	Up to Rumbia II	81355	200	73355	8000	73355	8000
XI	Up to Rumbia III	88565	160	77782	10783	46669	6470
XII	Up to Rumbia III	88565	170	77782	10783	5447	7548
XIII	Up to Rumbia III	88565	180	77782	10783	62226	8626
XIV	Up to Rumbia III	88565	190	77782	10783	70004	9705
XV	Up to Rumbia III	88565	200	77782	10783	77782	10783
XVI	Up to Rumbia IV	94123	160	83340	10783	50004	6470
XVII	Up to Rumbia IV	94123	170	83340	10783	58338	7548
XVIII	Up to Rumbia IV	94123	180	83340	10783	66672	8626
XIX	Up to Rumbia IV	94123	190	83340	10783	75006	9705
XX	Up to Rumbia IV	94123	200	83340	10783	83340	10783

Fig. 5.1 shows the cropping pattern and staggering of golongan to lower the peak water requirement in irrigation Way Sekampung. It also helps in lowering the peak labor requirement. In the rainy season, the land preparation in golongans1 starts in the second half of dry season, Paddy land in golongan 1 is prepared in the first half of March followed by golongan 1 and 3. After the land preparation for one month, nursery paddy is transplanted in the field. Two and half months after the transplanting, the irrigation is stopped and another half a month later, the matured

paddy is harvested. In the dry season, upland crops are planted between the two paddy cropping seasons, however, they are not provided with irrigation water.



Month	Monthly water requirement (m^3/month/ha)	
	Without system golongan	Apply system golongan
OCT	1529	418
NOV	5003	2761
DEC	3188	3501
JAN	3340	3487
FEB	855	2425
MAR	3551	2198
APR	4147	3886
MAY	3888	3243
JUN	3188	3110
JUL	0	1157
AUG	0	0
SEP	0	0

A: Nursery + Land preparation (1 month);
B: Planting + Growing (2.5 months)
C: Graining (0.5 month)

Fig. 5.1 Proposed cropping pattern and golongans.

5.2.3 Irrigation Diversion Requirement at Argoguruh Weir

The following procedure was used to estimate irrigation diversion water requirement (IDWR) at Argoguruh weir in each month:

Monthly IWD (MCM) = IDWR (litre/sec/ha) x Area x conversion .... (5.2)

IDWR (l/s/ha) $= \dfrac{IWR}{E}$ x conversion; E: Irrigation Efficiency .... (5.3)

IWR (mm/day) = ETc + LP + P – Re .... (5.4)

Where:

IWR : Irrigation Water Requirement (mm/day)

ETc : Consumptive Use (mm/day) : Kc x ETo.

LP : Land Preparation Water Requirement (mm/day): Mek / ek – 1

M : Water requirement to compensate for evaporation and percolation, M = Eo + P

Eo : Open water evaporation during land preparation.

k : M.T / S

T : Land preparation period (day)

S : Pre-saturation requirement

P : Percolation rate (mm/day)

Re : Effective Rainfall (mm/day)

Irrigation diversion water requirement (Table C.1, Appendix C) was estimated as follows. The required water allowance on monthly basis at Argoguruh weir for each of the six golongans are given in Table C.2, and Table C.3 (Appendix C) provides the computation result of annual water requirement for each of the six golongans as per the above scenarios of different irrigation areas. These have been taken from Report (1994). It is noted that the water requirement is significantly reduced by consideration of shift in crop calendar for each golongan. As shown in Fig. 5.1, the maximum monthly water requirement per ha of area is 5003 m^3/month/ha without consideration of group system and it is 3686 m^3/month/ha with consideration of group system.

5.2.4 Irrigation Demand at Batutegi Dam Site (DWD)

Part of irrigation diversion requirements can be met by interim catchments runoff between Batutegi dams and Argoguruh weir. Therefore, downstream releases to be made from the Batutegi are:

$$DWD = IWD - Qa / e \quad (5.6)$$

Where,

DWD = demand at Batutegi Dam site

IWD = irrigation diversion water requirement at Argoguruh weir

Qa = run off at Argoguruh weir

e = conveyance efficiency from Argoguruh weir to Batutegi dam

5.2.5 Efficiencies

The diversion requirement at the reservoir is more than the net field requirement because of losses in the distribution system. The efficiency of the system is usually broken down into the following components: field, tertiary head, secondary canals and main canals. The adopted efficiencies as well as and the calculated overall efficiencies are shown below:

Table 5.3. Efficiencies (%)

Element	Wet	Season Rice	Dry	Season Crop
	For element	Total (%)	For element	Total (%)
Field	100	100	75	75
Tertiary head	80	80	80	60
Secondary canals	90	72	90	54
Main canal	90	65	90	49

For Wet Season Rice:

Efficiency = 100 x 0.8 x 0.9 x 0.9 = 65%

For Dry Season Rice:

Efficiency = 75 x 0.8 x 0.9 x 0.9 = 49%

The field efficiency for wet season rice is assumed to be 100% because in most of the area "losses" simply spill into the next field. With dry season rice this would not be the case because only a very small proportion of the area is devoted to rice. The adopted overall efficiencies are 65% for the wet season and 50% for the dry season. These conform to Indonesian practice which is usually followed.

When return flows from part of the command area contribute to the supply for another part the overall efficiency will be higher than these values. It has been assumed that the area contributing such return flows has an effective efficiency 15% higher (i.e. 80% and 65% for wet and dry seasons, respectively). This means that in the wet season about 40% of the losses are in fact re-used, and 30% in the dry season.

An overall basin efficiency is calculated as a weighted average of areas with and without return flows. For Irrigation Way Sekampung 8,000 ha provide return flows (partly from Way Seputih and partly within the Way Sekampung command areas); wet season basin efficiency is as follows:

$$\text{Basin efficiency} = \frac{8000x80x73355x65}{81355} = 66.5\%$$

With the availability of CROPWAT Software, a practical tool, the following analysis attempts to study the effect of various governing factors, such as stipulated irrigation efficiency, staggering of planting date, irrigation scheduling option, maximum infiltration to soil, and maximum rooting depth on the field water supply (FWS)

5.3 CROPWAT APPLICATION

To evaluate the effect of the above described governing factors on the field water supply, these factors were varied in the practicable range, as shown in Table 5.4

Table 5.4 Range/values of governing factors

Sl. No	Governing Factor	Range / Value taken
1	Irrigation Efficiency	65%, 70%, 75%
2	Staggering of planting date	15 October, 1 November, 15 November
3	Irrigation scheduling option	75%, 80%, 100%
4	Maximum soil infiltration	35 mm, 40 mm, 45 mm
5	Maximum rooting depth	3 m, 5 m, 9 m

As an example, with irrigation efficiency at 65% and planting date of 15 October for rice crop, Tables 5.5a and 5.5b show a detailed CROPWAT output at 10-day interval. Table 5.5 is useful for computation of crop water requirement, and Table 5.5b for irrigation scheduling. In these tables, ETo is the potential evapotranspiration (mm/period), the planted area of 100% indicates that there exists only one crop in the command area, Kc is the crop factor to compute the actual evapotranspiration (ETm). Total rain is the total amount of rainfall (mm) during the period, Effect. Rain represents the effective amount of rainfall after exclusion of infiltration losses, Irr.

Req. is the amount of irrigation water required, FWS is the field water supply, TAM is the total available moisture (mm), RAM is the readily available moisture (mm), SMD is the soil moisture deficit, Interval. Is the time interval (days), Net Irr. Is the net amount of irrigation required, and Lost Irrigation is amount of water lost in irrigation. These calculations are consistent with the procedure described in Fig. 4.1 (chapter 4).

In Table 5.5a, since ETo and amount of rainfall vary within the year, the computed values of FWS also differ from each other during the whole year. Here, only rice is considered for further analysis, for it is the major crop of Indonesia. The field water supply (FWS) was taken as an indicator for investigating the effect of the above-mentioned governing factors.

The annual average values of FWS resulting from different values of governing factors in different runs are given in Table 5.6. For example, the computed field water supply (FWS) of 0.52 l/s/ha in this table stands for the annual average of FWS values resulting in the above cited combination of governing factors. It is seen from Table 5.6 that these annual average values of FWS are however constant for certain factors, viz., irrigation scheduling option, maximum soil infiltration, and maximum rooting depth. It implies that the ultimate field water supply does not depend on these factors. It however holds within the premise of the above range (Table 5.4). The FWS computations beyond this range were not attempted because of their non-practicability in Indonesia. Here, it is further noted that it is apparently unrealistic to assert the derived inference. It might be because of the size of dimensions of FWS, which are given as l/s/ha, a very small value and, in turn, resulting in rounded-off values. Thus, the constant 0.52 value is not actually constant, rather varying at higher decimal places, which are rounded at the second place.

The verification was not possible because of the non-availability of the source code. However, this much can certainly be ascertained that the impact of these factors is not significant on the ultimate field water supply computation.

Table 5.5a Crop Water Requirement Report

CROPWAT 4 Windows 4.3

Crop 1 : Rice
Blocks : All blocks
Planting Date : 15/10
Calculation Time Step : 10 Days
Irrigation Efficiency : 65%

Date	Eto	Planted Area (%)	Crop Kc	CWR (Etm) (mm/period)	Total Rain (mm/period)	Effect Rain (mm/period)	Irrigation Requirement (mm/period)	FWS (l/s/ha)
15/10	48.8	100	1.1	53.69	7.34	0	53.69	0.96
25/10	48.89	100	1.1	53.78	11.76	2.42	51.36	0.91
4-11	48.82	100	1.1	53.7	18.75	7.65	46, 04	0.83
14/11	48.58			53.44	27.29	14.35	39.09	0.7
24/11	48.17	100	1.1	52.99	35.81	20.62	32.37	0.58
4/12	47.6	100	1.1	52.36	42.81	25.33	27.03	0.48
14/12	46.89	100	1.1	51.58	47.26	28.07	23.5	0.42
24/12	46.17	100	1.1	50.79	48.52	28.73	22.06	0.39
3/1	46.6	100	1.1	51.26	48.07	28.63	22.63	0.4
13/1	47.06	100	1.1	51.76	49.61	30.17	21.6	0.38
23/1	47.39	100	1.1	52.13	50.74	31.29	20.84	0.37
2/2	47.59	100	1.1	52.35	51.11	31.66	20.7	0.37
12/2	47.66	100	1.07	51.11	50.48	31.06	20.06	0.36
22/2	47.6	100	1.02	48.67	48.72	29.42	19.24	0.34
4/3	47.42	100	0.97	46.12	45.8	26.94	19.27	0.34
Total	47.42			775.73	584.07	336.24	439.49	[0.52]

* Eto data is distributed using polinomial curve fitting
* Rainfall data is distributed using polinomial curve fitting

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Table 5.5b Irrigation Scheduling Report

CROPWAT 4 Windows Ver.4.3

* Crop Data
Crop # 1 : rice
Block # : 1
Planting Date : 15/10
* Soil Data
Soil description : Light
Initial soil moisture : 0%
* Irrigation Scheduling Criteria
Application Timing:
-Irrigate when 100% of readily soil moisture depletion occurs
Application Depth:
-Refill to 100 % of readily available soil moisture
Start of scheduling: 15/10

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efect. Rain (mm)	ETc (mm)	ETc/ETm %	SMD (mm)	Interv. (Days)	Net. Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
15/10	30	9	7.3	0	5.4	100%	5.4				
16/10	30	9	0	0	5.4	100%	10.7	1	8.9	0	
18/10	30	9	0	0	5.4	100%	12.5	2	10.7	0	
20/10	30	9	0	0	5.4		12.5	2	10.7	0	
22/10	30	9	0	0	5.4	100%	12.5	2	10.7	0	
24/10	30	9	0	0	5.4	100%	12.5	2	10.7	0	
25/10	30	9	11.8	1.8	5.4	100%	5.4				
26/10	30	9	0	0	5.4	100%	10.8	2	9	0	
28/10	30	9	0	0	5.4	100%	12.6	2	10.8	0	
30/10	30	9	0	0	5.4	100%	12.6	2	10.8	0	
1/11	30	9	0	0	5.4	100%	12.6	2	10.8	0	
3/11	30	9	0	0	5.4	100%	12.6	2	10.8	0	
4/11	30	9	18.7	1.8	5.4	100%	5.4				
5/11	30	9	0	0	5.4	100%	10.8	2	9	0	
7/11	30	9	0	0	5.4	100%	12.5	2	10.7	0	
9/11	30	9	0	0	5.4	100%	12.5	2	10.7	0	
11/11	30	9	0	0	5.4	100%	12.5	2	10.7	0	
13/11	30	9	0	0	5.4	100%	12.5	2	10.7	0	
14/11	30	9	27.3	1.8	5.4	100%	5.4				
15/11	30	9	0	0	5.4	100%	10.7	2	8.9	0	
17/11	30	9	0	0	5.3	100%	12.5	2	10.7	0	
19/11	30	9	0	0	5.3	100%	12.5	2	10.7	0	
21/11	30	9	0	0	5.3	100%	12.5	2	10.7	0	
23/11	30	9	0	0	5.3	100%	12.5	2	10.7	0	
24/11	30	9	35.8	1.8	5.3	100%	5.3				

Table 5.5b Contd

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efect. Rain (mm)	ETc (mm)	ETc/ETm %	SMD (mm)	Interv. (Days)	Net. Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
25/11	30	9	0	0	5.3	100%	10.6	2	8.8	0	
27/11	30	9	0	0	5.3	100%	12.4	2	10.6	0	
29/11	30	9	0	0	5.3	100%	12.4	2	10.6	0	
4/12	30	9	42.8	1.8	5.3	100%	5.3				
5/12	30	9	0	0	5.3	100%	10.5	2	8.7	0	
7/12	30	9	0	0	5.2	100%	12.3	2	10.5	0	
9/12	30	9	0	0	5.2	100%	12.3	2	10.5	0	
11/12	30	9	0	0	5.2	100%	12.2	2	10.4	0	
13/12	30	9	0	0	5.2	100%	12.2	2	10.4	0	
14/12	30	9	47.3	1.8	5.2	100%	5.2				
15/12	30	9	0	0	5.2	100%	10.4	2	8.6	0	
17/12	30	9	0	0	5.2	100%	12.2	2	10.4	0	
19/12	30	9	0	0	5.2	100%	12.1	2	10.3	0	
21/12	30	9	0	0	5.1	100%	12.1	2	10.3	0	
23/12	30	9	0	0	5.1	100%	12	2	10.2	0	
24/12	30	9	39.1	1.8	5.1	100%	5.1				
25/12	30	9	0	0	5.1	100%	10.2	2	8.4	0	
27/12	30	9	0	0	5.1	100%	12	2	10.2	0	
29/12	30	9	0	0	5.1	100%	11.9	2	10.1	0	
31/12	30	9	0	0	5.1	100%	11.9	2	10.1	0	
1/1	30	9	47.7	1.8	5.1	100%	5.1				
2/1	30	9	0	0	5.1	100%	10.2	2	8.4	0	
4/1	30	9	0	0	5.1	100%	12	2	10.2	0	
6/1	30	9	0	0	5.1	100%	12	2	10.2	0	
8/1	30	9	0	0	5.1	100%	12.1	2	10.3	0	
10/1	30	9	0	0	5.1	100%	12.1	2	10.3	0	
11/1	30	9	49.3	1.8	5.1	100%	5.1				
12/1	30	9	0	0	5.2	100%	10.3	2	8.5	0	
14/1	30	9	0	0	5.2	100%	12.1	2	10.3	0	
16/1	30	9	0	0	5.2	100%	12.1	2	10.3	0	
18/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	
20/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	
21/1	30	9	50.6	1.8	5.2	100%	5.2				
22/1	30	9	0	0	5.2	100%	10.4	2	8.6	0	
24/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	
26/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	
28/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	
30/1	30	9	0	0	5.2	100%	12.2	2	10.4	0	

Table 5.5b Contd

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efect. Rain (mm)	Etc (mm)	Etc/Etm %	SMD (mm)	Interv. (Days)	Net. Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
31/1	30	9	51.1	1.8	5.2	100%	5.2				
1/2	30	9	0	0	5.2	100%	10.4	2	8.6	0	
3/2	30	9	0	0	5.2	100%	12.3	2	10.5	0	
5/2	30	9	0	0	5.2	100%	12.3	2	10.5	0	
7/2	30	9	0	0	5.2	100%	12.3	2	10.5	0	
9/2	30	9	0	0	5.2	100%	12.3	2	10.5	0	
10/2	30	9	50.7	1.8	5.2	100%	5.2				
11/2	30	9	0	0	5.2	100%	10.5	2	8.7	0	
13/2	30	9	0	0	5.2	100%	12.2	2	10.4	0	
15/2	30	9	0	0	5.1	100%	12.1	2	10.3	0	
17/2	30	9	0	0	5.1	100%	12	2	10.2	0	
19/2	30	9	0	0	5.1	100%	11.9	2	10.1	0	
20/2	30	9	49.2	1.8	5	100%	5				
21/2	30	9	0	0	5	100%	10	2	8.2	0	
23/2	30	9	0	0	5	100%	11.7	2	9.9	0	
25/2	30	9	0	0	4.9	100%	11.6	2	9.8	0	
27/2	30	9	0	0	4.9	100%	11.5	2	9.7	0	
1/3	30	9	0	0	4.8	100%	11.4	2	9.6	0	
2/3	30	9	46.5	1.8	4.8	100%	4.8				
3/3	30	9	0	0	4.8	100%	9.5	2	7.7	0	
5/3	30	9	0	0	4.7	100%	11.2	2	9.4	0	
7/3	30	9	0	0	4.7	100%	4.7	2	9.3	0	
9/3	30	9	0	0	4.6	100%	4.6	2	9.2	0	
3/11	30	9	0	0	4.5	100%	4.5	2	9.1	0	
12/3	30	9	42.7	1.8	4.5	100%	4.5				
13/3	30	9	0	0	4.5	100%	4.5	2	7.2	0	
Total			618	27	775.7	100%		150	746.9	0	0

* Yield Reduction:

- Estimated Yield reduction in growth stage # 1 = 0.0%
- Estimated Yield reduction in growth stage # 2 = 0.0%
- Estimated Yield reduction in growth stage # 3 = 0.0%
- Estimated Yield reduction in growth stage # 4 = 0.0%
- Estimated Total Yield reduction = 0.0 %

* *These estimates may be used as guidelines and not as actual figures*

* Legend:

TAM = Total Available Moisture = (FC%-WP%) * Root Depth [mm]

RAM = Readily Available Moisture = TAM * P [mm]

SMD = Soil Moisture Deficit [mm]

* Notes:

Monthly Eto is distributed using polynomial curve fitting.

Monthly Rainfall is distributed using polynomial curve fitting

To generate rainfall events, each 5 days of distributed rainfall are accumulated as one strom

Only Net Irrigation Requirements are given here. No any kind of losses was taken into account in the calculations.

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Thus, considering the above three variables, viz., irrigation scheduling option, maximum soil infiltration, and maximum rooting depth, not significantly affecting the resulting FWS, the variation in irrigation efficiency and planting date and its effect on FWS is considered as show in Tables 5.6 – 5.14. The results of these tables are summarized in Table 5.15, and these are explained below:

It is seen from Table 5.15 that the staggering of planting dates significantly affects the FWS and shows consistently decreasing trend in the ranges (0.52-0.45), (0.48-0.42), and (0.45-0.39) for irrigation efficiencies of 65, 70, and 75%, respectively. The first inference that can be drawn is that FWS consistently decreases with (a) staggering of the beginning of plantation from October 15 to November 1 and (b) increase in irrigation efficiency. Since the former depends not only on the climate (temperature or evapotranspiration (Table B.1) and rainfall pattern in the year, it is little difficult to conclude with certainty the discrete effect of each of these factors. However, as seen from Table B.1 (Appendix-B), the evapotranspiration decreases as the date shifts from October to November, and therefore, requiring less amount of water by the crops for their sustenance. Furthermore, the probable amount of precipitation in October being less than that in November, as seen from Table 3.5 also leads to ascertaining the reduced amount of FWS. The inference of FWS reduction with increase in irrigation efficiency is in accordance with the expectation that the increase in irrigation efficiency would reduce field water supply for irrigation.

From the above discussion it is evident that, in the Way Sekampung command area, it is possible to (a) shift the planting date from October 15, commonly practiced in Indonesia, to November 1 for reducing significantly the required field water supply and (b) enhance the irrigation efficiency from 65 to 75, practically achievable level, by employing the available measures. The following text further examines the sensitivity of the governing factors to FWS computation.

Table 5.6 Runs for Irrigation Efficiency 65 % at 15 October

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
1	65	15 Oct	35	3	75	0.52	
2	65	15 Oct	35	3	80	0.52	
3	65	15 Oct	35	3	100	0.52	
4	65	15 Oct	35	5	75	0.52	
5	65	15 Oct	35	5	80	0.52	
6	65	15 Oct	35	5	100	0.52	
7	65	15 Oct	35	9	75	0.52	
8	65	15 Oct	35	9	80	0.52	
9	65	15 Oct	35	9	100	0.52	
10	65	15 Oct	40	3	75	0.52	
11	65	15 Oct	40	3	80	0.52	
12	65	15 Oct	40	3	100	0.52	
13	65	15 Oct	40	5	75	0.52	
14	65	15 Oct	40	5	80	0.52	
15	65	15 Oct	40	5	100	0.52	
16	65	15 Oct	40	9	75	0.52	
17	65	15 Oct	40	9	80	0.52	
18	65	15 Oct	40	9	100	0.52	
19	65	15 Oct	45	3	75	0.52	
20	65	15 Oct	45	3	80	0.52	
21	65	15 Oct	45	3	100	0.52	
22	65	15 Oct	45	5	75	0.52	
23	65	15 Oct	45	5	80	0.52	
24	65	15 Oct	45	5	100	0.52	
25	65	15 Oct	45	9	75	0.52	
26	65	15 Oct	45	9	80	0.52	
27	65	15 Oct	45	9	100	0.52	

Table 5.7. Runs for Irrigation Efficiency 65 % at 1November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth M	Refill Option %	FWS l/s/ha	Remark
28	65	1 Nov	35	3	75	0.47	
29	65	1 Nov	35	3	80	0.47	
30	65	1 Nov	35	3	100	0.47	
31	65	1 Nov	35	5	75	0.47	
32	65	1 Nov	35	5	80	0.47	
33	65	1 Nov	35	5	100	0.47	
34	65	1 Nov	35	9	75	0.47	
35	65	1 Nov	35	9	80	0.47	
36	65	1 Nov	35	9	100	0.47	
37	65	1 Nov	40	3	75	0.47	
38	65	1 Nov	40	3	80	0.47	
39	65	1 Nov	40	3	100	0.47	
40	65	1 Nov	40	5	75	0.47	
41	65	1 Nov	40	5	80	0.47	
42	65	1 Nov	40	5	100	0.47	
43	65	1 Nov	40	9	75	0.47	
44	65	1 Nov	40	9	80	0.47	
45	65	1 Nov	40	9	100	0.47	
46	65	1 Nov	45	3	75	0.47	
47	65	1 Nov	45	3	80	0.47	
48	65	1 Nov	45	3	100	0.47	
49	65	1 Nov	45	5	75	0.47	
50	65	1 Nov	45	5	80	0.47	
51	65	1 Nov	45	5	100	0.47	
52	65	1 Nov	45	9	75	0.47	
53	65	1 Nov	45	9	80	0.47	
54	65	1 Nov	45	9	100	0.47	

Table 5.8. Runs for Irrigation Efficiency 65 % at 15 November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
55	65	15 Nov	35	3	75	0.45	
56	65	15 Nov	35	3	80	0.45	
57	65	15 Nov	35	3	100	0.45	
58	65	15 Nov	35	5	75	0.45	
59	65	15 Nov	35	5	80	0.45	
60	65	15 Nov	35	5	100	0.45	
61	65	15 Nov	35	9	75	0.45	
62	65	15 Nov	35	9	80	0.45	
63	65	15 Nov	35	9	100	0.45	
64	65	15 Nov	40	3	75	0.45	
65	65	15 Nov	40	3	80	0.45	
66	65	15 Nov	40	3	100	0.45	
67	65	15 Nov	40	5	75	0.45	
68	65	15 Nov	40	5	80	0.45	
69	65	15 Nov	40	5	100	0.45	
70	65	15 Nov	40	9	75	0.45	
71	65	15 Nov	40	9	80	0.45	
72	65	15 Nov	40	9	100	0.45	
73	65	15 Nov	45	3	75	0.45	
74	65	15 Nov	45	3	80	0.45	
75	65	15 Nov	45	3	100	0.45	
76	65	15 Nov	45	5	75	0.45	
77	65	15 Nov	45	5	80	0.45	
78	65	15 Nov	45	5	100	0.45	
79	65	15 Nov	45	9	75	0.45	
80	65	15 Nov	45	9	80	0.45	
81	65	15 Nov	45	9	100	0.45	

Table 5.9. Runs for Irrigation Efficiency 70 % at 15 October

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
82	70	15 Oct	35	3	75	0.48	
83	70	15 Oct	35	3	80	0.48	
84	70	15 Oct	35	3	100	0.48	
85	70	15 Oct	35	5	75	0.48	
86	70	15 Oct	35	5	80	0.48	
87	70	15 Oct	35	5	100	0.48	
88	70	15 Oct	35	9	75	0.48	
89	70	15 Oct	35	9	80	0.48	
90	70	15 Oct	35	9	100	0.48	
91	70	15 Oct	40	3	75	0.48	
92	70	15 Oct	40	3	80	0.48	
93	70	15 Oct	40	3	100	0.48	
94	70	15 Oct	40	5	75	0.48	
95	70	15 Oct	40	5	80	0.48	
96	70	15 Oct	40	5	100	0.48	
97	70	15 Oct	40	9	75	0.48	
98	70	15 Oct	40	9	80	0.48	
99	70	15 Oct	40	9	100	0.48	
100	70	15 Oct	45	3	75	0.48	
101	70	15 Oct	45	3	80	0.48	
102	70	15 Oct	45	3	100	0.48	
103	70	15 Oct	45	5	75	0.48	
104	70	15 Oct	45	5	80	0.48	
105	70	15 Oct	45	5	100	0.48	
106	70	15 Oct	45	9	75	0.48	
107	70	15 Oct	45	9	80	0.48	
108	70	15 Oct	45	9	100	0.48	

Table 5.10. Runs for Irrigation Efficiency 70 % at 1November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
109	70	1 Nov	35	3	75	0.44	
110	70	1 Nov	35	3	80	0.44	
111	70	1 Nov	35	3	100	0.44	
112	70	1 Nov	35	5	75	0.44	
113	70	1 Nov	35	5	80	0.44	
114	70	1 Nov	35	5	100	0.44	
115	70	1 Nov	35	9	75	0.44	
116	70	1 Nov	35	9	80	0.44	
117	70	1 Nov	35	9	100	0.44	
118	70	1 Nov	40	3	75	0.44	
119	70	1 Nov	40	3	80	0.44	
120	70	1 Nov	40	3	100	0.44	
121	70	1 Nov	40	5	75	0.44	
122	70	1 Nov	40	5	80	0.44	
123	70	1 Nov	40	5	100	0.44	
124	70	1 Nov	40	9	75	0.44	
125	70	1 Nov	40	9	80	0.44	
126	70	1 Nov	40	9	100	0.44	
127	70	1 Nov	45	3	75	0.44	
128	70	1 Nov	45	3	80	0.44	
129	70	1 Nov	45	3	100	0.44	
130	70	1 Nov	45	5	75	0.44	
131	70	1 Nov	45	5	80	0.44	
132	70	1 Nov	45	5	100	0.44	
133	70	1 Nov	45	9	75	0.44	
134	70	1 Nov	45	9	80	0.44	
135	70	1 Nov	45	9	100	0.44	

Table 5.11 Runs for Irrigation Efficiency 70 % at 15 November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
136	70	15 Nov	35	3	75	0.42	
137	70	15 Nov	35	3	80	0.42	
138	70	15 Nov	35	3	100	0.42	
139	70	15 Nov	35	5	75	0.42	
140	70	15 Nov	35	5	80	0.42	
141	70	15 Nov	35	5	100	0.42	
142	70	15 Nov	35	9	75	0.42	
143	70	15 Nov	35	9	80	0.42	
144	70	15 Nov	35	9	100	0.42	
145	70	15 Nov	40	3	75	0.42	
146	70	15 Nov	40	3	80	0.42	
147	70	15 Nov	40	3	100	0.42	
148	70	15 Nov	40	5	75	0.42	
149	70	15 Nov	40	5	80	0.42	
150	70	15 Nov	40	5	100	0.42	
151	70	15 Nov	40	9	75	0.42	
152	70	15 Nov	40	9	80	0.42	
153	70	15 Nov	40	9	100	0.42	
154	70	15 Nov	45	3	75	0.42	
155	70	15 Nov	45	3	80	0.42	
156	70	15 Nov	45	3	100	0.42	
157	70	15 Nov	45	5	75	0.42	
158	70	15 Nov	45	5	80	0.42	
159	70	15 Nov	45	5	100	0.42	
160	70	15 Nov	45	9	75	0.42	
161	70	15 Nov	45	9	80	0.42	
162	70	15 Nov	45	9	100	0.42	

Table 5. 12 Runs for Irrigation Efficiency 75 % at 15 October

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
163	75	15 Oct	35	3	75	0.45	
164	75	15 Oct	35	3	80	0.45	
165	75	15 Oct	35	3	100	0.45	
166	75	15 Oct	35	5	75	0.45	
167	75	15 Oct	35	5	80	0.45	
168	75	15 Oct	35	5	100	0.45	
169	75	15 Oct	35	9	75	0.45	
170	75	15 Oct	35	9	80	0.45	
171	75	15 Oct	35	9	100	0.45	
172	75	15 Oct	40	3	75	0.45	
173	75	15 Oct	40	3	80	0.45	
174	75	15 Oct	40	3	100	0.45	
175	75	15 Oct	40	5	75	0.45	
176	75	15 Oct	40	5	80	0.45	
177	75	15 Oct	40	5	100	0.45	
178	75	15 Oct	40	9	75	0.45	
179	75	15 Oct	40	9	80	0.45	
180	75	15 Oct	40	9	100	0.45	
181	75	15 Oct	45	3	75	0.45	
182	75	15 Oct	45	3	80	0.45	
183	75	15 Oct	45	3	100	0.45	
184	75	15 Oct	45	5	75	0.45	
185	75	15 Oct	45	5	80	0.45	
186	75	15 Oct	45	5	100	0.45	
187	75	15 Oct	45	9	75	0.45	
188	75	15 Oct	45	9	80	0.45	
189	75	15 Oct	45	9	100	0.45	

Table 5.13 Runs for Irrigation Efficiency 75 % at 1November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
190	75	1 Nov	35	3	75	0.41	
191	75	1 Nov	35	3	80	0.41	
192	75	1 Nov	35	3	100	0.41	
193	75	1 Nov	35	5	75	0.41	
194	75	1 Nov	35	5	80	0.41	
195	75	1 Nov	35	5	100	0.41	
196	75	1 Nov	35	9	75	0.41	
197	75	1 Nov	35	9	80	0.41	
198	75	1 Nov	35	9	100	0.41	
199	75	1 Nov	40	3	75	0.41	
200	75	1 Nov	40	3	80	0.41	
201	75	1 Nov	40	3	100	0.41	
202	75	1 Nov	40	5	75	0.41	
203	75	1 Nov	40	5	80	0.41	
204	75	1 Nov	40	5	100	0.41	
205	75	1 Nov	40	9	75	0.41	
206	75	1 Nov	40	9	80	0.41	
207	75	1 Nov	40	9	100	0.41	
208	75	1 Nov	45	3	75	0.41	
209	75	1 Nov	45	3	80	0.41	
210	75	1 Nov	45	3	100	0.41	
211	75	1 Nov	45	5	75	0.41	
212	75	1 Nov	45	5	80	0.41	
213	75	1 Nov	45	5	100	0.41	
214	75	1 Nov	45	9	75	0.41	
215	75	1 Nov	45	9	80	0.41	
216	75	1 Nov	45	9	100	0.41	

Table 5.14 Runs for Irrigation Efficiency 75 % at 15 November

Run No	Irrigation Efficiency %	Planting Date	Maximum Infiltration mm	Maximum Rooting depth Depth m	Refill Option %	FWS l/s/ha	Remark
217	75	15 Nov	35	3	75	0.39	
218	75	15 Nov	35	3	80	0.39	
219	75	15 Nov	35	3	100	0.39	
220	75	15 Nov	35	5	75	0.39	
221	75	15 Nov	35	5	80	0.39	
222	75	15 Nov	35	5	100	0.39	
223	75	15 Nov	35	9	75	0.39	
224	75	15 Nov	35	9	80	0.39	
225	75	15 Nov	35	9	100	0.39	
226	75	15 Nov	40	3	75	0.39	
227	75	15 Nov	40	3	80	0.39	
228	75	15 Nov	40	3	100	0.39	
229	75	15 Nov	40	5	75	0.39	
230	75	15 Nov	40	5	80	0.39	
231	75	15 Nov	40	5	100	0.39	
232	75	15 Nov	40	9	75	0.39	
233	75	15 Nov	40	9	80	0.39	
234	75	15 Nov	40	9	100	0.39	
235	75	15 Nov	45	3	75	0.39	
236	75	15 Nov	45	3	80	0.39	
237	75	15 Nov	45	3	100	0.39	
238	75	15 Nov	45	5	75	0.39	
239	75	15 Nov	45	5	80	0.39	
240	75	15 Nov	45	5	100	0.39	
241	75	15 Nov	45	9	75	0.39	
242	75	15 Nov	45	9	80	0.39	
243	75	15 Nov	45	9	100	0.39	

Table 5.15 Summary of the CROPWAT computations of Tables 5.6-5.14

Run No.	Irrigation Efficiency %	Planting date	Field water supply (FWS) (l/s/ha)
1	65	15 October	0.52
2	65	1 November	0.47
3	65	15 November	0.45
4	70	15 October	0.48
5	70	1 November	0.44
6	70	15 November	0.42
7	75	15 October	0.45
8	75	1 November	0.41
9	75	15 November	0.39

5.3.1 SENSITIVITY ANALYSIS

It is of common knowledge that the sensitivity analysis is carried out to evaluate the sensitivity of the governing parameters to the output. In this study, it is also important that it would help decide the specific parameter to be taken up for improving the scheduling of irrigation with minimum water supply. The sensitivity of the governing factors is shown in Fig. 5.2. The figure shows that FWS decreases with increase in irrigation efficiency almost exponentially. The rate of decay of FWS increases as the date of plantation shifts from November 15 to October 15. It is quite obvious, as above, that the FWS is directly dependent on IWR and efficiency (Fig.4.1 chapter 4); the greater the efficiency of irrigation, the lesser would be the field water supply, for the conveyance losses would be less, and vice versa. Furthermore, since the evapotranspiration is relatively high on October 15 than on November 1 (Table B.1 (Appendix-B), the required field water supply would be greater to maintain the required moisture in the soil for paddy crop, and vice versa. Since both the factors show a significant influence on the computed field water supply it is worth recommending that any or both of these can be considered for ameliorating the irrigation schedule for optimum water supply.

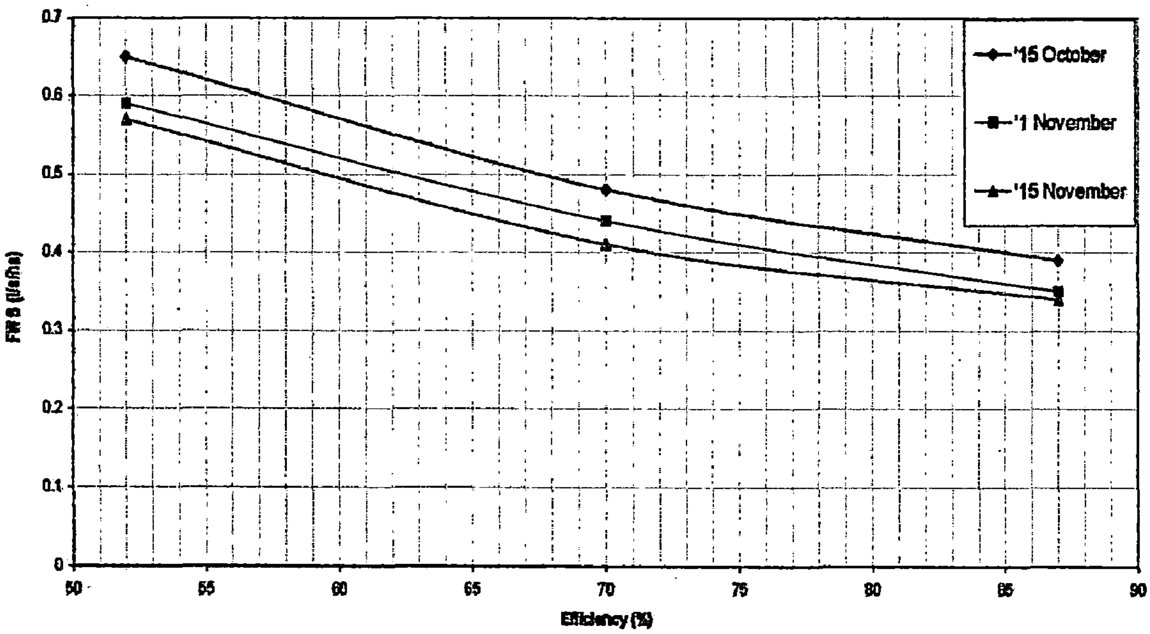

Fig. 5.2 Sensitivity Analysis

CHAPTER VI

SUMMARY AND CONCLUSIONS

Irrigation scheduling is a part of water distribution planning in the command area of an irrigation project. It is an important aspect of irrigation project planning but generally ignored in project preparation stage. While analyzing irrigation development during the project life, it is important to consider likely water deficit condition, resulting yield reduction, and plan for irrigation scheduling to manage water deficits at micro field and macro project level (field level and project level).

During operation stage, conventional procedure of water distribution planning is to prepare a roster of regulation for canal network specifying discharge and running days for each segment of canal network. It is prepared at the beginning of a crop season and published for the information of farmers. Modification in the roster is made if there is unexpected rain or other reason beyond control.

During project preparation stage irrigation scheduling is accounted for in terms crop type, number of watering and depth of irrigation. Thus, there is lot of subjectivity in assessment of demand and the procedure for meeting the spatially distributed irrigation demand. With availability of software's such as CROPWAT among others, it is possible to carry out irrigation scheduling and water distribution planning in more scientific manner. Based on the present study and available literature, the following can be asserted:

1. The Way Sekampung irrigation project is basically an agricultural improvement scheme to be attained through an increase in production of irrigated rice within the project area. An increase in the infrastructure development within the area can also be used as an incentive to promote and encourage further transmigration into the area from the move densely populated areas of Indonesia. The Way Sekampung irrigations need irrigation scheduling because one important aspect of irrigation management

which involves when to irrigate a crop and how much water is to be applied at each irrigation. The practice of farmers determining whether it was time to irrigate by the feel and colour of the soil is an old practice in irrigation. Even today, many farmers irrigate to the calendar or receive water at scheduled time and therefore use the water whether their crop need it or not. Whereas developed countries in areas of high energy use, farmers who have control on their water deliveries are searching for ways to determining the most beneficial time to apply just the right amount water.

2. CROPWAT is a decision support system developed by the land and water development Division of FAO to compute reference evapotranspiration, crop water requirement, and crop irrigation requirement; to develop irrigation schedules under various management conditions and scheme water supply; and to evaluate rainfed production and drought effects and efficiency of irrigation practices.

3. Using CROPWAT software, the present analysis attempted to study the effect of various governing factor, such as stipulated irrigation efficiency, staggering of planting date, irrigation scheduling option, maximum infiltration to soil, maximum rooting depth, on field water supply (FWS). The last three factors were found to have insignificant bearance on the computed field water supply.

4. The sensitivity analysis indicated FWS to decrease with increase in irrigation efficiency almost exponentially. The rate of decay of FWS increased significantly as the date of plantation shifted from November 15 to October 15. Since both the factors showed a significant influence on the computed field water supply it was recommended that any or both of these could be considered for ameliorating the irrigation schedule for optimum water supply.

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APPENDIX A

WATER BALANCE SIMULATION RESULT

Water Balance Simulation Result (1/27)

Batutegi Dam Water Balance Simulation Result - Case : 2-80zh24

Simulation Period : 1968 - 1993

HWL : El. 274.00 m
LWL : El. 208.00 m

MWR : 0.00 m3/s
CE : 0.95
RMF : 2.00 m3/s

IA Golongan 1	:	19,561 ha
Golongan 2	:	19,561 ha
Golongan 3	:	19,561 ha
Golongan 4	:	14,671 ha
Golongan 5	:	0 ha
Golongan 6	:	0 ha
Total Area	:	73,354 ha

Note

IWD : Irrigation Water Demand at Argoguruh Weir (m3/s)
MWD : Municipal Water Demand at Argoguruh (m3/s)
RMF : River Maintenance Flow from Batutegi (m3/s)
Qa : River Discharge at Argoguruh (m3/s)
DWD : Diversion Water Demand from Batutegi Dam (m3/s)
Qb : River Discharge at Batutegi (m3/s)
Ev : Evaporation from Batutegi Reservoir (mm/day)
Qp : Diversion Water for Power Generation (m3/s)
Qi : Diversion Water for Irrigation (m3/s)
Spl : Spillout Volume from Batutegi Dam (m3/s)
(Negative figure means water deficit.)
Qt : Total Diversion Discharge (m3/s)
DEFi: Irrigation Water Deficit (%)
DEFm: Municipal Water Deficit (%)
Pw : Generated Power (MWh)
WL : Water Level in Batutegi Reservoir (El. m)
A : Surface Area in Batutegi Reservoir (km2)
V : Storage Volume in Batutegi Reservoir (MCM)

DF1 : Irrigation Water Deficit (times)
DF2 : Irrigation Water Deficit (>10%, times)
DF3 : Municipal Water Deficit (times)
DF4 : River Maintenance Flow Deficit (times)

Unit in Output

CMS : cubic meter per second (m3/s)
mmd : millimeter per day (mm/day)
MWh : megawatt hour
GWh : gigawatt hour
MCM : million cubic meter

Water Balance Simulation Result (2/27)

Batutegi Dam Water Balance Simulation Summary - Case : 2-80zh24

Year	IWD (MCM)	MWD (MCM)	Qa (MCM)	DWD (MCM)	Qb (MCM)	Ev (MCM)	Qp (MCM)	Qi (MCM)	Spl (MCM)	Qt (MCM)	Pw (GWh)	DF1	DF2	DF3	DF4	WL (m)	A (km2)	V (MCM)
																274.00	21.100	578.83
1968/69	1,887	0.0	3,691	225	759	29.8	672.4	56.5	0.0	728.9	149.7	0	0	0	0	274.00	21.100	578.83
1969/70	1,887	0.0	4,367	423	892	28.0	670.2	193.3	0.0	863.6	143.4	0	0	0	0	274.00	21.100	578.83
1970/71	1,887	0.0	2,709	241	626	30.0	570.1	26.4	0.0	596.5	128.0	0	0	0	0	274.00	21.100	578.83
1971/72	1,892	0.0	3,254	148	719	30.3	679.7	9.5	0.0	689.2	152.3	0	0	0	0	274.00	21.100	578.83
1972/73	1,887	0.0	2,718	557	598	23.7	351.0	223.7	0.0	574.7	67.6	0	0	0	0	274.00	21.100	578.83
1973/74	1,887	0.0	2,192	467	550	28.8	482.1	81.9	0.0	564.1	105.7	0	0	0	0	271.89	19.777	535.61
1974/75	1,887	0.0	1,249	953	603	18.9	621.8	331.1	0.0	953.0	110.4	0	0	0	0	245.38	9.095	166.57
1975/76	1,892	0.0	1,294	929	520	6.5	247.2	392.6	0.0	639.8	33.6	5	5	0	0	225.61	3.967	40.58
1976/77	1,887	0.0	2,499	517	698	13.2	79.2	216.4	0.0	295.6	13.9	3	3	0	0	266.08	16.823	430.00
1977/78	1,887	0.0	3,216	391	827	25.2	525.0	128.4	0.0	653.3	108.9	0	0	0	0	274.00	21.100	578.83
1978/79	1,887	0.0	3,530	145	982	30.1	869.3	82.4	0.0	951.7	192.2	0	0	0	0	274.00	21.100	578.83
1979/80	1,892	0.0	3,074	574	655	27.3	439.9	225.8	0.0	665.7	91.8	0	0	0	0	272.16	19.946	541.05
1980/81	1,887	0.0	5,097	145	963	30.1	805.5	89.2	0.0	894.7	177.8	0	0	0	0	274.00	21.100	578.83
1981/82	1,887	0.0	3,208	485	645	27.4	694.1	140.5	0.0	834.5	148.5	0	0	0	0	261.77	14.981	361.53
1982/83	1,887	0.0	2,258	745	582	14.5	328.3	416.7	0.0	744.9	51.1	0	0	0	0	247.21	9.664	183.68
1983/84	1,892	0.0	2,382	582	548	11.1	237.2	243.2	0.0	480.4	35.9	2	2	0	0	252.54	11.452	239.87
1984/85	1,887	0.0	3,974	220	912	26.7	463.4	82.9	0.0	546.3	102.5	0	0	0	0	274.00	21.100	578.83
1985/86	1,887	0.0	3,859	601	698	26.5	395.4	275.7	0.0	671.1	80.2	0	0	0	0	274.00	21.100	578.83
1986/87	1,887	0.0	3,040	415	875	28.9	797.2	117.1	0.0	914.3	173.7	0	0	0	0	270.59	18.987	510.49
1987/88	1,892	0.0	2,209	806	667	23.1	487.6	318.1	0.0	805.7	93.2	0	0	0	0	260.90	14.622	348.57
1988/89	1,887	0.0	3,316	465	596	24.1	426.0	171.5	0.0	597.5	87.6	0	0	0	0	259.12	13.911	323.18
1989/90	1,887	0.0	2,409	666	494	16.5	455.9	210.3	0.0	666.2	77.1	0	0	0	0	241.64	7.978	134.64
1990/91	1,887	0.0	3,683	524	519	11.5	245.2	278.9	0.0	524.1	37.9	0	0	0	0	239.53	7.381	118.49
1991/92	1,892	0.0	2,856	564	650	10.8	255.5	308.6	0.0	564.1	39.4	0	0	0	0	248.18	9.975	193.25
1992/93	1,887	0.0	3,221	429	822	20.7	238.9	189.6	0.0	428.5	42.8	0	0	0	0	273.39	20.711	565.98
					[illegible]	22.5	481.5	192.4	0.0	673.9	97.8							

Water Balance Simulation Result (3/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1968 - 1969

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	69.16	2.00	21.23	4.00	20.26	0.00	0.00	20.26	0.00	0.00	5,956	274.00	21.100	578.83
Oct2	22.89	53.25	2.00	21.21	4.00	20.24	0.00	0.00	20.24	0.00	0.00	6,347	274.00	21.100	578.83
Nov1	63.96	57.03	7.30	19.74	4.13	18.73	0.00	0.00	18.73	0.00	0.00	5,519	274.00	21.100	578.83
Nov2	92.33	33.44	61.99	23.50	4.13	36.82	25.17	0.00	61.99	0.00	0.00	9,936	271.48	19.528	527.63
Dec1	106.66	96.51	10.68	22.52	3.74	10.68	0.00	0.00	10.68	0.00	0.00	3,110	272.20	19.972	541.89
Dec2	98.25	50.75	49.99	26.66	3.74	36.63	13.37	0.00	49.99	0.00	0.00	10,598	270.48	18.922	508.44
Jan1	93.60	168.83	2.00	21.31	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	271.73	19.679	532.46
Jan2	93.16	231.56	2.00	33.66	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	273.82	20.988	575.11
Feb1	81.62	226.85	2.00	31.52	4.28	27.62	0.00	0.00	27.62	0.00	0.00	8,003	274.00	21.100	578.83
Feb2	61.28	163.69	2.00	33.91	4.28	32.87	0.00	0.00	32.87	0.00	0.00	8,160	274.00	21.100	578.83
Mar1	53.84	106.53	2.00	28.59	4.13	27.58	0.00	0.00	27.58	0.00	0.00	8,001	274.00	21.100	578.83
Mar2	61.62	159.33	2.00	31.53	4.13	30.52	0.00	0.00	30.52	0.00	0.00	9,380	274.00	21.100	578.83
Apr1	94.09	225.80	2.00	33.46	4.20	32.43	0.00	0.00	32.43	0.00	0.00	9,300	274.00	21.100	578.83
Apr2	108.95	157.54	2.00	33.52	4.20	32.49	0.00	0.00	32.49	0.00	0.00	9,317	274.00	21.100	578.83
May1	90.18	147.42	2.00	24.05	3.87	23.10	0.00	0.00	23.10	0.00	0.00	6,761	274.00	21.100	578.83
May2	87.44	102.83	2.00	21.63	3.87	20.68	0.00	0.00	20.68	0.00	0.00	6,484	274.00	21.100	578.83
Jun1	89.20	118.64	2.00	23.65	3.73	22.73	0.00	0.00	22.73	0.00	0.00	6,658	274.00	21.100	578.83
Jun2	76.29	106.06	2.00	19.62	3.73	18.71	0.00	0.00	18.71	0.00	0.00	5,514	274.00	21.100	578.83
Jul1	47.34	212.77	2.00	24.37	3.61	23.49	0.00	0.00	23.49	0.00	0.00	6,869	274.00	21.100	578.83
Jul2	16.04	57.92	2.00	19.38	3.61	18.50	0.00	0.00	18.50	0.00	0.00	5,817	274.00	21.100	578.83
Aug1	0.00	31.58	2.00	16.02	3.61	15.14	0.00	0.00	15.14	0.00	0.00	4,482	274.00	21.100	578.83
Aug2	0.00	21.30	2.00	14.30	3.61	13.42	0.00	0.00	13.42	0.00	0.00	4,247	274.00	21.100	578.83
Sep1	0.00	82.04	2.00	13.02	4.27	11.98	0.00	0.00	11.98	0.00	0.00	3,559	274.00	21.100	578.83
Sep2	0.00	143.57	2.00	20.32	4.27	19.28	0.00	0.00	19.28	0.00	0.00	5,678	274.00	21.100	578.83
Total	1,887 (MCM)	3,691 (MCM)	225 (MCM)	759 (MCM)	29.8 (MCM)	672.4 (MCM)	56.5 (MCM)	0.0 (MCM)	729 (MCM)	0 (tms)	0 (tms)	149.7 (GWh)			

Water Balance Simulation Result (4/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1969 - 1970

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	34.13	2.00	14.46	4.00	13.49	0.00	0.00	13.49	0.00	0.00	4,001	274.00	21.100	578.83
Oct2	22.89	22.12	2.00	14.16	4.00	13.19	0.00	0.00	13.19	0.00	0.00	4,174	274.00	21.100	578.83
Nov1	63.96	21.38	44.82	22.44	4.13	35.57	9.25	0.00	44.82	0.00	0.00	9,936	272.53	20.177	548.51
Nov2	92.33	16.01	80.33	17.59	4.13	37.60	42.73	0.00	80.33	0.00	0.00	9,485	268.16	17.773	465.95
Dec1	106.66	14.50	97.00	18.03	3.74	37.60	59.40	0.00	97.00	0.00	0.00	8,468	261.85	15.010	362.61
Dec2	98.25	41.78	59.44	20.43	3.74	37.60	21.84	0.00	59.44	0.00	0.00	9,379	257.99	13.473	307.78
Jan1	93.60	156.34	2.00	36.89	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	261.15	14.725	352.28
Jan2	93.16	161.51	2.00	37.27	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	264.27	16.026	400.20
Feb1	81.62	321.67	2.00	39.76	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	267.14	17.305	448.11
Feb2	61.28	246.79	2.00	36.12	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	269.24	18.278	485.47
Mar1	53.84	452.82	2.00	46.50	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	272.21	19.976	542.00
Mar2	61.62	301.86	2.00	49.85	4.13	22.26	0.00	0.00	22.26	0.00	0.00	6,899	274.00	21.100	578.83
Apr1	94.09	156.83	2.00	39.01	4.20	34.99	2.99	0.00	37.98	0.00	0.00	9,936	274.00	21.100	578.83
Apr2	108.95	265.66	2.00	37.62	4.20	34.94	1.66	0.00	36.59	0.00	0.00	9,936	274.00	21.100	578.83
May1	90.18	237.19	2.00	35.40	3.87	34.45	0.00	0.00	34.45	0.00	0.00	9,828	274.00	21.100	578.83
May2	87.44	187.36	2.00	32.69	3.87	31.74	0.00	0.00	31.74	0.00	0.00	9,728	274.00	21.100	578.83
Jun1	89.20	130.55	2.00	32.70	3.73	31.79	0.00	0.00	31.79	0.00	0.00	9,132	274.00	21.100	578.83
Jun2	76.29	96.41	2.00	29.13	3.73	28.22	0.00	0.00	28.22	0.00	0.00	8,175	274.00	21.100	578.83
Jul1	47.34	101.55	2.00	23.63	3.61	22.75	0.00	0.00	22.75	0.00	0.00	6,663	274.00	21.100	578.83
Jul2	16.04	94.33	2.00	23.96	3.61	23.08	0.00	0.00	23.08	0.00	0.00	7,206	274.00	21.100	578.83
Aug1	0.00	62.40	2.00	19.72	3.61	18.83	0.00	0.00	18.83	0.00	0.00	5,550	274.00	21.100	578.83
Aug2	0.00	131.28	2.00	19.51	3.61	18.63	0.00	0.00	18.63	0.00	0.00	5,858	274.00	21.100	578.83
Sep1	0.00	43.35	2.00	16.86	4.27	15.82	0.00	0.0C	15.82	0.00	0.00	4,681	274.00	21.100	578.83
Sep2	0.00	42.19	2.00	15.87	4.27	14.83	0.00	0.00	14.83	0.00	0.00	4,392	274.00	21.100	578.83
Total	1,887 (MCM)	4,367 (MCM)	423 (MCM)	892 (MCM)	28.0 (MCM)	670.2 (MCM)	193.3 (MCM)	0.0 (MCM)	864 (MCM)	0 (tms)	0 (tms)	143.4 (GWh)			

Water Balance Simulation Result (5/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1970 - 1971

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	101.17	2.00	15.81	4.00	14.83	0.00	0.00	14.83	0.00	0.00	4,394	274.00	21.100	578.83
Oct2	22.89	60.31	2.00	19.03	4.00	18.05	0.00	0.00	18.05	0.00	0.00	5,681	274.00	21.100	578.83
Nov1	63.96	56.76	7.58	19.88	4.13	18.87	0.00	0.00	18.87	0.00	0.00	5,560	274.00	21.100	578.83
Nov2	92.33	52.75	41.66	25.40	4.13	35.35	6.31	0.00	41.66	0.00	0.00	9,936	272.92	20.420	556.44
Dec1	106.66	62.92	46.04	21.48	3.74	36.10	9.94	0.00	46.04	0.00	0.00	9,936	271.27	19.397	523.47
Dec2	98.25	102.71	2.00	24.21	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	272.75	20.315	553.01
Jan1	93.60	204.32	2.00	32.71	3.55	11.95	0.00	0.00	11.95	0.00	0.00	3,530	274.00	21.100	578.83
Jan2	93.16	197.98	2.00	26.69	3.55	25.82	0.00	0.00	25.82	0.00	0.00	8,019	274.00	21.100	578.83
Feb1	81.62	91.18	2.00	21.25	4.28	20.20	0.00	0.00	20.20	0.00	0.00	5,941	274.00	21.100	578.83
Feb2	61.28	114.86	2.00	22.91	4.28	21.86	0.00	0.00	21.86	0.00	0.00	5,557	274.00	21.100	578.83
Mar1	53.84	71.14	2.00	20.79	4.13	19.78	0.00	0.00	19.78	0.00	0.00	5,822	274.00	21.100	578.83
Mar2	61.62	105.64	2.00	25.79	4.13	24.78	0.00	0.00	24.78	0.00	0.00	7,713	274.00	21.100	578.83
Apr1	94.09	143.88	2.00	29.23	4.20	28.21	0.00	0.00	28.21	0.00	0.00	8,172	274.00	21.100	578.83
Apr2	108.95	125.53	2.00	22.14	4.20	21.12	0.00	0.00	21.12	0.00	0.00	6,201	274.00	21.100	578.83
May1	90.18	110.15	2.00	21.77	3.87	20.82	0.00	0.00	20.82	0.00	0.00	6,118	274.00	21.100	578.83
May2	87.44	78.96	8.93	17.53	3.87	16.58	0.00	0.00	16.58	0.00	0.00	5,229	274.00	21.100	578.83
Jun1	89.20	62.71	27.88	16.39	3.73	27.88	0.00	0.00	27.88	0.00	0.00	8,052	273.23	20.613	562.75
Jun2	76.29	60.15	16.98	14.02	3.73	16.98	0.00	0.00	16.98	0.00	0.00	4,974	272.99	20.460	557.76
Jul1	47.34	63.36	2.00	14.07	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	273.69	20.903	572.29
Jul2	16.04	48.15	2.00	13.99	3.61	8.39	0.00	0.00	8.39	0.00	0.00	2,661	274.00	21.100	578.83
Aug1	0.00	22.46	2.00	11.75	3.61	10.87	0.00	0.00	10.87	0.00	0.00	3,233	274.00	21.100	578.83
Aug2	0.00	27.97	2.00	11.60	3.61	10.72	0.00	0.00	10.72	0.00	0.00	3,400	274.00	21.100	578.83
Sep1	0.00	74.52	2.00	15.41	4.27	14.37	0.00	0.00	14.37	0.00	0.00	4,258	274.00	21.100	578.83
Sep2	0.00	24.34	2.00	13.36	4.27	12.32	0.00	0.00	12.32	0.00	0.00	3,658	274.00	21.100	578.83
Total	1,887 (MCM)	2,709 (MCM)	241 (MCM)	626 (MCM)	30.0 (MCM)	570.1 (MCM)	26.4 (MCM)	0.0 (MCM)	597 (MCM)	0 (tms)	0 (tms)	128.0 (GWh)			

(3/25)

Water Balance Simulation Result (6/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1971 - 1972

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	16.75	2.00	12.61	4.00	11.63	0.00	0.00	11.63	0.00	0.00	3,457	274.00	21.100	578.83
Oct2	22.89	54.96	2.00	20.18	4.00	19.20	0.00	0.00	19.20	0.00	0.00	6,032	274.00	21.100	578.83
Nov1	63.96	114.06	2.00	24.93	4.13	23.92	0.00	0.00	23.92	0.00	0.00	6,991	274.00	21.100	578.83
Nov2	92.33	334.28	2.00	34.95	4.13	33.94	0.00	0.00	33.94	0.00	0.00	9,694	274.00	21.100	578.83
Dec1	106.66	224.36	2.00	30.34	3.74	29.43	0.00	0.00	29.43	0.00	0.00	8,502	274.00	21.100	578.83
Dec2	98.25	323.74	2.00	35.18	3.74	34.27	0.00	0.00	34.27	0.00	0.00	10,432	274.00	21.100	578.83
Jan1	93.60	167.02	2.00	33.97	3.55	33.10	0.00	0.00	33.10	0.00	0.00	9,477	274.00	21.100	578.83
Jan2	93.16	158.58	2.00	35.47	3.55	34.60	0.00	0.00	34.60	0.00	0.00	10,523	274.00	21.100	578.83
Feb1	81.62	126.64	2.00	30.00	4.28	28.96	0.00	0.00	28.96	0.00	0.00	8,375	274.00	21.100	578.83
Feb2	61.28	105.47	2.00	25.20	4.28	24.15	0.00	0.00	24.15	0.00	0.00	6,584	274.00	21.100	578.83
Mar1	53.84	73.47	2.00	22.71	4.13	21.70	0.00	0.00	21.70	0.00	0.00	6,367	274.00	21.100	578.83
Mar2	61.62	112.46	2.00	25.65	4.13	24.64	0.00	0.00	24.64	0.00	0.00	7,671	274.00	21.100	578.83
Apr1	94.09	83.75	10.88	24.50	4.20	23.47	0.00	0.00	23.47	0.00	0.00	6,865	274.00	21.100	578.83
Apr2	108.95	89.96	19.99	28.18	4.20	27.15	0.00	0.00	27.15	0.00	0.00	7,883	274.00	21.100	578.83
May1	90.18	104.95	2.00	29.81	3.87	28.87	0.00	0.00	28.87	0.00	0.00	8,350	274.00	21.100	578.83
May2	87.44	97.64	2.00	28.44	3.87	27.49	0.00	0.00	27.49	0.00	0.00	8,508	274.00	21.100	578.83
Jun1	89.20	62.92	27.66	21.86	3.73	27.66	0.00	0.00	27.66	0.00	0.00	8,006	273.59	20.837	570.13
Jun2	76.29	67.40	9.36	17.72	3.73	10.11	0.00	0.00	10.11	0.00	0.00	3,003	274.00	21.100	578.83
Jul1	47.34	40.19	7.52	12.90	3.61	12.02	0.00	0.00	12.02	0.00	0.00	3,571	274.00	21.100	578.83
Jul2	16.04	26.12	2.00	10.83	3.61	9.94	0.00	0.00	9.94	0.00	0.00	3,157	274.00	21.100	578.83
Aug1	0.00	35.63	2.00	12.75	3.61	11.87	0.00	0.00	11.87	0.00	0.00	3,527	274.00	21.100	578.83
Aug2	0.00	21.23	2.00	9.93	3.61	9.05	0.00	0.00	9.05	0.00	0.00	2,875	274.00	21.100	578.83
Sep1	0.00	14.49	2.00	9.30	4.27	8.26	0.00	0.00	8.26	0.00	0.00	2,460	274.00	21.100	578.83
Sep2	0.00	8.59	2.00	8.38	4.27	0.00	7.34	0.00	7.34	0.00	0.00	0	274.00	21.100	578.83
Total	1,892 (MCM)	3,254 (MCM)	148 (MCM)	719 (MCM)	30.3 (MCM)	679.7 (MCM)	9.5 (MCM)	0.0 (MCM)	689 (MCM)	0 (tms)	0 (tms)	152.3 (GWh)			

Water Balance Simulation Result (7/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1972 - 1973

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	2.32	2.00	6.96	4.00	0.00	5.98	0.00	5.98	0.00	0.00	0	274.00	21.100	578.83
Oct2	22.89	2.21	21.76	6.53	4.00	21.76	0.00	0.00	21.76	0.00	0.00	6,773	272.92	20.419	556.42
Nov1	63.96	6.25	60.75	6.88	4.13	37.44	23.31	0.00	60.75	0.00	0.00	9,936	269.24	18.274	485.34
Nov2	92.33	20.21	75.92	9.44	4.13	37.60	38.32	0.00	75.92	0.00	0.00	9,192	264.13	15.969	398.05
Dec1	106.66	28.64	82.12	11.81	3.74	37.60	44.52	0.00	82.12	0.00	0.00	8,432	257.86	13.423	306.03
Dec2	98.25	32.14	69.58	13.93	3.74	37.60	31.98	0.00	69.58	0.00	0.00	8,568	251.51	11.090	228.29
Jan1	93.60	67.13	27.87	15.97	3.55	27.87	0.00	0.00	27.87	0.00	0.00	6,220	250.03	10.580	212.28
Jan2	93.16	125.22	2.00	25.55	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	252.92	11.586	244.23
Feb1	81.62	108.63	2.00	17.01	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	254.49	12.155	262.94
Feb2	61.28	137.83	2.00	26.49	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	256.63	12.952	289.77
Mar1	53.84	308.85	2.00	30.67	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	259.33	13.994	326.13
Mar2	61.62	238.91	2.00	29.07	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	261.85	15.011	362.63
Apr1	94.09	106.64	2.00	24.85	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	263.71	15.789	391.30
Apr2	108.95	81.93	28.44	23.12	4.20	28.44	0.00	0.00	28.44	0.00	0.00	7,375	263.21	15.576	383.41
May1	90.18	123.04	2.00	27.50	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	265.21	16.434	415.55
May2	87.44	152.00	2.00	31.46	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	267.56	17.493	455.26
Jun1	89.20	107.01	2.00	24.56	3.73	0.00	2.00	0.00	2.00	0.00	0.00	0	269.14	18.227	483.52
Jun2	76.29	64.39	12.53	18.90	3.73	12.53	0.00	0.00	12.53	0.00	0.00	3,553	269.53	18.413	490.75
Jul1	47.34	33.48	14.59	16.56	3.61	14.59	0.00	0.00	14.59	0.00	0.00	4,137	269.62	18.453	492.30
Jul2	16.04	25.12	2.00	12.63	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	270.35	18.842	505.93
Aug1	0.00	27.55	2.00	13.19	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	271.06	19.270	519.41
Aug2	0.00	63.40	2.00	16.38	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	272.01	19.857	538.18
Sep1	0.00	60.36	2.00	18.70	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	273.02	20.484	558.54
Sep2	0.00	149.68	2.00	28.08	4.27	11.41	0.00	0.00	11.41	0.00	0.00	3,377	274.00	21.100	578.83
Total	1,887 (MCM)	2,718 (MCM)	557 (MCM)	598 (MCM)	23.7 (MCM)	351.0 (MCM)	223.7 (MCM)	0.0 (MCM)	575 (MCM)	0 (tms)	0 (tms)	67.6 (GWh)			

(5/25)

Water Balance Simulation Result (8/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1973 - 1974

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	73.44	2.00	17.51	4.00	16.53	0.00	0.00	16.53	0.00	0.00	4,887	274.00	21.100	578.83
Oct2	22.89	66.86	2.00	18.80	4.00	17.82	0.00	0.00	17.82	0.00	0.00	5,610	274.00	21.100	578.83
Nov1	63.96	55.28	9.14	20.19	4.13	19.18	0.00	0.00	19.18	0.00	0.00	5,649	274.00	21.100	578.83
Nov2	92.33	36.99	58.26	15.88	4.13	36.61	21.64	0.00	58.26	0.00	0.00	9,936	271.22	19.370	522.60
Dec1	106.66	116.40	2.00	25.21	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	272.68	20.271	551.59
Dec2	98.25	165.00	2.00	31.86	3.74	11.28	0.00	0.00	11.28	0.00	0.00	3,555	274.00	21.100	578.83
Jan1	93.60	60.82	34.51	16.53	3.55	34.51	0.00	0.00	34.51	0.00	0.00	9,784	272.82	20.357	554.40
Jan2	93.16	58.16	36.84	16.80	3.55	35.68	1.16	0.00	36.84	0.00	0.00	10,598	271.37	19.462	525.53
Feb1	81.62	130.45	2.00	23.92	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	272.74	20.305	552.69
Feb2	61.28	97.58	2.00	18.27	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	273.57	20.828	569.84
Mar1	53.84	99.04	2.00	15.87	4.13	7.94	0.00	0.00	7.94	0.00	0.00	2,362	274.00	21.100	578.83
Mar2	61.62	49.46	12.80	13.92	4.13	12.91	0.00	0.00	12.91	0.00	0.00	4,087	274.00	21.100	578.83
Apr1	94.09	81.10	13.67	19.55	4.20	18.52	0.00	0.00	18.52	0.00	0.00	5,461	274.00	21.100	578.83
Apr2	108.95	85.79	24.39	20.77	4.20	24.39	0.00	0.00	24.39	0.00	0.00	7,110	273.71	20.918	572.82
May1	90.18	95.60	2.00	20.15	3.87	14.57	0.00	0.00	14.57	0.00	0.00	4,312	274.00	21.100	578.83
May2	87.44	70.56	17.76	15.88	3.87	17.76	0.00	0.00	17.76	0.00	0.00	5,588	273.81	20.982	574.92
Jun1	89.20	44.48	47.07	12.42	3.73	35.92	11.15	0.00	47.07	0.00	0.00	9,936	271.54	19.566	528.83
Jun2	76.29	28.49	50.31	12.73	3.73	37.12	13.19	0.00	50.31	0.00	0.00	9,936	268.89	18.112	479.04
Jul1	47.34	23.69	24.89	12.20	3.61	24.89	0.00	0.00	24.89	0.00	0.00	6,860	267.92	17.660	461.62
Jul2	16.04	26.49	2.00	11.79	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	268.62	17.985	474.14
Aug1	0.00	49.49	2.00	12.82	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	269.34	18.322	487.18
Aug2	0.00	39.98	2.00	13.49	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	270.14	18.717	502.00
Sep1	0.00	82.95	2.00	18.22	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	271.18	19.346	521.83
Sep2	0.00	34.18	2.00	13.59	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	271.89	19.777	535.61
Total	1,887 (MCM)	2,192 (MCM)	467 (MCM)	550 (MCM)	28.8 (MCM)	482.1 (MCM)	81.9 (MCM)	0.0 (MCM)	564 (MCM)	0 (tms)	0 (tms)	105.7 (GWh)			

Water Balance Simulation Result (9/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1974 - 1975

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													271.89	19.777	535.61
Oct1	0.00	24.25	2.00	13.47	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	272.57	20.200	549.29
Oct2	22.89	9.05	14.57	13.10	4.00	14.57	0.00	0.00	14.57	0.00	0.00	4,537	272.40	20.098	545.97
Nov1	63.96	10.97	55.79	14.30	4.13	37.14	18.65	0.00	55.79	0.00	0.00	9,936	269.54	18.419	490.96
Nov2	92.33	23.38	72.58	15.68	4.13	37.60	34.98	0.00	72.58	0.00	0.00	9,342	265.25	16.448	416.07
Dec1	106.66	33.66	76.84	17.09	3.74	37.60	39.24	0.00	76.84	0.00	0.00	8,740	260.15	14.318	337.71
Dec2	98.25	41.41	59.83	20.10	3.74	37.60	22.23	0.00	59.83	0.00	0.00	9,160	256.02	12.722	281.94
Jan1	93.60	63.73	31.44	30.67	3.55	31.44	0.00	0.00	31.44	0.00	0.00	7,409	255.89	12.672	280.27
Jan2	93.16	48.69	46.82	24.53	3.55	37.60	9.22	0.00	46.82	0.00	0.00	8,978	253.30	11.725	248.75
Feb1	81.62	159.74	2.00	34.77	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	256.68	12.972	290.46
Feb2	61.28	76.97	2.00	24.97	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	258.56	13.695	315.54
Mar1	53.84	45.82	8.44	22.36	4.13	8.44	0.00	0.00	8.44	0.00	0.00	2,156	259.80	14.179	332.73
Mar2	61.62	54.15	7.86	19.14	4.13	7.86	0.00	0.00	7.86	0.00	0.00	2,169	260.82	14.589	347.38
Apr1	94.09	96.02	2.00	31.19	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	263.26	15.600	384.29
Apr2	108.95	58.20	53.43	28.86	4.20	37.60	15.83	0.00	53.43	0.00	0.00	9,138	261.10	14.703	351.47
May1	90.18	43.98	48.63	22.60	3.87	37.60	11.03	0.00	48.63	0.00	0.00	8,962	258.66	13.733	316.88
May2	87.44	33.94	56.31	20.42	3.87	37.60	18.71	0.00	56.31	0.00	0.00	9,068	254.78	12.260	266.41
Jun1	89.20	24.00	68.63	16.30	3.73	37.32	31.31	0.00	68.63	0.00	0.00	7,680	248.64	10.124	197.90
Jun2	76.29	14.52	65.01	12.92	3.73	35.75	29.26	0.00	65.01	0.00	0.00	6,749	241.03	7.803	129.81
Jul1	47.34	10.51	38.77	10.59	3.61	35.05	3.72	0.00	38.77	0.00	0.00	6,361	235.81	6.375	92.87
Jul2	16.04	16.07	2.00	15.94	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	238.61	7.124	111.76
Aug1	0.00	13.52	2.00	15.13	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	240.84	7.751	128.40
Aug2	0.00	14.70	2.00	12.21	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	242.55	8.244	142.06
Sep1	0.00	10.60	2.00	13.08	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	244.18	8.729	155.89
Sep2	0.00	31.94	2.00	10.68	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	245.38	9.095	166.57
Total	1,887 (MCM)	1,249 (MCM)	953 (MCM)	603 (MCM)	18.9 (MCM)	621.8 (MCM)	331.1 (MCM)	0.0 (MCM)	953 (MCM)	0 (tms)	0 (tms)	110.4 (GWh)			

Water Balance Simulation Result (10/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1975 - 1976

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													245.38	9.095	166.57
Oct1	0.00	24.16	2.00	12.68	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	246.81	9.539	179.87
Oct2	22.89	17.23	5.95	15.89	4.00	0.00	5.95	0.00	5.95	0.00	0.00	0	248.15	9.967	192.99
Nov1	63.96	16.43	50.03	15.95	4.13	36.59	13.45	0.00	50.03	0.00	0.00	7,233	243.29	8.461	148.20
Nov2	92.33	15.35	81.03	18.44	4.13	32.84	48.19	0.00	81.03	0.00	0.00	5,231	231.27	5.242	66.55
Dec1	106.66	71.02	37.51	12.80	3.74	32.11	5.40	0.00	37.51	0.00	0.00	4,889	223.94	3.591	34.24
Dec2	98.25	24.82	77.29	13.42	3.74	0.00	36.57	-40.72	36.57	39.37	0.00	0	208.00	0.680	2.02
Jan1	93.60	77.23	17.23	19.41	3.55	0.00	17.23	0.00	17.23	0.00	0.00	0	211.06	1.138	4.80
Jan2	93.16	77.27	16.73	18.89	3.55	0.00	16.73	0.00	16.73	0.00	0.00	0	213.28	1.491	7.72
Feb1	81.62	74.93	7.04	31.70	4.28	0.00	7.04	0.00	7.04	0.00	0.00	0	225.36	3.914	39.59
Feb2	61.28	57.97	3.48	29.35	4.28	0.00	3.48	0.00	3.48	0.00	0.00	0	232.04	5.426	70.65
Mar1	53.84	64.18	2.00	19.99	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	235.93	6.406	93.63
Mar2	61.62	196.54	2.00	29.01	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	241.12	7.829	130.55
Apr1	94.09	74.88	20.22	27.15	4.20	20.22	0.00	0.00	20.22	0.00	0.00	4,067	242.18	8.137	139.05
Apr2	108.95	61.21	50.26	19.57	4.20	34.95	15.30	0.00	50.26	0.00	0.00	6,308	236.71	6.613	98.76
May1	90.18	54.52	37.53	17.37	3.87	34.04	3.49	0.00	37.53	0.00	0.00	5,828	232.33	5.497	72.24
May2	87.44	11.93	79.49	12.22	3.87	0.00	62.77	-16.71	62.77	18.16	0.00	0	208.00	0.680	2.02
Jun1	89.20	13.39	79.80	11.06	3.73	0.00	11.03	-68.77	11.03	73.25	0.00	0	208.00	0.680	2.02
Jun2	76.29	8.16	71.71	8.66	3.73	0.00	8.63	-63.08	8.63	78.56	0.00	0	208.00	0.680	2.02
Jul1	47.34	5.26	44.29	14.10	3.61	0.00	14.07	-30.22	14.07	60.64	0.00	0	208.00	0.680	2.02
Jul2	16.04	5.85	10.72	11.35	3.61	0.00	10.72	0.00	10.72	0.00	0.00	0	209.09	0.841	2.85
Aug1	0.00	13.43	2.00	12.82	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	218.05	2.350	16.83
Aug2	0.00	6.60	2.00	10.17	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	222.09	3.180	27.99
Sep1	0.00	3.78	2.00	7.26	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	224.04	3.615	34.61
Sep2	0.00	3.74	2.00	6.79	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	225.61	3.967	40.58
Total	1,892 (MCM)	1,294 (MCM)	929 (MCM)	520 (MCM)	6.5 (MCM)	247.2 (MCM)	392.6 (MCM)	0.0 (MCM)	640 (MCM)	5 (tms)	0 (tms)	33.6 (GWh)			

(8/25)

Water Balance Simulation Result (11/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1976 - 1977

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													225.61	3.967	40.58
Oct1	0.00	9.48	2.00	13.56	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	229.01	4.715	55.33
Oct2	22.89	15.15	8.15	14.92	4.00	8.15	0.00	0.00	8.15	0.00	0.00	1,489	230.85	5.143	64.39
Nov1	63.96	14.88	51.67	11.60	4.13	0.00	51.67	0.00	51.67	0.00	0.00	0	215.86	1.944	12.14
Nov2	92.33	18.45	77.77	16.38	4.13	0.00	24.09	-53.68	24.09	55.23	0.00	0	208.00	0.680	2.02
Dec1	106.66	17.59	93.75	14.92	3.74	0.00	14.89	-78.86	14.89	70.24	0.00	0	208.00	0.680	2.02
Dec2	98.25	44.32	56.76	20.74	3.74	0.00	20.71	-36.04	20.71	34.85	0.00	0	208.00	0.680	2.02
Jan1	93.60	97.31	2.00	18.42	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	220.52	2.852	23.27
Jan2	93.16	175.00	2.00	31.58	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	230.78	5.125	64.00
Feb1	81.62	305.55	2.00	42.84	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	239.28	7.309	116.60
Feb2	61.28	197.62	2.00	29.95	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	243.22	8.440	147.59
Mar1	53.84	85.57	2.00	22.56	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	246.16	9.334	173.71
Mar2	61.62	257.27	2.00	29.65	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	249.94	10.549	211.31
Apr1	94.09	157.57	2.00	40.87	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	254.33	12.098	261.03
Apr2	108.95	105.00	4.16	35.89	4.20	0.00	4.16	0.00	4.16	0.00	0.00	0	257.52	13.289	301.38
May1	90.18	93.22	2.00	24.68	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	259.61	14.103	330.00
May2	87.44	35.86	54.29	20.82	3.87	37.60	16.69	0.00	54.29	0.00	0.00	9,233	256.09	12.749	282.87
Jun1	89.20	116.86	2.00	28.34	3.73	0.00	2.00	0.00	2.00	0.00	0.00	0	258.62	13.716	316.30
Jun2	76.29	74.55	2.00	25.63	3.73	0.00	2.00	0.00	2.00	0.00	0.00	0	260.73	14.555	346.15
Jul1	47.34	35.64	12.32	22.30	3.61	12.32	0.00	0.00	12.32	0.00	0.00	3,203	261.56	14.892	358.30
Jul2	16.04	15.65	2.00	16.09	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	262.79	15.401	376.92
Aug1	0.00	10.49	2.00	12.78	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	263.63	15.755	390.06
Aug2	0.00	7.61	2.00	13.01	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	264.53	16.136	404.37
Sep1	0.00	16.88	2.00	11.70	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	265.24	16.444	415.90
Sep2	0.00	10.08	2.00	13.69	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	266.08	16.823	430.00
Total	1,887 (MCM)	2,499 (MCM)	517 (MCM)	698 (MCM)	13.2 (MCM)	79.2 (MCM)	216.4 (MCM)	0.0 (MCM)	296 (MCM)	3 (tms)	0 (tms)	13.9 (GWh)			

(9/25)

Water Balance Simulation Result (12/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1977 - 1978

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													266.08	16.823	430.00
Oct1	0.00	5.48	2.00	9.16	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	266.57	17.044	438.26
Oct2	22.89	3.85	20.04	13.57	4.00	20.04	0.00	0.00	20.04	0.00	0.00	5,813	265.98	16.776	428.23
Nov1	63.96	17.30	49.12	11.53	4.13	37.60	11.52	0.00	49.12	0.00	0.00	9,447	262.89	15.443	378.47
Nov2	92.33	13.59	82.88	8.61	4.13	37.60	45.28	0.00	82.88	0.00	0.00	8,243	255.97	12.701	281.25
Dec1	106.66	46.14	63.70	22.39	3.74	37.60	26.10	0.00	63.70	0.00	0.00	8,041	251.39	11.050	227.00
Dec2	98.25	77.21	22.14	28.18	3.74	22.14	0.00	0.00	22.14	0.00	0.00	5,413	252.08	11.291	234.70
Jan1	93.60	103.99	2.00	26.72	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	254.75	12.251	266.13
Jan2	93.16	103.29	2.00	24.82	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	257.18	13.162	296.99
Feb1	81.62	128.21	2.00	32.62	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	260.02	14.265	335.82
Feb2	61.28	189.11	2.00	37.02	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	262.62	15.331	374.36
Mar1	53.84	231.42	2.00	44.50	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	265.99	16.783	428.49
Mar2	61.62	335.42	2.00	56.15	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	270.15	18.724	502.23
Apr1	94.09	151.27	2.00	33.34	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	272.19	19.965	541.67
Apr2	108.95	85.52	24.67	28.98	4.20	24.67	0.00	0.00	24.67	0.00	0.00	7,078	272.41	20.099	546.00
May1	90.18	149.89	2.00	37.68	3.87	11.45	0.00	0.00	11.45	0.00	0.00	3,377	274.00	21.100	578.83
May2	87.44	155.24	2.00	30.25	3.87	29.30	0.00	0.00	29.30	0.00	0.00	9,032	274.00	21.100	578.83
Jun1	89.20	197.04	2.00	35.92	3.73	34.88	0.13	0.00	35.01	0.00	0.00	9,936	274.00	21.100	578.83
Jun2	76.29	99.40	2.00	27.73	3.73	26.82	0.00	0.00	26.82	0.00	0.00	7,793	274.00	21.100	578.83
Jul1	47.34	97.82	2.00	26.31	3.61	25.43	0.00	0.00	25.43	0.00	0.00	7,410	274.00	21.100	578.83
Jul2	16.04	48.84	2.00	19.35	3.61	18.47	0.00	0.00	18.47	0.00	0.00	5,808	274.00	21.100	578.83
Aug1	0.00	44.01	2.00	18.55	3.61	17.67	0.00	0.00	17.67	0.00	0.00	5,216	274.00	21.100	578.83
Aug2	0.00	65.08	2.00	20.11	3.61	19.23	0.00	0.00	19.23	0.00	0.00	6,041	274.00	21.100	578.83
Sep1	0.00	66.90	2.00	20.17	4.27	19.13	0.00	0.00	19.13	0.00	0.00	5,634	274.00	21.100	578.83
Sep2	0.00	37.71	2.00	16.82	4.27	15.78	0.00	0.00	15.78	0.00	0.00	4,670	274.00	21.100	578.83
Total	1,887 (MCM)	3,216 (MCM)	391 (MCM)	827 (MCM)	25.2 (MCM)	525.0 (MCM)	128.4 (MCM)	0.0 (MCM)	653 (MCM)	0 (tms)	0 (tms)	108.9 (GWh)			

(10/25)

Water Balance Simulation Result (13/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1978 - 1979

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	84.43	2.00	15.81	4.00	14.83	0.00	0.00	14.83	0.00	0.00	4,394	274.00	21.100	578.83
Oct2	22.89	87.24	2.00	18.77	4.00	17.80	0.00	0.00	17.80	0.00	0.00	5,603	274.00	21.100	578.83
Nov1	63.96	124.63	2.00	23.78	4.13	22.77	0.00	0.00	22.77	0.00	0.00	6,669	274.00	21.100	578.83
Nov2	92.33	109.08	2.00	30.91	4.13	29.90	0.00	0.00	29.90	0.00	0.00	8,629	274.00	21.100	578.83
Dec1	106.66	185.73	2.00	51.34	3.74	35.57	14.86	0.00	50.43	0.00	0.00	9,936	274.00	21.100	578.83
Dec2	98.25	221.40	2.00	40.94	3.74	35.07	4.95	0.00	40.02	0.00	0.00	10,598	274.00	21.100	578.83
Jan1	93.60	166.63	2.00	32.34	3.55	31.47	0.00	0.00	31.47	0.00	0.00	9,048	274.00	21.100	578.83
Jan2	93.16	224.14	2.00	32.32	3.55	31.45	0.00	0.00	31.45	0.00	0.00	9,645	274.00	21.100	578.83
Feb1	81.62	336.90	2.00	49.80	4.28	35.48	13.27	0.00	48.76	0.00	0.00	9,936	274.00	21.100	578.83
Feb2	61.28	162.63	2.00	41.46	4.28	35.09	5.33	0.00	40.42	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	154.10	2.00	33.66	4.13	32.65	0.00	0.00	32.65	0.00	0.00	9,359	274.00	21.100	578.83
Mar2	61.62	67.88	2.00	32.33	4.13	31.32	0.00	0.00	31.32	0.00	0.00	9,607	274.00	21.100	578.83
Apr1	94.09	185.55	2.00	38.81	4.20	34.98	2.80	0.00	37.79	0.00	0.00	9,936	274.00	21.100	578.83
Apr2	108.95	109.57	2.00	30.03	4.20	29.00	0.00	0.00	29.00	0.00	0.00	8,387	274.00	21.100	578.83
May1	90.18	129.69	2.00	33.07	3.87	32.13	0.00	0.00	32.13	0.00	0.00	9,221	274.00	21.100	578.83
May2	87.44	76.09	9.84	32.67	3.87	31.73	0.00	0.00	31.73	0.00	0.00	9,723	274.00	21.100	578.83
Jun1	89.20	87.49	2.00	28.32	3.73	27.41	0.00	0.00	27.41	0.00	0.00	7,954	274.00	21.100	578.83
Jun2	76.29	21.92	57.23	19.61	3.73	36.48	20.75	0.00	57.23	0.00	0.00	9,936	271.54	19.567	528.99
Jul1	47.34	76.42	2.00	28.78	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	273.22	20.606	562.53
Jul2	16.04	39.56	2.00	47.39	3.61	34.74	0.00	0.00	34.74	0.00	0.00	10,519	274.00	21.100	578.83
Aug1	0.00	11.75	2.00	25.47	3.61	24.59	0.00	0.00	24.59	0.00	0.00	7,177	274.00	21.100	578.83
Aug2	0.00	6.12	2.00	20.88	3.61	20.00	0.00	0.00	20.00	0.00	0.00	6,275	274.00	21.100	578.83
Sep1	0.00	7.24	2.00	19.23	4.27	18.19	0.00	0.00	18.19	0.00	0.00	5,365	274.00	21.100	578.83
Sep2	0.00	18.83	2.00	20.32	4.27	19.28	0.00	0.00	19.28	0.00	0.00	5,678	274.00	21.100	578.83
Total	1,887 (MCM)	3,530 (MCM)	145 (MCM)	982 (MCM)	30.1 (MCM)	869.3 (MCM)	82.4 (MCM)	0.0 (MCM)	952 (MCM)	0 (tms)	0 (tms)	192.2 (GWh)			

(11/25)

Water Balance Simulation Result (14/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1979 - 1980

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	35.37	2.00	14.57	4.00	13.59	0.00	0.00	13.59	0.00	0.00	4,031	274.00	21.100	578.83
Oct2	22.89	24.05	2.00	15.07	4.00	14.09	0.00	0.00	14.09	0.00	0.00	4,457	274.00	21.100	578.83
Nov1	63.96	41.08	24.09	16.78	4.13	24.09	0.00	0.00	24.09	0.00	0.00	7,019	273.49	20.774	568.05
Nov2	92.33	8.41	88.33	14.14	4.13	37.60	50.73	0.00	88.33	0.00	0.00	9,349	268.42	17.894	470.60
Dec1	106.66	12.62	98.98	14.17	3.74	37.60	61.38	0.00	98.98	0.00	0.00	8,414	261.65	14.930	359.68
Dec2	98.25	128.96	2.00	20.83	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	263.30	15.614	384.82
Jan1	93.60	350.93	2.00	33.45	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	265.77	16.683	424.75
Jan2	93.16	275.60	2.00	36.56	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	268.48	17.919	471.57
Feb1	81.62	83.28	2.00	20.02	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	269.70	18.490	493.77
Feb2	61.28	332.22	2.00	30.94	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	271.48	19.529	527.68
Mar1	53.84	121.75	2.00	23.92	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	272.84	20.372	554.87
Mar2	61.62	104.83	2.00	20.54	4.13	0.00	2.24	0.00	2.24	0.00	0.00	0	274.00	21.100	578.83
Apr1	94.09	73.78	21.37	21.89	4.20	21.37	0.00	0.00	21.37	0.00	0.00	6,273	273.97	21.080	578.17
Apr2	108.95	166.22	2.00	27.44	4.20	25.91	0.00	0.00	25.91	0.00	0.00	7,541	274.00	21.100	578.83
May1	90.18	121.06	2.00	24.86	3.87	23.91	0.00	0.00	23.91	0.00	0.00	6,988	274.00	21.100	578.83
May2	87.44	44.04	45.68	16.81	3.87	35.72	9.96	0.00	45.68	0.00	0.00	10,598	271.99	19.840	537.62
Jun1	89.20	34.28	57.81	14.89	3.73	37.49	20.32	0.00	57.81	0.00	0.00	9,936	268.99	18.160	480.88
Jun2	76.29	34.53	43.96	18.76	3.73	37.60	6.36	0.00	43.96	0.00	0.00	9,908	267.09	17.281	447.20
Jul1	47.34	21.57	27.13	13.20	3.61	27.13	0.00	0.00	27.13	0.00	0.00	7,295	265.98	16.776	428.22
Jul2	16.04	38.55	2.00	14.78	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	266.96	17.221	444.92
Aug1	0.00	61.21	2.00	20.04	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	268.24	17.810	467.37
Aug2	0.00	53.35	2.00	17.41	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	269.36	18.333	487.64
Sep1	0.00	99.21	2.00	26.36	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	270.98	19.226	518.03
Sep2	0.00	82.29	2.00	20.72	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	272.16	19.946	541.05
Total	1,892 (MCM)	3,074 (MCM)	574 (MCM)	655 (MCM)	27.3 (MCM)	439.9 (MCM)	225.8 (MCM)	0.0 (MCM)	666 (MCM)	0 (tms)	0 (tms)	91.8 (GWh)			

Water Balance Simulation Result (15/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1980 - 1981

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													272.16	19.946	541.05
Oct1	0.00	87.31	2.00	16.02	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	273.00	20.468	558.02
Oct2	22.89	113.50	2.00	19.45	4.00	0.00	3.46	0.00	3.46	0.00	0.00	0	274.00	21.100	578.83
Nov1	63.96	235.01	2.00	39.19	4.13	35.00	3.19	0.00	38.18	0.00	0.00	9,936	274.00	21.100	578.83
Nov2	92.33	116.66	2.00	34.73	4.13	33.72	0.00	0.00	33.72	0.00	0.00	9,639	274.00	21.100	578.83
Dec1	106.66	133.10	2.00	44.28	3.74	35.22	8.14	0.00	43.36	0.00	0.00	9,936	274.00	21.100	578.83
Dec2	98.25	259.97	2.00	43.09	3.74	35.17	7.01	0.00	42.18	0.00	0.00	10,598	274.00	21.100	578.83
Jan1	93.60	211.69	2.00	31.96	3.55	31.09	0.00	0.00	31.09	0.00	0.00	8,947	274.00	21.100	578.83
Jan2	93.16	275.03	2.00	29.49	3.55	28.62	0.00	0.00	28.62	0.00	0.00	8,836	274.00	21.100	578.83
Feb1	81.62	168.33	2.00	22.85	4.28	21.80	0.00	0.00	21.80	0.00	0.00	6,395	274.00	21.100	578.83
Feb2	61.28	262.29	2.00	36.61	4.28	34.90	0.67	0.00	35.57	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	269.08	2.00	33.66	4.13	32.65	0.00	0.00	32.65	0.00	0.00	9,357	274.00	21.100	578.83
Mar2	61.62	300.64	2.00	47.77	4.13	35.38	11.38	0.00	46.76	0.00	0.00	10,598	274.00	21.100	578.83
Apr1	94.09	273.53	2.00	45.28	4.20	35.26	8.99	0.00	44.25	0.00	0.00	9,936	274.00	21.100	578.83
Apr2	108.95	235.59	2.00	41.60	4.20	35.10	5.48	0.00	40.57	0.00	0.00	9,936	274.00	21.100	578.83
May1	90.18	223.27	2.00	45.14	3.87	35.26	8.93	0.00	44.19	0.00	0.00	9,936	274.00	21.100	578.83
May2	87.44	240.99	2.00	41.39	3.87	35.09	5.35	0.00	40.44	0.00	0.00	10,598	274.00	21.100	578.83
Jun1	89.20	68.82	21.45	27.20	3.73	26.28	0.00	0.00	26.28	0.00	0.00	7,646	274.00	21.100	578.83
Jun2	76.29	61.63	15.43	24.94	3.73	24.03	0.00	0.00	24.03	0.00	0.00	7,021	274.00	21.100	578.83
Jul1	47.34	16.41	32.56	19.73	3.61	32.56	0.00	0.00	32.56	0.00	0.00	9,294	273.15	20.561	561.06
Jul2	16.04	35.98	2.00	16.03	3.61	0.00	2.32	0.00	2.32	0.00	0.00	0	274.00	21.100	578.83
Aug1	0.00	31.73	2.00	13.88	3.61	13.00	0.00	0.00	13.00	0.00	0.00	3,858	274.00	21.100	578.83
Aug2	0.00	33.65	2.00	12.89	3.61	12.01	0.00	0.00	12.01	0.00	0.00	3,806	274.00	21.100	578.83
Sep1	0.00	75.42	2.00	16.17	4.27	15.13	0.00	0.00	15.13	0.00	0.00	4,480	274.00	21.100	578.83
Sep2	0.00	154.15	2.00	30.22	4.27	29.18	0.00	0.00	29.18	0.00	0.00	8,435	274.00	21.100	578.83
Total	1,887 (MCM)	5,097 (MCM)	145 (MCM)	963 (MCM)	30.1 (MCM)	805.5 (MCM)	89.2 (MCM)	0.0 (MCM)	895 (MCM)	0 (tms)	0 (tms)	177.8 (GWh)			

(13/25)

Water Balance Simulation Result (16/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1981 - 1982

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	108.31	2.00	19.43	4.00	18.45	0.00	0.00	18.45	0.00	0.00	5,440	274.00	21.100	578.83
Oct2	22.89	61.72	2.00	13.24	4.00	12.27	0.00	0.00	12.27	0.00	0.00	3,886	274.00	21.100	578.83
Nov1	63.96	48.53	16.25	15.18	4.13	16.25	0.00	0.00	16.25	0.00	0.00	4,801	273.87	21.019	576.14
Nov2	92.33	59.27	34.80	16.14	4.13	34.80	0.00	0.00	34.80	0.00	0.00	9,842	272.64	20.243	550.66
Dec1	106.66	99.44	7.60	19.60	3.74	7.60	0.00	0.00	7.60	0.00	0.00	2,242	273.34	20.684	565.08
Dec2	98.25	104.60	2.00	22.30	3.74	11.45	0.00	0.00	11.45	0.00	0.00	3,620	274.00	21.100	578.83
Jan1	93.60	390.18	2.00	48.58	3.55	35.43	12.28	0.00	47.71	0.00	0.00	9,936	274.00	21.100	578.83
Jan2	93.16	233.39	2.00	33.23	3.55	32.37	0.00	0.00	32.37	0.00	0.00	9,903	274.00	21.100	578.83
Feb1	81.62	336.54	2.00	43.17	4.28	35.16	6.96	0.00	42.12	0.00	0.00	9,936	274.00	21.100	578.83
Feb2	61.28	292.58	2.00	41.36	4.28	35.09	5.23	0.00	40.31	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	228.91	2.00	36.33	4.13	34.89	0.43	0.00	35.32	0.00	0.00	9,936	274.00	21.100	578.83
Mar2	61.62	118.48	2.00	26.66	4.13	25.65	0.00	0.00	25.65	0.00	0.00	7,968	274.00	21.100	578.83
Apr1	94.09	74.73	20.37	21.99	4.20	20.97	0.00	0.00	20.97	0.00	0.00	6,159	274.00	21.100	578.83
Apr2	108.95	105.09	4.06	26.49	4.20	25.46	0.00	0.00	25.46	0.00	0.00	7,418	274.00	21.100	578.83
May1	90.18	41.22	51.53	19.85	3.87	36.05	15.49	0.00	51.53	0.00	0.00	9,936	271.93	19.806	536.54
May2	87.44	31.05	59.35	15.81	3.87	37.60	21.75	0.00	59.35	0.00	0.00	10,577	268.67	18.011	475.12
Jun1	89.20	51.87	39.29	13.12	3.73	37.60	1.69	0.00	39.29	0.00	0.00	9,927	266.68	17.095	440.20
Jun2	76.29	14.78	64.74	11.38	3.73	37.60	27.14	0.00	64.74	0.00	0.00	9,191	262.34	15.215	370.08
Jul1	47.34	5.53	44.01	10.28	3.61	37.60	6.41	0.00	44.01	0.00	0.00	9,127	259.29	13.978	325.55
Jul2	16.04	25.47	2.00	11.47	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	260.16	14.322	337.83
Aug1	0.00	5.99	2.00	8.69	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	260.70	14.543	345.73
Aug2	0.00	6.66	2.00	7.13	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	261.13	14.717	351.98
Sep1	0.00	4.52	2.00	5.87	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	261.41	14.830	356.05
Sep2	0.00	26.44	2.00	6.96	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	261.77	14.981	361.53
Total	1,887 (MCM)	3,208 (MCM)	485 (MCM)	645 (MCM)	27.4 (MCM)	694.1 (MCM)	140.5 (MCM)	0.0 (MCM)	835 (MCM)	0 (tms)	0 (tms)	148.5 (GWh)			

Water Balance Simulation Result (17/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1982 - 1983

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													261.77	14.981	361.53
Oct1	0.00	20.53	2.00	5.37	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	262.00	15.076	365.00
Oct2	22.89	20.42	2.60	5.25	4.00	0.00	2.60	0.00	2.60	0.00	0.00	0	262.18	15.150	367.70
Nov1	63.96	7.96	58.96	5.92	4.13	37.60	21.36	0.00	58.96	0.00	0.00	8,780	257.26	13.192	298.02
Nov2	92.33	4.44	92.51	4.83	4.13	36.12	56.39	0.00	92.51	0.00	0.00	6,960	247.19	9.660	183.57
Dec1	106.66	7.64	104.23	10.74	3.74	31.57	72.66	0.00	104.23	0.00	0.00	4,647	230.36	5.027	61.87
Dec2	98.25	47.28	53.65	21.24	3.74	0.00	53.65	0.00	53.65	0.00	0.00	0	218.01	2.344	16.76
Jan1	93.60	252.06	2.00	34.57	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	229.75	4.885	58.65
Jan2	93.16	341.89	2.00	35.52	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	237.63	6.857	104.91
Feb1	81.62	197.96	2.00	29.07	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	242.25	8.155	139.55
Feb2	61.28	90.42	2.00	22.80	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	244.93	8.955	162.46
Mar1	53.84	142.01	2.00	27.66	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	248.37	10.036	195.17
Mar2	61.62	66.98	2.00	27.70	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	251.67	11.145	230.03
Apr1	94.09	113.30	2.00	32.62	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	254.99	12.337	269.00
Apr2	108.95	158.18	2.00	23.41	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	257.11	13.132	295.98
May1	90.18	34.89	58.19	25.38	3.87	37.60	20.59	0.00	58.19	0.00	0.00	8,323	253.64	11.845	252.68
May2	87.44	105.60	2.00	33.16	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	257.03	13.105	295.03
Jun1	89.20	22.44	70.27	20.89	3.73	37.60	32.67	0.00	70.27	0.00	0.00	7,984	251.69	11.153	230.30
Jun2	76.29	15.31	64.19	15.55	3.73	36.73	27.46	0.00	64.19	0.00	0.00	7,322	245.39	9.097	166.64
Jul1	47.34	13.08	36.06	15.09	3.61	36.06	0.00	0.00	36.06	0.00	0.00	7,110	242.18	8.134	138.98
Jul2	16.04	16.29	2.00	12.13	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	243.79	8.612	152.51
Aug1	0.00	7.08	2.00	10.45	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	244.99	8.974	163.00
Aug2	0.00	5.29	2.00	8.84	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	245.97	9.276	171.94
Sep1	0.00	15.23	2.00	7.55	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	246.67	9.495	178.54
Sep2	0.00	8.05	2.00	6.43	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	247.21	9.664	183.68
Total	1,887 (MCM)	2,258 (MCM)	745 (MCM)	582 (MCM)	14.5 (MCM)	328.3 (MCM)	416.7 (MCM)	0.0 (MCM)	745 (MCM)	0 (tms)	0 (tms)	51.1 (GWh)			

Water Balance Simulation Result (18/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1983 - 1984

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													247.21	9.664	183.68
Oct1	0.00	14.62	2.00	6.37	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	247.73	9.930	188.76
Oct2	22.89	27.35	2.00	8.13	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	249.52	10.083	196.61
Nov1	63.96	24.40	41.65	10.65	4.13	37.01	4.64	0.00	41.65	0.00	0.00	7,487	244.17	9.726	155.81
Nov2	92.33	11.57	85.01	14.78	4.13	32.65	52.36	0.00	85.01	0.00	0.00	5,139	230.83	5.137	64.26
Dec1	106.66	9.61	102.15	10.16	3.74	0.00	57.96	-44.19	57.96	39.36	0.00	0	208.00	0.680	2.02
Dec2	98.25	52.31	48.35	16.50	3.74	0.00	16.47	-31.88	16.47	30.83	0.00	0	208.00	0.680	2.02
Jan1	93.60	86.48	7.50	18.95	3.55	0.00	7.50	0.00	7.50	0.00	0.00	0	218.05	2.350	16.83
Jan2	93.16	111.64	2.00	23.46	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	227.02	4.267	46.36
Feb1	81.62	88.05	2.00	17.13	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	231.10	5.203	65.69
Feb2	61.28	99.63	2.00	16.02	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	234.10	5.936	82.34
Mar1	53.84	301.81	2.00	36.96	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	240.70	7.709	127.28
Mar2	61.62	146.59	2.00	25.24	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	244.52	8.833	158.89
Apr1	94.09	120.38	2.00	29.52	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	248.26	9.999	194.00
Apr2	108.95	71.46	39.47	23.61	4.20	37.27	2.20	0.00	39.47	0.00	0.00	7,648	246.06	9.304	172.81
May1	90.18	76.68	14.21	28.34	3.87	14.21	0.00	0.00	14.21	0.00	0.00	3,109	247.91	9.889	190.59
May2	87.44	64.62	24.02	10.70	3.87	24.02	0.00	0.00	24.02	0.00	0.00	5,492	245.93	9.263	171.57
Jun1	89.20	115.99	2.00	8.87	3.73	0.00	2.00	0.00	2.00	0.00	0.00	0	246.82	9.542	179.96
Jun2	76.29	28.17	50.65	18.65	3.73	36.24	14.42	0.00	50.65	0.00	0.00	7,028	242.05	9.098	137.95
Jul1	47.34	44.97	2.49	17.26	3.61	0.00	2.49	0.00	2.49	0.00	0.00	0	244.27	8.756	156.66
Jul2	16.04	14.37	2.00	12.85	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	245.88	9.249	171.15
Aug1	0.00	9.72	2.00	11.33	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	247.11	9.633	182.75
Aug2	0.00	49.22	2.00	13.64	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	248.68	10.136	198.28
Sep1	0.00	111.38	2.00	17.93	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	250.59	10.773	218.28
Sep2	0.00	132.42	2.00	19.20	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	252.54	11.452	239.87
Total	1,892 (MCM)	2,382 (MCM)	582 (MCM)	548 (MCM)	11.1 (MCM)	237.2 (MCM)	243.2 (MCM)	0.0 (MCM)	480 (MCM)	2 (tms)	0 (tms)	35.9 (GWh)			

Water Balance Simulation Result (19/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1984 - 1985

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													252.54	11.452	239.87
Oct1	0.00	149.73	2.00	24.38	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	254.92	12.313	268.12
Oct2	22.89	118.77	2.00	20.57	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	256.38	13.048	293.07
Nov1	63.96	98.89	2.00	24.83	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	259.02	13.874	321.85
Nov2	92.33	132.77	2.00	29.24	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	261.42	14.837	356.30
Dec1	106.66	183.22	2.00	25.17	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	263.34	15.633	385.50
Dec2	98.25	148.56	2.00	26.94	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	265.43	16.529	419.04
Jan1	93.60	208.17	2.00	32.75	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	267.71	17.565	458.01
Jan2	93.16	157.59	2.00	39.01	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	270.47	18.914	508.17
Feb1	81.62	233.98	2.00	100.23	4.28	35.98	8.80	0.00	44.78	0.00	0.00	9,936	274.00	21.100	578.83
Feb2	61.28	25.84	37.30	41.35	4.28	35.09	5.22	0.00	40.30	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	77.98	2.00	42.49	4.13	35.14	6.35	0.00	41.48	0.00	0.00	9,936	274.00	21.100	578.83
Mar2	61.62	107.07	2.00	23.19	4.13	22.18	0.00	0.00	22.18	0.00	0.00	6,936	274.00	21.100	578.83
Apr1	94.09	160.50	2.00	43.91	4.20	35.20	7.69	0.00	42.88	0.00	0.00	9,936	274.00	21.100	578.83
Apr2	108.95	130.22	2.00	28.24	4.20	27.22	0.00	0.00	27.22	0.00	0.00	7,901	274.00	21.100	578.83
May1	90.18	59.69	32.09	22.58	3.87	32.09	0.00	0.00	32.09	0.00	0.00	9,180	273.35	20.690	565.29
May2	87.44	127.75	2.00	30.97	3.87	20.25	0.00	0.00	20.25	0.00	0.00	6,331	274.00	21.100	578.83
Jun1	89.20	73.94	16.06	19.74	3.73	18.83	0.00	0.00	18.83	0.00	0.00	5,549	274.00	21.100	578.83
Jun2	76.29	30.29	48.42	18.15	3.73	35.86	12.56	0.00	48.42	0.00	0.00	9,936	272.03	19.865	538.42
Jul1	47.34	49.72	2.00	15.40	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	272.84	20.367	554.72
Jul2	16.04	146.40	2.00	23.57	3.61	0.00	5.27	0.00	5.27	0.00	0.00	0	274.00	21.100	578.83
Aug1	0.00	47.13	2.00	17.06	3.61	16.18	0.00	0.00	16.18	0.00	0.00	4,786	274.00	21.100	578.83
Aug2	0.00	181.49	2.00	16.28	3.61	15.40	0.00	0.00	15.40	0.00	0.00	4,863	274.00	21.100	578.83
Sep1	0.00	223.29	2.00	16.00	4.27	14.96	0.00	0.00	14.96	0.00	0.00	4,431	274.00	21.100	578.83
Sep2	0.00	130.97	2.00	15.06	4.27	14.01	0.00	0.00	14.01	0.00	0.00	4,155	274.00	21.100	578.83
Total	1,887 (MCM)	3,974 (MCM)	220 (MCM)	912 (MCM)	26.7 (MCM)	463.4 (MCM)	82.9 (MCM)	0.0 (MCM)	546 (MCM)	0 (tms)	0 (tms)	102.5 (GWh)			

Water Balance Simulation Result (20/27)

Batutegi Dam Water Balance Simulation - Case : 2-30zh24
Year : 1985 - 1986

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	86.92	2.00	15.49	4.00	14.51	0.00	0.00	14.51	0.00	0.00	4,300	274.00	21.100	578.83
Oct2	22.89	329.29	2.00	18.30	4.00	17.32	0.00	0.00	17.32	0.00	0.00	5,456	274.00	21.100	578.83
Nov1	63.96	55.23	9.20	15.05	4.13	14.04	0.00	0.00	14.04	0.00	0.00	4,163	274.00	21.100	578.83
Nov2	92.33	16.54	79.77	13.87	4.13	37.60	42.17	0.00	79.77	0.00	0.00	9,655	269.51	18.448	492.11
Dec1	106.66	12.88	98.71	13.64	3.74	37.60	61.11	0.00	98.71	0.00	0.00	8,560	263.04	15.506	380.81
Dec2	98.25	25.72	76.34	16.93	3.74	37.60	38.74	0.00	76.34	0.00	0.00	9,040	257.24	13.184	297.75
Jan1	93.60	164.49	2.00	28.48	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	259.70	14.141	331.37
Jan2	93.16	91.86	2.00	21.84	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	261.54	14.883	357.99
Feb1	81.62	249.52	2.00	27.45	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	263.63	15.754	390.01
Feb2	61.28	204.81	2.00	20.60	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	264.98	16.286	410.02
Mar1	53.84	336.50	2.00	36.66	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	267.48	17.458	453.93
Mar2	61.62	158.40	2.00	31.35	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	269.67	18.479	493.34
Apr1	94.09	257.09	2.00	32.38	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	271.68	19.651	531.56
Apr2	108.95	101.36	8.00	23.56	4.20	8.00	0.00	0.00	8.00	0.00	0.00	2,341	272.63	20.237	550.49
May1	90.18	103.34	2.00	26.03	3.87	0.00	3.26	0.00	3.26	0.00	0.00	0	274.00	21.100	578.83
May2	87.44	27.15	63.46	19.64	3.87	37.04	26.42	0.00	63.46	0.00	0.00	10,598	270.93	19.192	516.94
Jun1	89.20	46.29	45.16	21.76	3.73	36.89	8.28	0.00	45.16	0.00	0.00	9,936	269.25	18.279	485.53
Jun2	76.29	36.87	41.49	24.54	3.73	37.34	4.15	0.00	41.49	0.00	0.00	9,936	267.97	17.584	462.54
Jul1	47.34	69.62	2.00	27.25	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	269.72	18.504	494.30
Jul2	16.04	34.28	2.00	18.45	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	270.88	19.161	515.97
Aug1	0.00	127.62	2.00	20.96	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	272.08	19.898	539.51
Aug2	0.00	107.46	2.00	13.08	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	272.79	20.335	553.68
Sep1	0.00	164.48	2.00	19.95	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	273.85	21.004	575.63
Sep2	0.00	145.65	2.00	24.54	4.27	21.03	0.00	0.00	21.03	0.00	0.00	6,173	274.00	21.100	578.83
Total	1,887 (MCM)	3,859 (MCM)	601 (MCM)	698 (MCM)	26.5 (MCM)	395.4 (MCM)	275.7 (MCM)	0.0 (MCM)	671 (MCM)	0 (tms)	0 (tms)	80.2 (GWh)			

(18/25)

Water Balance Simulation Result (21/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1986 - 1987

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													274.00	21.100	578.83
Oct1	0.00	67.51	2.00	18.63	4.00	17.65	0.00	0.00	17.65	0.00	0.00	5,211	274.00	21.100	578.83
Oct2	22.89	154.46	2.00	23.26	4.00	22.29	0.00	0.00	22.29	0.00	0.00	6,967	274.00	21.100	578.83
Nov1	63.96	126.86	2.00	31.24	4.13	30.23	0.00	0.00	30.23	0.00	0.00	8,718	274.00	21.100	578.83
Nov2	92.33	133.00	2.00	30.98	4.13	29.98	0.00	0.00	29.98	0.00	0.00	8,649	274.00	21.100	578.83
Dec1	106.66	93.29	14.07	37.86	3.74	34.95	2.00	0.00	36.95	0.00	0.00	9,936	274.00	21.100	578.83
Dec2	98.25	54.23	46.33	33.84	3.74	35.53	10.80	0.00	46.33	0.00	0.00	10,598	273.11	20.538	560.29
Jan1	93.60	243.53	2.00	48.47	3.55	33.33	0.00	0.00	33.33	0.00	0.00	9,493	274.00	21.100	578.83
Jan2	93.16	267.66	2.00	40.00	3.55	35.04	4.10	0.00	39.14	0.00	0.00	10,598	274.00	21.100	578.83
Feb1	81.62	173.06	2.00	37.93	4.28	34.95	1.94	0.00	36.89	0.00	0.00	9,936	274.00	21.100	578.83
Feb2	61.28	310.96	2.00	46.56	4.28	35.32	10.20	0.00	45.52	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	217.19	2.00	34.87	4.13	33.86	0.00	0.00	33.86	0.00	0.00	9,674	274.00	21.100	578.83
Mar2	61.62	54.47	7.52	27.49	4.13	26.48	0.00	0.00	26.48	0.00	0.00	8,214	274.00	21.100	578.83
Apr1	94.09	89.76	4.55	31.09	4.20	30.07	0.00	0.00	30.07	0.00	0.00	8,673	274.00	21.100	578.83
Apr2	108.95	149.50	2.00	37.37	4.20	34.93	1.42	0.00	36.35	0.00	0.00	9,936	274.00	21.100	578.83
May1	90.18	73.84	17.20	31.38	3.87	30.44	0.00	0.00	30.44	0.00	0.00	8,773	274.00	21.100	578.83
May2	87.44	35.61	54.55	25.28	3.87	36.22	18.33	0.00	54.55	0.00	0.00	10,598	271.96	19.822	537.06
Jun1	89.20	55.79	35.17	29.89	3.73	35.17	0.00	0.00	35.17	0.00	0.00	9,785	271.55	19.574	529.11
Jun2	76.29	16.78	62.64	24.67	3.73	37.60	25.04	0.00	62.64	0.00	0.00	9,847	268.88	18.106	478.80
Jul1	47.34	13.72	35.39	16.17	3.61	35.39	0.00	0.00	35.39	0.00	0.00	9,474	267.42	17.431	452.91
Jul2	16.04	9.29	7.10	14.52	3.61	0.00	7.10	0.00	7.10	0.00	0.00	0	267.95	17.674	462.16
Aug1	0.00	4.74	2.00	12.47	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	268.66	18.002	474.78
Aug2	0.00	2.91	2.00	11.33	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	269.31	18.307	486.63
Sep1	0.00	0.27	2.00	11.10	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	269.88	18.579	497.25
Sep2	0.00	0.00	2.00	13.13	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	270.59	18.987	510.49
Total	1,887 (MCM)	3,040 (MCM)	415 (MCM)	875 (MCM)	28.9 (MCM)	797.2 (MCM)	117.1 (MCM)	0.0 (MCM)	914 (MCM)	0 (tms)	0 (tms)	173.7 (GWh)			

Water Balance Simulation Result (22/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1987 - 1988

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													270.59	18.987	510.49
Oct1	0.00	10.30	2.00	11.21	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	271.15	19.329	521.28
Oct2	22.89	23.40	2.00	9.99	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	271.46	19.636	531.08
Nov1	63.96	25.86	40.11	17.76	4.13	36.31	3.79	0.00	40.11	0.00	0.00	9,936	270.08	18.682	500.90
Nov2	92.33	11.96	84.60	12.26	4.13	37.60	47.00	0.00	84.60	0.00	0.00	9,057	264.63	16.179	405.99
Dec1	106.66	11.03	100.66	19.65	3.74	37.60	63.06	0.00	100.66	0.00	0.00	7,930	257.42	13.252	300.09
Dec2	98.25	44.44	56.64	21.98	3.74	37.60	19.04	0.00	56.64	0.00	0.00	8,918	253.53	11.805	251.38
Jan1	93.60	164.48	2.00	39.69	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	257.38	13.237	290.60
Jan2	93.16	366.16	2.00	42.41	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	261.31	14.793	354.70
Feb1	81.62	276.60	2.00	38.70	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	264.34	16.056	401.31
Feb2	61.28	95.53	2.00	27.09	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	266.12	16.842	430.70
Mar1	53.84	95.29	2.00	40.73	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	269.94	19.133	479.85
Mar2	61.62	127.87	2.00	39.99	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	271.66	19.639	531.17
Apr1	94.09	34.10	63.15	22.77	4.20	37.60	25.55	0.00	63.15	0.00	0.00	9,839	268.81	18.075	477.61
Apr2	108.95	76.65	34.00	21.48	4.20	34.00	0.00	0.00	34.00	0.00	0.00	9,157	267.84	17.624	460.25
May1	90.18	70.21	21.01	21.22	3.87	21.01	0.00	0.00	21.01	0.00	0.00	5,798	267.80	17.604	459.50
May2	87.44	61.40	27.41	18.03	3.87	27.41	0.00	0.00	27.41	0.00	0.00	7,929	266.99	17.234	445.44
Jun1	89.20	29.96	62.36	16.53	3.73	37.60	24.76	0.00	62.36	0.00	0.00	9,305	263.31	15.621	385.08
Jun2	76.29	8.32	71.54	13.53	3.73	37.60	33.94	0.00	71.54	0.00	0.00	8,641	258.08	13.509	309.02
Jul1	47.34	21.13	27.58	12.04	3.61	27.58	0.00	0.00	27.58	0.00	0.00	6,678	256.50	12.904	288.13
Jul2	16.04	13.70	2.47	15.39	3.61	0.00	2.47	0.00	2.47	0.00	0.00	0	257.81	13.401	305.26
Aug1	0.00	14.01	2.00	12.05	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	258.71	13.752	317.55
Aug2	0.00	26.35	2.00	14.10	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	259.85	14.200	333.48
Sep1	0.00	33.07	2.00	10.26	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	260.53	14.474	343.27
Sep2	0.00	24.32	2.00	6.80	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	260.90	14.622	348.57
Total	1,892 (MCM)	2,209 (MCM)	806 (MCM)	667 (MCM)	23.1 (MCM)	487.6 (MCM)	318.1 (MCM)	0.0 (MCM)	806 (MCM)	0 (tms)	0 (tms)	93.2 (GWh)			

Water Balance Simulation Result (23/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1988 - 1989

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													260.90	14.622	348.57
Oct1	0.00	28.73	2.00	6.03	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	261.19	14.743	352.91
Oct2	22.89	69.19	2.00	11.22	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	261.99	15.068	364.72
Nov1	63.96	105.14	2.00	21.58	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	263.57	15.731	389.16
Nov2	92.33	143.99	2.00	19.49	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	264.93	16.308	410.86
Dec1	106.66	100.84	6.12	17.99	3.74	0.00	6.12	0.00	6.12	0.00	0.00	0	265.80	16.698	425.33
Dec2	98.25	97.35	2.00	16.90	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	266.96	17.221	444.93
Jan1	93.60	223.36	2.00	36.56	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	269.43	18.363	488.81
Jan2	93.16	172.44	2.00	33.43	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	271.66	19.640	531.21
Feb1	81.62	240.06	2.00	36.00	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	273.77	20.955	574.01
Feb2	61.28	279.19	2.00	47.14	4.28	35.19	6.62	0.00	41.82	0.00	0.00	8,611	274.00	21.100	578.83
Mar1	53.84	343.62	2.00	32.09	4.13	31.09	0.00	0.00	31.09	0.00	0.00	8,945	274.00	21.100	578.83
Mar2	61.62	196.78	2.00	29.60	4.13	28.59	0.00	0.00	28.59	0.00	0.00	8,827	274.00	21.100	578.83
Apr1	94.09	79.81	15.03	26.56	4.20	25.54	0.00	0.00	25.54	0.00	0.00	7,440	274.00	21.100	578.83
Apr2	108.95	73.81	36.99	18.38	4.20	35.19	1.81	0.00	36.99	0.00	0.00	9,936	272.77	20.326	553.35
May1	90.18	18.12	75.84	16.24	3.87	37.60	38.24	0.00	75.84	0.00	0.00	9,629	268.66	18.006	474.94
May2	87.44	24.01	66.76	17.78	3.87	37.60	29.16	0.00	66.76	0.00	0.00	10,008	264.64	16.183	406.11
Jun1	89.20	57.33	33.55	27.84	3.73	33.55	0.00	0.00	33.55	0.00	0.00	8,666	264.12	15.962	397.80
Jun2	76.29	19.08	60.22	2.83	3.73	37.60	22.62	0.00	60.22	0.00	0.00	8,960	259.07	13.893	322.52
Jul1	47.34	21.64	27.05	2.82	3.61	27.05	0.00	0.00	27.05	0.00	0.00	6,603	256.69	12.969	290.38
Jul2	16.04	18.00	2.00	2.90	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	256.72	12.984	290.87
Aug1	0.00	12.06	2.00	1.12	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	256.57	12.930	289.03
Aug2	0.00	15.87	2.00	6.93	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	257.04	13.107	295.10
Sep1	0.00	203.21	2.00	13.81	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	258.13	13.525	309.57
Sep2	0.00	6.83	2.00	13.17	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	259.12	13.911	323.19
Total	1,887 (MCM)	3,316 (MCM)	465 (MCM)	596 (MCM)	24.1 (MCM)	426.0 (MCM)	171.5 (MCM)	0.0 (MCM)	597 (MCM)	0 (tms)	0 (tms)	87.6 (GWh)			

Water Balance Simulation Result (24/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1989 - 1990

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													259.12	13.911	323.18
Oct1	0.00	29.85	2.00	6.07	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	259.44	14.036	327.62
Oct2	22.89	10.53	13.00	11.49	4.00	13.00	0.00	0.00	13.00	0.00	0.00	3,532	259.22	13.952	324.63
Nov1	63.96	18.99	47.34	3.75	4.13	37.60	9.74	0.00	47.34	0.00	0.00	8,673	254.85	12.285	267.26
Nov2	92.33	49.38	45.21	7.25	4.13	37.60	7.61	0.00	45.21	0.00	0.00	8,232	250.50	10.742	217.31
Dec1	106.66	139.83	2.00	14.52	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	251.93	11.236	232.93
Dec2	98.25	123.71	2.00	12.10	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	253.09	11.647	246.22
Jan1	93.60	126.16	2.00	26.76	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	255.65	12.596	277.68
Jan2	93.16	69.06	25.37	19.89	3.55	25.37	0.00	0.00	25.37	0.00	0.00	6,436	255.02	12.349	269.40
Feb1	81.62	294.15	2.00	42.66	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	258.98	13.858	321.30
Feb2	61.28	303.25	2.00	25.96	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	260.82	14.591	347.44
Mar1	53.84	201.58	2.00	25.01	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	262.75	15.385	376.36
Mar2	61.62	109.08	2.00	21.87	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	264.43	16.095	402.81
Apr1	94.09	36.11	61.03	21.49	4.20	37.60	23.43	0.00	61.03	0.00	0.00	9,068	261.03	14.677	350.55
Apr2	108.95	34.19	78.70	17.13	4.20	37.60	41.10	0.00	78.70	0.00	0.00	8,195	255.05	12.362	269.83
May1	90.18	54.37	37.69	17.31	3.87	37.60	0.09	0.00	37.69	0.00	0.00	8,459	252.78	11.539	242.70
May2	87.44	64.56	24.08	19.35	3.87	24.08	0.00	0.00	24.08	0.00	0.00	5,915	252.15	11.315	235.46
Jun1	89.20	33.58	58.55	15.33	3.73	37.19	21.36	0.00	58.55	0.00	0.00	7,600	246.70	9.504	178.81
Jun2	76.29	12.03	67.64	13.75	3.73	34.99	32.65	0.00	67.64	0.00	0.00	6,328	238.14	6.995	108.44
Jul1	47.34	23.59	24.99	13.75	3.61	24.99	0.00	0.00	24.99	0.00	0.00	4,634	235.90	6.400	93.48
Jul2	16.04	21.67	2.00	9.59	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	237.44	6.806	103.61
Aug1	0.00	37.46	2.00	9.39	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	238.76	7.165	112.83
Aug2	0.00	18.49	2.00	7.62	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	239.76	7.445	120.19
Sep1	0.00	38.18	2.00	9.63	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	241.00	7.794	129.59
Sep2	0.00	21.74	2.00	6.28	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	241.64	7.978	134.64
Total	1,887 (MCM)	2,409 (MCM)	666 (MCM)	494 (MCM)	16.5 (MCM)	455.9 (MCM)	210.3 (MCM)	0.0 (MCM)	666 (MCM)	0 (tms)	0 (tms)	77.1 (GWh)			

Water Balance Simulation Result (25/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1990 - 1991

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													241.64	7.978	134.64
Oct1	0.00	9.41	2.00	3.51	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	241.82	8.032	136.12
Oct2	22.89	17.65	5.51	3.61	4.00	0.00	5.51	0.00	5.51	0.00	0.00	0	241.43	7.918	132.99
Nov1	63.96	33.29	32.29	2.21	4.13	32.29	0.00	0.00	32.29	0.00	0.00	5,987	235.91	6.401	93.52
Nov2	92.33	22.98	73.00	7.66	4.13	0.00	73.00	0.00	73.00	0.00	0.00	0	213.75	1.571	8.44
Dec1	106.66	97.97	9.15	14.20	3.74	0.00	9.15	0.00	9.15	0.00	0.00	0	217.19	2.187	14.90
Dec2	98.25	169.96	2.00	23.78	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	226.67	4.192	44.88
Jan1	93.60	324.13	2.00	29.76	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	233.81	5.863	80.63
Jan2	93.16	395.51	2.00	21.89	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	238.04	6.970	107.79
Feb1	81.62	233.90	2.00	20.50	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	241.22	7.858	131.33
Feb2	61.28	202.04	2.00	15.21	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	242.99	8.374	145.73
Mar1	53.84	261.69	2.00	24.43	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	246.22	9.353	174.28
Mar2	61.62	360.24	2.00	32.24	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	250.33	10.682	215.45
Apr1	94.09	259.75	2.00	26.62	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	253.13	11.662	246.69
Apr2	108.95	188.81	2.00	23.96	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	255.42	12.499	274.42
May1	90.18	126.03	2.00	42.39	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	259.32	13.991	326.04
May2	87.44	41.61	48.24	26.63	3.87	37.60	10.64	0.00	48.24	0.00	0.00	9,371	257.05	13.112	295.29
Jun1	89.20	14.72	78.40	18.08	3.73	37.34	41.07	0.00	78.40	0.00	0.00	7,687	250.42	10.712	216.37
Jun2	76.29	10.02	69.75	13.51	3.73	35.96	33.79	0.00	69.75	0.00	0.00	6,870	242.65	8.274	142.89
Jul1	47.34	3.81	45.82	10.50	3.61	35.13	10.69	0.00	45.82	0.00	0.00	5,403	236.39	6.528	96.66
Jul2	16.04	8.58	7.85	8.34	3.61	7.85	0.00	0.00	7.85	0.00	0.00	1,592	236.44	6.541	96.96
Aug1	0.00	6.19	2.00	7.56	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	237.47	6.814	103.82
Aug2	0.00	3.83	2.00	7.19	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	238.44	7.079	110.60
Sep1	0.00	4.13	2.00	7.81	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	239.42	7.350	117.68
Sep2	0.00	6.09	2.00	2.99	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	239.53	7.381	118.49
Total	1,887 (MCM)	3,683 (MCM)	524 (MCM)	519 (MCM)	11.5 (MCM)	245.2 (MCM)	278.9 (MCM)	0.0 (MCM)	524 (MCM)	0 (tms)	0 (tms)	37.9 (GWh)			

Water Balance Simulation Result (26/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1991 - 1992

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													239.53	7.381	118.49
Oct1	0.00	4.52	2.00	3.36	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	239.71	7.431	119.81
Oct2	22.89	5.03	18.79	3.39	4.00	18.79	0.00	0.00	18.79	0.00	0.00	3,844	236.60	5.584	98.04
Nov1	63.96	10.07	56.73	6.96	4.13	32.11	24.62	0.00	56.73	0.00	0.00	4,891	223.62	3.520	33.13
Nov2	92.33	57.78	36.37	17.39	4.13	0.00	36.37	0.00	36.37	0.00	0.00	0	213.59	1.559	8.33
Dec1	106.65	154.46	2.00	25.29	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	225.05	3.252	38.43
Dec2	98.25	63.39	36.69	18.97	3.74	0.00	36.69	0.00	36.69	0.00	0.00	0	216.53	2.083	13.70
Jan1	93.60	234.04	2.00	21.70	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	225.24	3.889	39.11
Jan2	93.16	58.62	36.35	14.24	3.55	0.00	36.35	0.00	36.35	0.00	0.00	0	213.59	1.558	8.32
Feb1	81.62	294.84	2.00	32.95	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	227.47	4.369	48.33
Feb2	61.28	68.95	2.00	22.12	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	232.36	5.504	72.41
Mar1	53.84	139.67	2.00	60.19	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	243.20	8.436	147.47
Mar2	61.62	287.43	2.00	37.86	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	248.50	10.079	196.48
Apr1	94.09	122.70	2.00	36.68	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	252.62	11.480	240.80
Apr2	108.95	184.31	2.00	39.22	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	256.52	12.909	288.31
May1	90.18	181.87	2.00	29.53	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	259.12	13.913	323.23
May2	87.44	45.40	44.25	17.99	3.87	37.60	6.65	0.00	44.25	0.00	0.00	9,377	256.34	12.843	286.07
Jun1	89.20	27.67	64.77	13.64	3.73	37.60	27.17	0.00	64.77	0.00	0.00	8,002	250.67	10.799	219.09
Jun2	76.29	7.27	72.65	12.86	3.73	35.82	36.83	0.00	72.65	0.00	0.00	6,798	242.42	8.207	141.00
Jul1	47.34	34.58	13.43	15.60	3.61	13.43	0.00	0.00	13.43	0.00	0.00	2,771	242.71	8.291	143.37
Jul2	16.04	0.00	16.88	17.87	3.61	16.88	0.00	0.00	16.88	0.00	0.00	3,706	242.82	8.322	144.25
Aug1	0.00	12.06	2.00	13.25	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	244.47	8.815	158.39
Aug2	0.00	45.37	2.00	11.12	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	245.81	9.227	170.49
Sep1	0.00	105.28	2.00	11.84	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	247.10	9.630	182.65
Sep2	0.00	28.94	2.00	10.65	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	248.19	9.975	193.25
Total	1,892 (MCM)	2,856 (MCM)	564 (MCM)	650 (MCM)	10.8 (MCM)	255.5 (MCM)	308.6 (MCM)	0.0 (MCM)	564 (MCM)	0 (tms)	0 (tms)	39.4 (GWh)			

Water Balance Simulation Result (27/27)

Batutegi Dam Water Balance Simulation - Case : 2-80zh24
Year : 1992 - 1993

	IWD (CMS)	Qa (CMS)	DWD (CMS)	Qb (CMS)	Ev (mmd)	Qp (CMS)	Qi (CMS)	Spl (CMS)	Qt (CMS)	DEFi (%)	DEFm (%)	Pw (MWh)	WL (m)	A (km2)	V (MCM)
													248.18	9.975	193.25
Oct1	0.00	17.27	2.00	12.46	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	249.45	10.388	206.21
Oct2	22.89	23.61	2.00	12.07	4.00	0.00	2.00	0.00	2.00	0.00	0.00	0	250.70	10.811	219.46
Nov1	63.96	19.47	46.83	18.97	4.13	37.49	9.35	0.00	46.83	0.00	0.00	7,781	247.10	9.631	182.68
Nov2	92.33	14.11	82.34	20.19	4.13	34.10	48.24	0.00	82.34	0.00	0.00	5,856	237.13	6.724	101.55
Dec1	106.66	120.76	2.00	26.07	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	241.35	7.896	132.37
Dec2	98.25	122.72	2.00	28.80	3.74	0.00	2.00	0.00	2.00	0.00	0.00	0	245.64	9.175	168.94
Jan1	93.60	213.97	2.00	42.83	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	250.88	10.871	221.37
Jan2	93.16	259.16	2.00	32.43	3.55	0.00	2.00	0.00	2.00	0.00	0.00	0	254.48	12.152	262.81
Feb1	81.62	264.45	2.00	32.66	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	257.54	13.300	301.76
Feb2	61.28	136.18	2.00	32.17	4.28	0.00	2.00	0.00	2.00	0.00	0.00	0	259.95	14.240	334.91
Mar1	53.84	197.22	2.00	34.42	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	262.73	15.377	376.04
Mar2	61.62	112.81	2.00	35.64	4.13	0.00	2.00	0.00	2.00	0.00	0.00	0	265.58	16.596	421.53
Apr1	94.09	109.65	2.00	31.96	4.20	0.00	2.00	0.00	2.00	0.00	0.00	0	267.79	17.599	459.31
Apr2	108.95	72.28	38.61	34.14	4.20	37.60	1.01	0.00	38.61	0.00	0.00	9,925	267.39	17.418	452.41
May1	90.18	146.40	2.00	26.72	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	269.13	18.226	483.44
May2	87.44	91.69	2.00	25.61	3.87	0.00	2.00	0.00	2.00	0.00	0.00	0	270.82	19.129	514.96
Jun1	89.20	37.93	53.97	24.41	3.73	37.55	16.41	0.00	53.97	0.00	0.00	9,936	268.70	18.023	475.59
Jun2	76.29	9.57	70.23	15.25	3.73	37.60	32.63	0.00	70.23	0.00	0.00	9,304	264.46	16.109	403.33
Jul1	47.34	116.95	2.00	22.98	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	266.06	16.814	429.64
Jul2	16.04	82.99	2.00	31.78	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	268.38	17.874	469.84
Aug1	0.00	72.35	2.00	29.43	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	270.27	18.795	504.43
Aug2	0.00	68.61	2.00	26.45	3.61	0.00	2.00	0.00	2.00	0.00	0.00	0	271.96	19.825	537.15
Sep1	0.00	94.56	2.00	14.97	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	272.74	20.305	552.69
Sep2	0.00	48.16	2.00	13.26	4.27	0.00	2.00	0.00	2.00	0.00	0.00	0	273.39	20.711	565.98
Total	1,887 (MCM)	3,221 (MCM)	429 (MCM)	822 (MCM)	20.7 (MCM)	238.9 (MCM)	189.6 (MCM)	0.0 (MCM)	429 (MCM)	0 (tms)	0 (tms)	42.8 (GWh)			

APPENDIX B

CROP WATER REQUIREMENT

APPENDIX B

CROP WATER REQUIREMENT

CONTENTS

LIST OF TABLES

Table B.1 Reference Crop Evapotranspiration (ETo)

Station : Branti (C11)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
RH (%)	85	85	85	84	84	84	82	80	79	78	82	84
Tmax (°C)	30.5	31.0	31.6	31.9	31.9	31.6	31.3	31.7	32.3	32.6	32.0	31.2
Tmin (°C)	22.5	22.5	22.6	22.7	22.6	22.1	21.4	21.6	21.3	21.9	22.3	22.5
Tmean (°C)	25.9	26.0	26.2	26.5	26.4	26.1	25.6	25.6	26.0	26.5	26.4	26.2
Wind Run (km/day)	80.6	76.1	64.2	62.0	69.4	187.9	85.8	130.5	83.7	76.2	66.2	69.6
Sunshine (hr)	6.3	6.9	7.6	7.7	8.2	8.3	8.4	8.6	8.0	7.9	6.9	6.6
ea (mbar)	33.344	33.642	33.982	34.592	34.518	33.716	32.850	32.930	33.538	34.663	34.389	33.976
ed (mbar)	28.210	28.701	28.909	29.223	29.131	28.200	26.982	26.491	26.636	27.176	28.136	28.406
ea-ed (mbar)	5.133	4.941	5.073	5.369	5.387	5.516	5.868	6.439	6.903	7.487	6.254	5.571
f(u)	0.488	0.475	0.443	0.437	0.457	0.777	0.502	0.622	0.496	0.476	0.449	0.458
W	0.749	0.750	0.752	0.755	0.754	0.751	0.746	0.746	0.750	0.755	0.754	0.752
Ra (mm/day)	15.650	15.900	15.600	14.800	13.600	13.000	13.250	14.150	15.050	15.650	15.650	15.550
N (hr)	12.300	12.300	12.100	12.000	11.900	11.800	11.800	11.900	12.000	12.200	12.300	12.400
Rs (mm/day)	7.898	8.447	8.800	8.477	8.109	7.809	8.043	8.631	8.803	8.952	8.328	8.048
Rns (mm/day)	5.924	6.335	6.600	6.357	6.081	5.856	6.032	6.473	6.602	6.714	6.246	6.036
f(T)	15.866	15.904	15.936	15.994	15.987	15.911	15.801	15.812	15.892	16.001	15.975	15.936
f(ed)	0.106	0.104	0.103	0.102	0.103	0.106	0.111	0.114	0.113	0.111	0.107	0.105
f(n/N)	0.558	0.606	0.665	0.681	0.723	0.731	0.743	0.748	0.703	0.680	0.608	0.582
Rnl (mm/day)	0.942	1.005	1.097	1.112	1.185	1.237	1.308	1.343	1.261	1.203	1.035	0.978
Rn (mm/day)	4.982	5.330	5.503	5.245	4.896	4.619	4.725	5.131	5.341	5.511	5.211	5.058
ETo (mm/day)	4.58	4.81	4.93	4.76	4.51	4.76	4.49	5.09	5.10	5.28	4.85	4.66

Adjustment factor c is set at 1.05 .

Table 5*

Tmean	ea
20.0	23.4
21.0	24.9
22.0	26.4
23.0	28.1
24.0	29.8
25.0	31.7
26.0	33.6
27.0	35.7
28.0	37.8
29.0	40.1
30.0	42.4
31.0	44.9

Table 9*

Tmean	W
20.0	0.69
22.0	0.71
24.0	0.73
26.0	0.75
28.0	0.77
30.0	0.78

Table 13*

Tmean	Ra
20.0	14.6
22.0	15.0
24.0	15.4
26.0	15.9
28.0	16.3
30.0	16.7

* : FAO Irrigation and Drainage Paper 24, Crop Water Requirements

$ETo = c\,(W \cdot Rn + (1-W) \cdot f(u) \cdot (ea-ed))$

where,

ea : obtained by Tmean through Table 5*

$ed = ea \times RH/100$

$f(u) = 0.27\,(1 + U/100)$

U : Wind Run (km/day)

W : obtained by Tmean through Table 9*

Ra : obtained by latitude

N : obtained by latitude

$Rs = (0.25 + 0.50 \cdot n/N)$

n : Sunshine Hour

$Rns = (1 - 0.25) \cdot Rs$

f(T) : obtained by Tmean through Table 13*

$f(ed) = 0.34 - 0.44\ \mathrm{sqrt}(ed)$

$f(n/N) = 0.1 + 0.9\,n/N$

$Rnl = f(T) \cdot f(ed) \cdot f(n/N)$

$Rn = Rns - Rnl$

APPENDIX C

IRRIGATION WATER DEMAND

APPENDIX C

RESULT AND DISCUSSION

CONTENTS

LIST OF TABLE

TABLE C.1. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN I)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan I																								
Kc				0.5	1	1.08	1.15	1.15	0.58				0.5	1	1.08	1.15	1.15	0.58						
LP (mm/day)		6.92	13.52	6.76							6.79	13.79	6.89											
Etc (mm/day)				2.43	4.66	5.01	5.27	5.27	2.77				2.38	4.76	4.85	5.19	5.47	2.74						
P (mm/day)				1.75	3.5	3.5	3.5	3.5	1.75				2	4	4	4	4	2						
Re (mm/day)		0.33	1.27	1.51	1.14	1.72	1.51	1.4	0.87		1.35	3.68	1.6	0.51	0.68	0.48	0.3	0.09						
IWR	0	0.76	1.42	1.09	0.81	0.79	0.84	0.85	0.42	0	0.63	1.14	1.12	0.95	0.95	1.01	1.06	0.54	0	0	0	0	0	0
IDWR	0	1.17	2.18	1.68	1.25	1.21	1.29	1.31	0.65	0	0.97	1.76	1.72	1.47	1.45	1.55	1.63	0.83	0	0	0	0	0	0

TABLE C.1. Cont. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN II)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan II																								
Kc					0.5	1	1.08	1.15	1.15	0.58				0.5	1	1.08	1.15	1.15	0.58					
LP (mm/day)			6.76	13.52	6.69							6.79	13.79	6.89										
Etc (mm/day)					2.33	4.66	4.92	5.27	5.53	2.77				2.38	4.51	4.85	5.47	5.47	2.58					
P (mm/day)					1.75	3.5	3.5	3.5	3.5	1.75				2	4	4	4	4	2					
Re (mm/day)			0.64	2.12	1.9	1.72	1.51	1.4	1.75	0.6		1.84	2.24	0.86	0.68	0.48	0.3	0.18	0.06					
IWR	0	0	0.71	1.32	1.03	0.75	0.8	0.85	0.84	0.45	0	0.57	1.34	1.21	0.91	0.97	1.06	1.08	0.52	0	0	0	0	0
IDWR	0	0	1.09	2.03	1.56	1.15	1.23	1.31	1.3	0.7	0	0.88	2.06	1.86	1.39	1.49	1.63	1.66	0.81		0	0	0	0

TABLE C.1. Cont. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN IV)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan IV																								
Kc							0.5	1	1.08	1.15	1.15	0.58												
LP (mm/day)					6.69	13.38	6.66																	
Etc (mm/day)							2.29	4.58	5.17	5.53	5.67	2.83												
P (mm/day)							1.75	3.5	3.5	3.5	3.5	1.75												
Re (mm/day)					1.33	4.01	2.52	1.4	1.75	1.21	1.16	0.79												
IWR	0	0	0	0	0.62	1.08	0.95	0.77	0.8	0.91	0.93	0.44	0	0	0	0	0	0	0	0	0	0	0	0
IDWR	0	0	0	0	0.95	1.67	1.46	1.19	1.23	1.39	1.43	0.68	0	0	0	0	0	0	0	0	0	0	0	0

TABLE C.1 Cont. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN III)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan III																								
Kc						0.5	1	1.08	1.15	1.15	0.58				0.5	1	1.08	1.15	1.15	0.58				
LP (mm/day)				6.76	13.38	6.92							6.89	13.79	6.8									
Etc (mm/day)						2.33	4.58	4.92	5.53	5.53	2.83				2.26	4.51	5.12	5.47	5.16	2.58				
P (mm/day)						1.75	3.5	3.5	3.5	3.5	1.75				2	4	4	4	4	2				
Re (mm/day)				1.06	2.66	2.87	1.58	1.4	1.75	1.21	0.58		1.12	1.2	1.13	0.48	0.3	0.18	0.12	0				
IWR	0	0	0	0.66	1.24	0.91	0.76	0.81	0.84	0.91	0.46	0	0.67	1.46	1.15	0.93	1.02	1.08	1.05	0.53	0	0	0	0
IDWR	0	0	0	1.01	1.91	1.41	1.17	1.25	1.3	1.39	0.71	0	1.03	2.24	1.77	1.43	1.57	1.66	1.61	0.82	0	0	0	0

TABLE C.1. Cont. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN V)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan V																								
Kc								0.5	1	1.08	1.15	1.15	0.58											
LP (mm/day)						6.69	13.32	6.66																
Etc (mm/day)								2.29	4.81	5.17	5.67	5.67	2.74											
P (mm/day)								1.75	3.5	3.5	3.5	3.5	1.75											
Re (mm/day)						2.01	3.53	2.33	1.75	1.21	1.16	1.58	0.48											
IWR	0	0	0	0	0	0.54	1.13	0.97	0.76	0.86	0.93	0.88	0.49	0	0	0	0	0	0	0	0	0	0	0
IDWR	0	0	0	0	0	0.83	1.74	1.43	1.17	1.33	1.43	1.35	0.76	0	0	0	0	0	0	0	0	0	0	0

TABLE C.1.Cont. IRRIGATION DIVERSION WATER REQUIREMENT AT ARGOGURUH (GOLONGAN VI)

	Oct1	Oct2	Nov1	Nov2	Dec1	Dec2	Jan1	Jan2	Feb1	Feb2	Mar1	Mar2	Apr1	Apr2	May1	May2	Jun1	Jun2	Jul1	Jul2	Aug1	Aug2	Sep1	Sep2
Eto (mm/day)	5.28	5.28	4.85	4.85	4.66	4.66	4.58	4.58	4.81	4.81	4.93	4.93	4.76	4.76	4.51	4.51	4.76	4.76	4.49	4.49	5.09	5.09	5.1	5.1
P (mm/day)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
R80 (mm/day)	5	13.93	27.27	45.4	56.93	86	75.58	69.79	87.4	60.4	57.89	78.96	48	25.68	34	23.86	14.96	8.89	6	0	0	0	0	1
M (mm/day)	9.31	9.31	8.84	8.84	8.63	8.63	8.54	8.54	8.79	8.79	8.92	8.92	9.24	9.24	8.96	8.96	9.24	9.24	8.94	8.94	9.6	9.6	9.61	9.61
K (mm/day)	1.12	1.12	1.06	1.06	1.04	1.04	1.02	1.02	1.05	1.05	1.07	1.07	1.11	1.11	1.08	1.08	1.11	1.11	1.07	1.07	1.15	1.15	1.15	1.15
LP (mm/day)	13.84	13.84	13.52	13.52	13.38	13.38	13.32	13.32	13.49	13.49	13.58	13.58	13.79	13.79	13.6	13.6	13.79	13.79	13.59	13.59	14.03	14.03	14.01	14.01
Kc	1	1	1.15	1.15	1.15																			
Golongan VI																								
Kc									0.5	1	1.08	1.15	1.15	0.58										
LP (mm/day)							6.66	13.32	6.74															
Etc (mm/day)									2.41	4.81	5.3	5.67	5.47	2.74										
P (mm/day)									1.75	3.5	3.5	3.5	3.5	1.75										
Re (mm/day)							1.76	3.26	2.91	1.21	1.16	1.58	0.96	0.26										
IWR	0	0	0	0	0	0	0.57	1.16	0.92	0.82	0.88	0.88	0.99	0.52	0	0	0	0	0	0	0	0	0	0
IDWR	0	0	0	0	0	0	0.87	1.79	1.42	1.26	1.36	1.36	1.52	0.8	0	0	0	0	0	0	0	0	0	0

Table C.2: Required Water Allowance at Argoguruh Weir

Golongan	Water Allowance (in l/s/ha)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
I	0.59	1.93	1.23	1.3	0.33	1.37	1.6	1.5	1.23	0	0	0
II	0	1.56	1.37	1.27	1	0.44	1.96	1.44	1.65	0.41	0	0
III	0	0.51	1.66	1.21	1.35	0.36	1.64	1.6	1.63	1.22	0	0
IV	0	0	1.31	1.33	1.31	1.06	0	0	0	0	0	0
V	0	0	0.42	1.62	1.25	1.39	0.38	0	0	0	0	0
VI	0	0	0	1.33	1.34	1.36	1.16	0	0	0	0	0

Table C.3: Annual Water Requirement for Each Condition

Total Irrigation Area (Ha)	Crop Intensity	Direct Divertion in Wet Season	Direct Divertion in Dry Season	Irrigation Area Per Golongan					Annual Water Requirement in Weir (MCM)
				Gol. I	Gol. II	Gol. III	Gol. IV	Gol. V	
2	3	4	5	6	7	8	9	10	11
76789	160	68789	41273	13758	13758	13758	13758	13758	1568
76789	170	68789	48152	16051	16051	16051	10381	10381	1678
76789	180	68789	55031	18344	18344	18344	6879	6879	1788
76789	190	68789	61910	20637	20637	20637	3439	3439	1897
76789	200	68789	68789	22930	22930	22930	0	0	2007
81355	160	73355	44013	14671	14671	14671	14671	14671	1672
81355	170	73355	51349	17116	17116	17116	11003	11003	1789
81355	180	73355	58684	19561	19561	19561	7336	7336	1906
81355	190	73355	66020	22007	22007	22007	3668	3668	2023
81355	200	73355	73355	24452	24452	24452	0	0	2140
88565	160	77782	46669	15556	15556	15556	15556	15556	1773
88565	170	77782	5447	18149	18149	18149	11667	11667	1897
88565	180	77782	62226	20742	20742	20742	7778	7778	2021
88565	190	77782	70004	23335	23335	23335	3889	3889	2145
88565	200	77782	77782	25927	25927	25927	0	0	2270
94123	160	83340	50004	16668	16668	16668	16668	16668	1900
94123	170	83340	58338	19446	19446	19446	12501	12501	2033
94123	180	83340	66672	22224	22224	22224	8334	8334	2166
94123	190	83340	75006	25002	25002	25002	4167	4167	2299
94123	200	83340	83340	27780	27780	27780	0	0	2432

APPENDIX D

REFERENCE TABLES (FAO NO.33) FOR ETo CALCULATION

APPENDIX D
REFERENCE TABLES (FAO NO. 33) FOR CALCULATION
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Table 9 — Saturation Vapour Pressure (ea) in mbar as Function of Mean Air Temperature (T) in °C [1]

Temperature °C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ea mbar	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0	10.7	11.5	12.3	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6	22.0
Temperature °C	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
ea mbar	23.4	24.9	26.4	28.1	29.8	31.7	33.6	35.7	37.8	40.1	42.4	44.9	47.6	50.3	53.2	56.2	59.4	62.8	66.3	69.9

[1] Also actual vapour pressure (ed) can be obtained from this table using available Tdewpoint data. (Example: Tdewpoint is 18°C; ed is 20.6 mbar)

Table 10 — Extra-terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere													Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40°	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 11

Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Northern Latitudes	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Southern Latitudes	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9*	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Table 12

Effect of Temperature f(T) on Longwave Radiation (Rnl)

T^oC	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
$f(T) = \delta Tk^4$	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2	14.6	15.0	15.4	15.9	16.3*	16.7	17.2	17.7	18.1

Table 13

Effect of Vapour Pressure f(ed) on Longwave Radiation (Rnl)

ed mbar	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
$f(ed) = 0.34 - 0.044\sqrt{ed}$	0.23	.22	.20	.19	.18	.16	.15	.14	.13*	.12	.12	.11	.10	.09	.08	.08	.07	.06

Table 14

Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation (Rnl)

n/N	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
$f(n/N) = 0.1 + 0.9n/N$	0.10	.15	.19	.24	.28	.33	.37	.42	.46	.51	.55	.60	.64	.69	.73	.78	.82*	.87	.91	.96	1.0

Table 15 Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude m																				
0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77*	.78	.80	.82	.83	.84	.85
500	.45	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.88	.88	.89

Table 16 Adjustment Factor (c) in Presented Penman Equation

	RHmax = 30%				RHmax = 60%				RHmax = 90%			
Rs mm/day	3	6	9	12	3	6	9	12	3	6	9	12
Uday m/sec	Uday/Unight = 4.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
	Uday/Unight = 3.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
	Uday/Unight = 2.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
	Uday/Unight = 1.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.96