IMPROVEMENTS IN LONG TERM SIMULATION STUDY FOR RESERVOIR PLANNING

A DISSERTATION
Submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled " **IMPROVEMENTS IN LONG TERM SIMULATION STUDY FOR RESERVOIR PLANNING"**, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Water Resources Development (Civil), submitted in the Water Resources Development Training Centre, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period from July 15th 2002 to November 30th 2002 under the supervision of **Dr. U.C. Chaube**, Professor, WRDTC, Indian Institute of Technology Roorkee, Roorkee.

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

Date : December 2 , 2002
Place : Roorkee

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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Roorkee, December 2 ,2002

(AGUNG BUDI WASKITO)

ABSTRACT

Conventional procedures of reservoir planning were evolved considering limitations of data, computational facility and methods of analysis. With availability of computer technology and analytical tools, it is now possible to simulate long-term behaviour of reservoir under variety of conditions and make the reservoir planning more realistic as well as reliable. Even the preliminary reservoir design in prefeasibility stage can be made more realistic and informative. In this study, certain improvement for reservoir planning have been formulated and illustrated through a case study.

Preliminary Design

In the present study, Gould Gamma method and simulation procedure have been used for developing storage size-withdrawal-probability of failure relationship during preliminary design phase.

Analysis of Sediment Distribution

Standard type classification of a reservoir in the Area Reduction Method is not constant over entire project life. Due to change in standard type classification, sediment distribution pattern will also change and vice versa. Even if standard type classification does not change during a period, elevation–area–capacity curve will still undergo revision due to new zero elevation and due to the updated elevation–area–capacity curve at the beginning of the period. Therefore, progressive change in elevation–area–capacity relationship and consequent change in available live storage capacity have been considered in long-term simulation study of Batutegi reservoir.

Improvements in Hydropower Simulation Algorithm

Linear regression equations have been developed between a). *Initial and average elevation*, and b). *Initial area and average area* for different power targets to find net head for power generation and net gain/loss of water due to rainfall and evaporation over reservoir area. Further, net gain/loss have been considered to vary over entire simulation period due to random rainfall. Similarly, variation in power plant efficiency with turbine discharge has been accounted for in the simulation study.

Relationships between storage size, power generation (and annual energy generation) and dependability have been developed. Such studies provide useful information to work out trade off between storage capacity, power generation and reliability.

Improvements in Irrigation Simulation Algorithm

(i.) Alternate irrigation demand pattern related with different scenarios of target irrigation area and different cropping intensities have been considered. Irrigation release requirements at Batutegi reservoir vary from year to year also due to randomness of flow contribution from interim catchment between Batutegi reservoir and Argoguruh weir.

(ii.) The concept of *Golongan* (Group) system of irrigation has been introduced and applied to reduce peak irrigation demand. *In case of Batutegi project, peak demand has been reduces from 5003 m^3/month/ha to 3686 m^3/month/ha by staggering crop calendar over six groups of service area.*

(iii.) Storage capacity requirement have been worked out for different dependability levels of irrigation water utilization. Dependability has been analyzed on crop seasonal basis also, so as to give due to importance for planning irrigation in a particular season.

(iv.) Trade off between irrigation water supply and power generation at different reliability levels provide flexibility to a planner to choose a combination of irrigation supply and power generation at desired reliability levels.

Simulation algorithms :

(i.) An algorithm for a multipurpose reservoir (hydropower and irrigation) incorporating various improvements has been prepared (Figure 5.2).

(ii.) An algorithm for estimation of turbine flow and power generation with variable head loss and efficiency has been developed (Figure 4.4).

(iii.) An algorithm depicting application of reservoir operation rules for estimation of water release through power intake and through irrigation intake with irrigation priority has been developed (Figure 5.3).

Conclusions from case study of Batutegi reservoir are :

(i.) Installed Capacity greater than 16 MW is not necessary if only hydropower generation is considered.

(ii.) With same gross storage size (580 MCM), Installed Capacity (24 MW) and target irrigation area (condition VIII) as in project report, annual irrigation reliability by present study is 88%, which is higher than reliability of 75% considered in project report. A storage of 460 MCM is adequate to meet 75% irrigation reliability criteria.

(iii.) A cultivable area of 94,123 ha with 160% crop intensity (100% in wet season and 60% in dry season) can be served with 88% reliability in wet season, 96% reliability in dry season and 88% annual reliability. In addition, 96.5 GWh average annual energy (11 MW average power) will also be available.

CONTENTS

PAGE NO.

CHAPTER 1 : INTRODUCTION

CHAPTER 2 : PROGRESSIVE SILT DEPOSITION IN LIVE STORAGE

CHAPTER 3 : PRELIMINARY DESIGN OF RESERVOIR

CHAPTER 4 : IMPROVEMENTS IN SIMULATION STUDY FOR HYDROPOWER

CHAPTER 5 : RESERVOIR SIMULATION STUDY FOR IRRIGATION AND HYDROPOWER

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

NOTATIONS

S = Slope of the line obtained by plotting reservoir depth as ordinate and reservoir capacity as abscissa on log-log scale
M = Reciprocal of the type of reservoir (1 / S)
m = Standardized inflow
D = Draft expressed as a ratio of mean annual flow
$\bar{x}$ = Mean annual flow
s = Standard Deviation of annual flow
P_f = Probability of failure
n_f = Time the reservoir is unable to meet the full demand
n = Total time period
R_f = Reliability
R_v = Volumetric reliability
V_s = Volume of water supplied
V_d = Volume of water demand
$q_{n,p}$ = n year flow with a probability of occurrence of p% that is, for p% of time n year flow $\leq q_{n,p}$
z_p = Standardized normal variant at p%
$C_{n,p}$ = Depletion of an initially full storage at end of an n year period during which time the n year flow ($q_{n,p}$) has a probability of occurrence of p%
D_n = Constant draft from the reservoir over n year
CP = Length of critical draw down period in years
Cv = Annual coefficient of variation
C = Maximum required storage in volume unit
τ = Maximum required storage expressed as a ratio of mean annual flow
$C\gamma$ = Storage volume in gamma unit
$Z\gamma$ = Required storage divided by mean annual flow in gamma unit
R_B = Mean annual runoff before reservoir simulation
P_B = Mean annual rainfall

ET_B = Mean annual evapotranspiration

R_A = Mean annual runoff after reservoir is filled

P_A = Mean annual rainfall

EO_A = Mean annual evaporation from the water surface

ΔE = Mean annual net evaporation loss

ΔSE = Amount that computed storage needs to be increased to account for the net reservoir evaporation loss

A_F = Surface area of the reservoir at full supply level

c = Constant

T = Total number of years of simulation

n = A particular month

t = A particular year

$C_{f(n)}$ = Monthly Capacity Factor

C_f = Annual Capacity Factor

Qb = Discharge at Batutegi Dam

Qk = Discharge at Kunyit

qi = Discharge through irrigation waterway

qp = Discharge through power tunnel

P = Power Generation

WL = Water level

η = Efficiency of turbine

H = Net head

WA = Gross Water Available

DWD = Irrigation Demand at Dam

G/L = Net Gain/Loss water from reservoir

IWS = Irrigation Water Supply

DSp = Dead Storage (below MDDL)

CHAPTER 1

INTRODUCTION

1.1. GENERAL

Design of storage capacity of a reservoir to meet a pattern of demand (within year and over the year) is often difficult task not only because of socio economic and physical constraints, but also due to stochastic variability of the inflow and multipurpose demand. Over estimation of the storage capacity may result in considerably high cost of the project, sometimes rendering the project to be uneconomical.

Irrigation and hydroelectric generation are the two major purposes for which a multipurpose reservoir project is generally taken up. Some of the concepts, basis and approach followed in planning for irrigation water supply and hydroelectric generation are given below. It is proposed to critically examine these and analyze some of the possible improvements, through a case study.

Hydro electric generation	Irrigation supply
1. Electricity can not be stored	1. Irrigation water can be stored
2. Production has to match with demand instant by instant	2. A few days mismatch between demand and supply is tolerable depending upon crop type
3. No normal way of constraining quantity of supply	3. Rotational delivery or *golongan* delivery is possible in case of inadequate water supply
4. Seasonal demand for power is widely divergent from pattern of river inflows	4. Irrigation demand is also widely divergent from pattern of river inflows
5. 90% dependability of power generation is the criteria	5. 75% dependability of water supply is the criteria
6. Storage helps in increasing head and dependable discharge	6. Storage helps in increasing dependable discharge

7. MDDL is based on silting and safe limit of operating head	7. MDDL is based on silting
8. Alternate sources for electricity supply possible through grid	8. No alternate source for irrigation water supply in project command if conjunctive use not planned
9. Water is a throughput for conversion of potential energy into electrical energy. No loss of water	9. Water is resource input for consumptive use, considerable loss of water
10. Benefit of hydropower are in terms of cost of alternate project for similar dependable energy/capacity and energy supplied to power grid	10. Benefit of irrigation are in terms of increased crop production, social welfare, self reliance in food crop production, etc.

In case of multipurpose development where major benefit is irrigation, the releases are made primarily in the interest of irrigation and power generation follows the pattern of irrigation. Normally, 75% dependability criteria on annual basis are being followed in the case of irrigation projects. Power benefits in such a year would be higher than in 90% year. It would be desirable to assess the power benefits corresponding to irrigation releases made in a 90% year also. Hence, in the case of multipurpose storage projects, studies should be carried out for different levels of dependability for irrigation and hydropower. Wherever possible, multipurpose storage projects should provide for specific releases in the interest of power or irrigation during periods, which are considered critical from the point of view of power generation or irrigation water supplies *(IWRS, 1999)*.

In a river basin interlinkages occur in different projects serving single or multipurposes. In addition, hydropower projects are part of a larger energy generation system comprising of thermal, nuclear and other power plants. Figure 1.1 shows the various interlinkages.

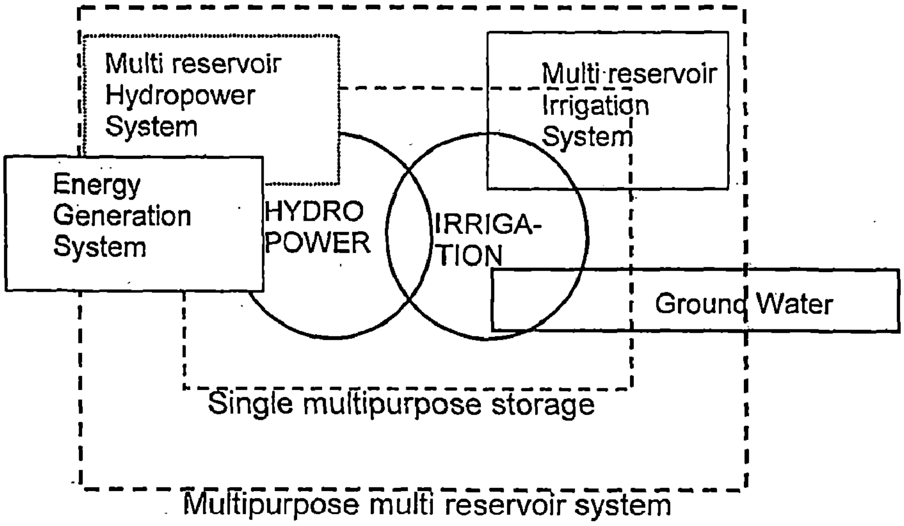


Fig. 1.1: Interlinkages in River Valley Projects

1.2. BACKGROUND

(i.) Hydrologic design of a multipurpose reservoir in terms of :

- storage capacity for conservative use
- provision of storage for silt deposition
- dependable power
- dependable irrigation water supply
- irrigation canal capacity, and
- dependable area of irrigation

should be based on long term simulation study of reservoir performance.

(ii.) In prefeasibility stage of a project, preliminary design of a reservoir is based on a critical sequence of dry years with several simplifying assumptions. However, even in the prefeasibility stage, some idea of storage-yield-reliability relationship is required, which is not possible if Rippl's mass curve method or sequent peak algorithm is used.

(iii.) During project life, storage capacity actually keeps on decreasing due to deposition of sediment. Deposition of sediment occurs not only in dead storage zone but also in live storage zone. Realistic estimation of sediment deposition pattern is of utmost importance for planning of water allocation to various purposes.

(iv.) Prevalent dependable criteria for irrigation and power planning are empirical in nature. It is necessary to carry out, planning studies for different levels of water utilization and for different levels of reliability both for irrigation and power generation.

(v.) Irrigation demand in conventional planning procedure is assumed to be constant over the period of simulation though its variation within a year is considered. It is well known that irrigation demand changes from year to year depending on change in cropping pattern, effective rainfall, reliability of water supply, physical performance of delivery system and other infrastructure development.

1.3. STUDY AREA

1.3.1 Batutegi Dam and Power Plant

The Batutegi dam site is located on the Sekampung River about 65 km upstream from Argoguruh weir where water is diverted for irrigation for the Way Sekampung service area in Central Lampung District of Lampung Province in Indonesia. The site is about 2 km downstream from where the Sangharus river joins the Sekampung river. The service area is shown in Figure 1.2 and schematic configuration of the project is presented on Figure 1.3.

The primary function of Batutegi dam and appurtenances is to store and regulate the flow of the Way Sekampung (CA. 424 km^2) during the wet season for use in the irrigation service area of about 75,500 ha during the dry season. Secondary function is for power generation (2 x 12 MW). Batutegi Dam would be basically a rockfill dam with height of 113 m above river bed, capacity of 500 Mm^3. Power plant will provide firm supply only during irrigation season after bay location and therefore peaking power will not produced.

1.3.2 Argoguruh Weir and Irrigation System

Way Sekampung irrigation area lies in Central Lampung District of Lampung Province, Sumatera. The gross area is around 124,780 ha and the irrigation water is taken at Argoguruh weir, some 65 km downstream from Batutegi dam, and conveyed to fields through Feeder-I and II canals, primary canals, secondary canals and tertiary canals.

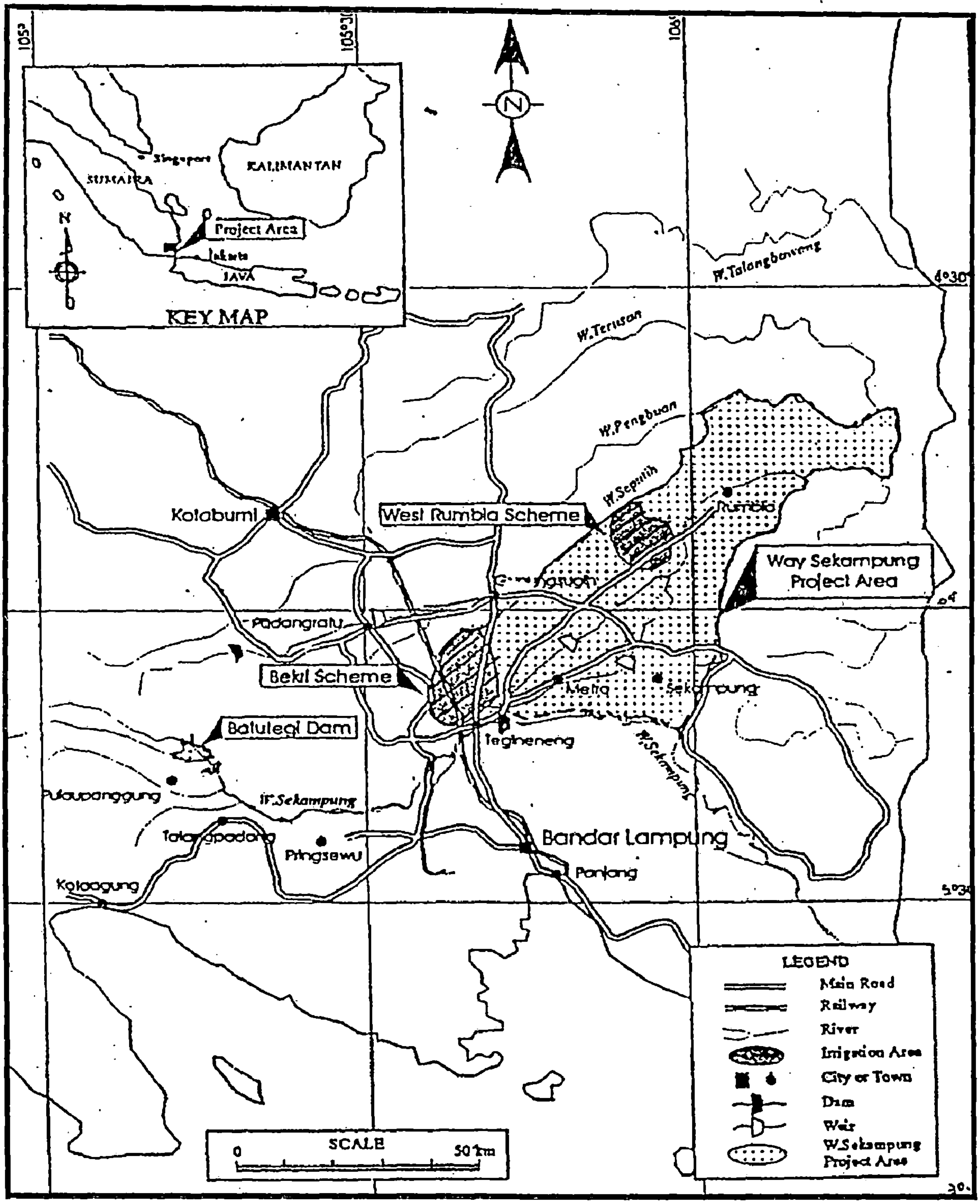


Fig. 1.2 : Location Map of Batutegi Dam and Way Sekampung Irrigation Scheme

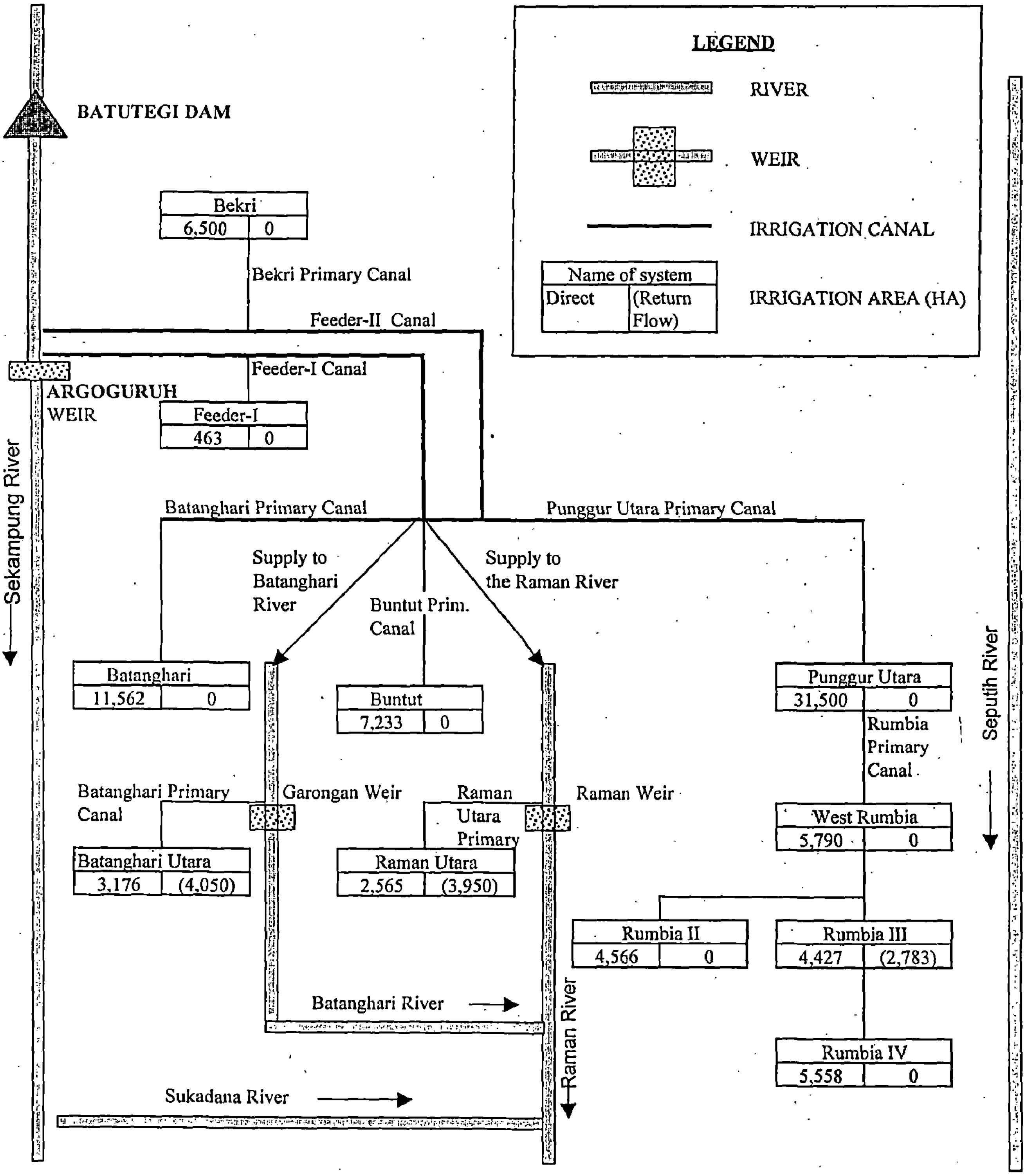


Figure 1.3 : Schematic Layout of Way Sekampung Irrigation Area

In Batanghari and Raman Utara Irrigation schemes, irrigation water will be diverted from Feeder-I canal to natural streams and taken at weirs located downstream. Some areas, (6,900 ha at present) receive return flow from other irrigation scheme areas. The irrigation diagram is schematically presented in Figure 1.3.

1.4. OBJECTIVES OF THE STUDY

The main objective of the study is to formulate and apply more realistic simulation algorithms for analysis of reservoir behaviour on long-term basis. To meet the stated objective, following improvements are suggested, and analysis of the Batutegi dam and Way Sekampung Irrigation scheme of Lampung Province, Indonesia is proposed.

(i.) Analysis of deposition of sediment in storage zone to study the impact on elevation-area-capacity curve and reservoir behaviour using Empirical Area Reduction Method.

(ii.) Application of an appropriate preliminary design procedure to establish reservoir capacity-yield-reliability relationship.

(iii.) Identify and incorporate possible improvements in simulation study of a single reservoir considering irrigation and hydropower, as the main purposes.

1.5 SCOPE OF DISSERTATION WORK

I : It deals with the introduction of the issues and statement of the objective, scope, and the study area.

II : Review of silt deposition pattern in some reservoirs and analysis of progressive silt deposition in live storage using Empirical Area Reduction Method.

III : Definition of terms related to storage, yield, reliability and preliminary design using Gould Gamma method to develop storage-yield-reliability relationship for Batutegi reservoir.

IV : Critical review of planning approach and suggest improvements in long term simulation study for hydropower. Formulation of improved simulation algorithm incorporating *(i) revision of elevation-area-capacity curve at regular interval, (ii) average area and average head adjustment, (iii) consideration of varying turbine efficiency, (iv) group rotation for reducing peak irrigation demand, (v) evaluation of time reliability, seasonal reliability and annual reliability.*

V : Simulation study of irrigation and hydropower and reliability analysis for hydropower and irrigation as single purposes and as joint multipurpose of a reservoir.

CHAPTER 2

PROGRESSIVE SILT DEPOSITION IN LIVE STORAGE

2.1 INTRODUCTION

The sediment deposition in the reservoir is a complex process and results in reduction of storage capacity, increase in backwater levels in head reaches, raising of floods levels, choking of irrigation, navigation and power outlets and formation of islands. For long term planning of efficient utilization of reservoir capacity, mere estimation of total sediment is not sufficient. More important is the estimation of trapped sediment at different levels in the reservoir. The sediment accumulation in storage zone has direct effect on allocation of storage volumes for irrigation, power, flood moderation and industrial and municipal water supplies. Therefore, realistic estimation of sediment deposition pattern in the reservoir is of utmost importance for long term planning of water volume allocations.

The sediment deposition in a reservoir is governed by factors such as longitudinal and lateral valley slopes, length and shape of the reservoir, grain size distribution of sediment, flow patterns in the reservoir, capacity/inflow ratio and mode of reservoir operation. The process of sedimentation in the reservoir is three dimensional in nature. Use of three dimensional mathematical models to predict sedimentation patterns is still restricted due to complexity of sedimentation process, exhaustive data requirement, uncertainties and difficulties in realistic assessment of parameters such as bed friction, diffusion coefficient, bed and suspended sediment transport rates *(Kulkarni and Deshmukh, 1997)*. However, use of one and two-dimensional models is being made with due consideration to the limitations of such models to simulate the complex process.

Among the empirical methods of estimation of sediment accumulation and distribution, the Area Reduction Method proposed by *Borland and Miller (1958)* is most suitable and widely used on account of its simplicity and minimum data requirement. The 'Reservoir Sediment Committee' appointed by the Government of India had also recommended use of this method *(Government of India, 1985).*

2.2 EMPIRICAL AREA REDUCTION METHOD

This method proposed by *Borland and Miller (1958)* of USBR is based on the hypothesis that there exists a definite relationship between the shape of the reservoir and the percentage of the sediment volume deposited up to various depths of a reservoir. They analyzed deposition patterns of more than 40 reservoirs in USA with capacities ranging from 492 million ha m to 1.6 million ha m. These reservoirs varied in location, catchment characteristics and operation schedules. The reservoirs are classified into four types. The reciprocal (M) of the slope (S) of the line obtained by plotting reservoir depth as ordinate and reservoir capacity as abscissa on log-log scale is used as key to decide the reservoir type as per Table 2.1.

Table 2.1 : Evaluation of Reservoir Type

M	Reservoir Type	Standard Type
3.5 and above	Lake I	I
2.5 to 3.5	Flood plain, foot hill	II
1.5 to 2.5	Hill	III
1.0 to 1.5	Gorge	IV

For each of the above type, sediment storage and area design curve (Fig. 2.1 and Fig. 2.2) were developed using observed data of the reservoirs. From these curves or the equations representing the curves, the sediment deposition at various levels could be computed. Theory and details of computational procedure are presented by *Borland and Miller (1958) and Murthy (1977).* The method for determining the sediment distribution is given below in brief:

(i.) From catchment area, siltation index (sediment volume/unit area/year) and period for sediment deposition, total sediment yield is computed. Siltation index could be available from earlier hydrographic surveys or from isoerodant maps of the region derived by *Garde and Kothyari (1985).*

(ii.) From the trap efficiency of the reservoir as defined by *Brune (1953)* and total sediment yield, sediment volume likely to be deposited in reservoir is computed.

(iii.) The reservoir type and corresponding deposition pattern can be determined by plotting depth-capacity relation.

(iv.) Take suitable interval (2 m to 5 m) and find the levels over the total depth at dam (up to FRL). Compute relative depth at different levels starting from FRL to riverbed.

$$\text{Relative depth} \quad \frac{\text{Depth above riverbed at any elevation}}{\text{Total depth at dam (FRL – bed level)}}$$

(v.) For these relative depths, compute relative sediment area factor 'a' using appropriate type of curve.

(vi.) Assume a new bed level (ho) near the dam after siltation. Compute reservoir area, capacity, relative depth and factor 'a' at level 'ho', compute 'K' as

$$K = \frac{\text{Area at level (ho)}}{\text{'a' at level (ho)}}$$

(vii.) Multiply 'a' at each level computed in step (v) by 'K' to obtain sediment area at each level.

(viii.) Compute the sediment volume deposited between two successive levels and cumulative sediment volume deposited below each level.

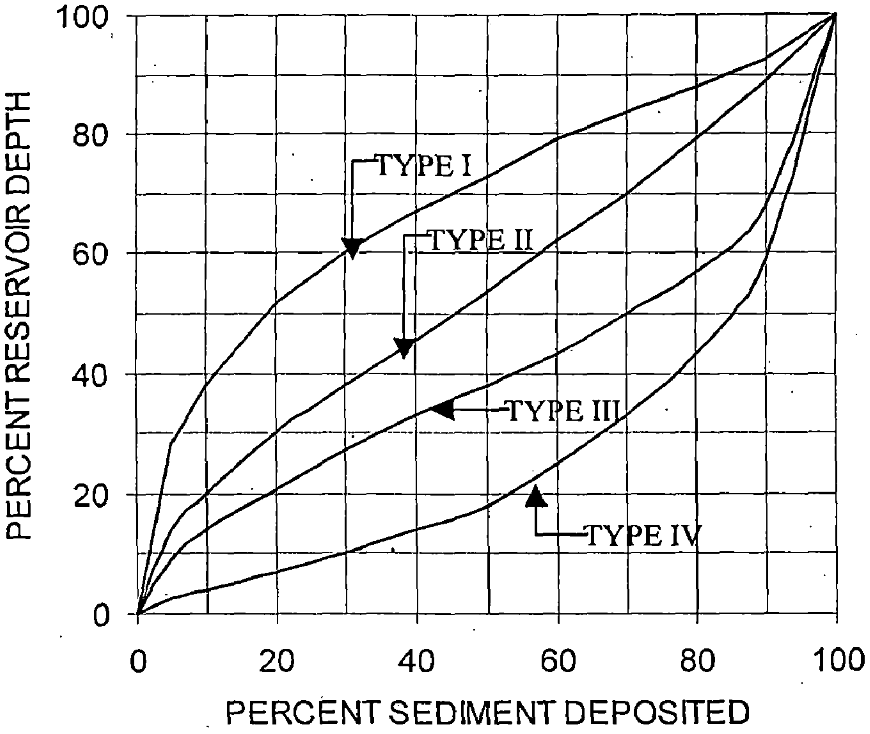


Fig. 2.1 : Type Curves as per Borland and Miller

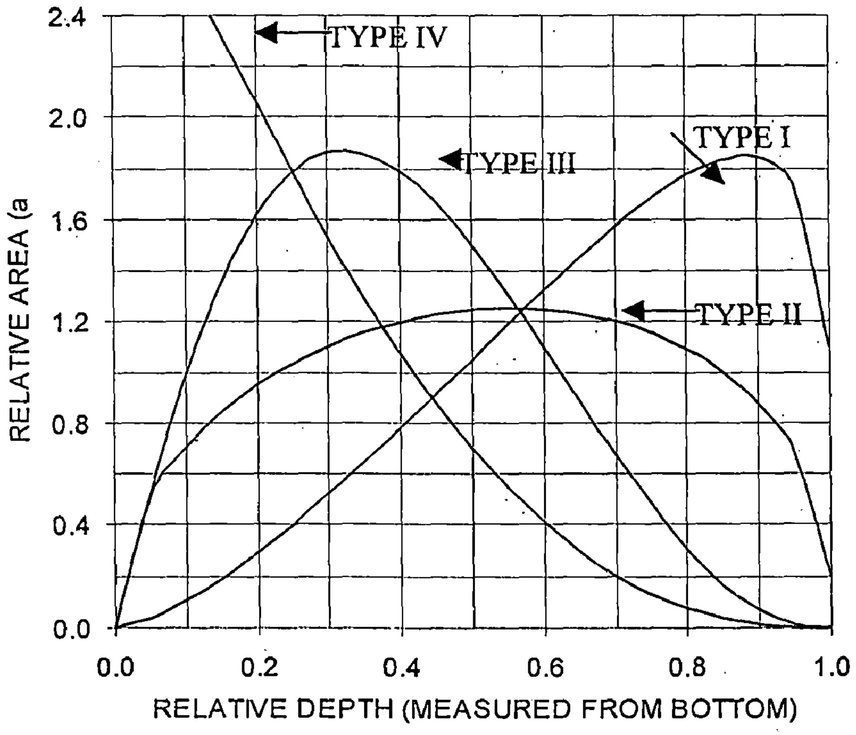


Fig. 2.2 : Area Design Curves

(ix.) If computed sediment volume below FRL or highest water level is equal to the total sediment volume likely to be deposited (computed in step (ii) in assumed duration), stop the computations. Else, assume a new value of 'ho' and repeat steps (vi) to (ix) till the above condition is satisfied.

(x.) Compute revised elevation–area–capacity relations by deducting sediment area and volume from initial area and volume at respective levels.

The computations by Area Reduction Method need following basic input data:

- elevation – area – capacity curves
- sediment yield/unit of catchment area/cathment area year (siltation index)
- trap efficiency of reservoir
- period for prediction (years)
- deepest riverbed level near the dam

2.3 DISCREPANCIES IN PREDICTED AND OBSERVED DEPOSITION PATTERNS FOR SOME RESERVOIRS

Kulkarni and Deshmukh (1947) studied the observed sediment deposition patterns of Bhakra, Gandhisagar, Pagara, Panchet, Maithon and Tungabhadra reservoirs in India to check how far these reservoirs behaved differently from the standard deposition patterns indicated by Area Reduction Method.

Fig. 2.3 and Fig. 2.4 show depth capacity curves for Gandhisagar and Pagara reservoirs of Chambal project respectively. As per criteria of *Borland and Miller*, the Gandhisagar and Pagara reservoirs fall under Type I (i.e. lake) and major part of sediment, nearly 50% of sediment trapped in the reservoir should settle in upper 30% depth i.e. in live storage. However, the hydrographic survey of the reservoir in 1975 (15 years after filling of reservoir) indicated that only 30 % of incoming sediment was deposited in upper 30% portion. This pattern matches with Type II. Fig.2.5 shows that the observed data closely match with the computed elevation-capacity curve assuming Type II.

From Fig. 2.4 also, it is seen that the Pagara reservoir falls under Type III. However, the hydrographic survey carried out in 1982 (55 years after construction of dam in 1927) revealed that the deposition pattern was close to Type IV. Figure 2.6 shows close agreement of computed elevation capacity curve (assuming reservoir as Type IV) with the observed data.

The observed deposition pattern of Bhakra, Maithon, Panchet, Gandhisagar and Tungabhadra reservoirs are superimposed on the four standard deposition patterns (as per *Borland and Miller, 1958*) in Fig. 2.7. Table 2.2 summarizes observations made from Fig. 2.7.

It is seen that none of the reservoirs totally behaves as per type estimated by the standard procedure given in Area Reduction Method. Underestimation in dead storage may effect operation of hydropower plants due to entry of sediment into penstock. It is also seen from Fig. 2.7 that some reservoirs like Bhakra and Gandhisagar behave as per different types at different depths. This shows that adoption of only single type of deposition pattern to such reservoirs can lead to errors in estimation of sediment deposition patterns. It is also useful to know actual deposition pattern and shift in it, if any, with respect to time. Fig. 2.8 shows how the Maithon reservoir deposition pattern shifted from Type II to Type I during the period 1963 to 1994.

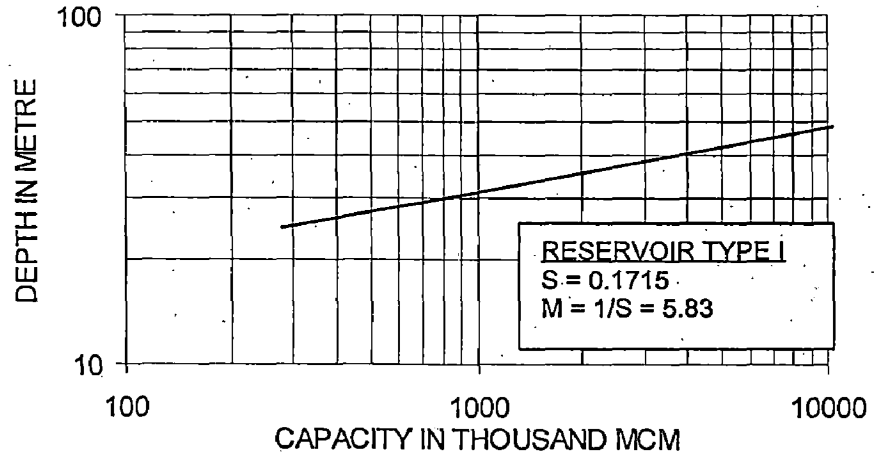


Fig. 2.3 : Depth – Capacity Curve for Gandhisagar

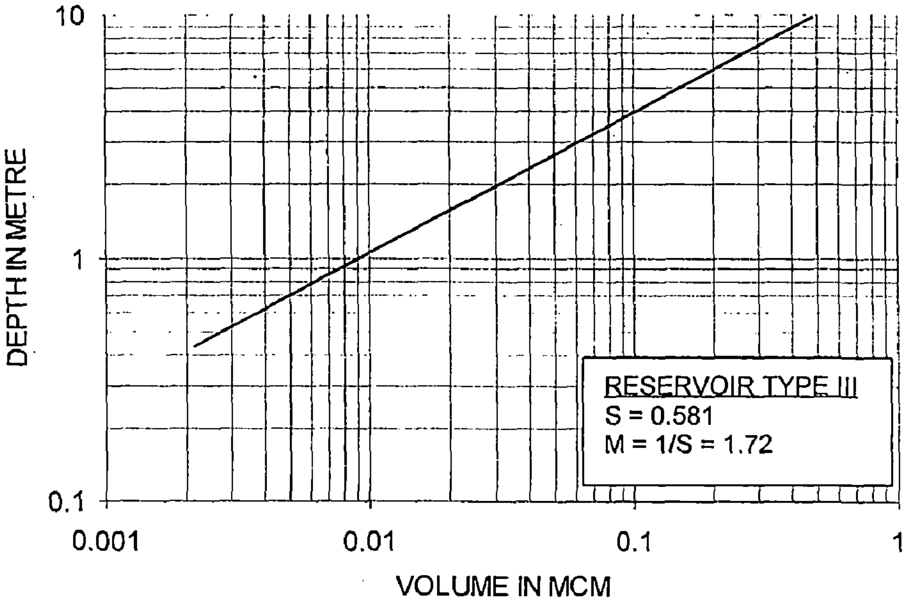


Fig. 2.4 : Depth – Volume Relation for Pagara Reservoir

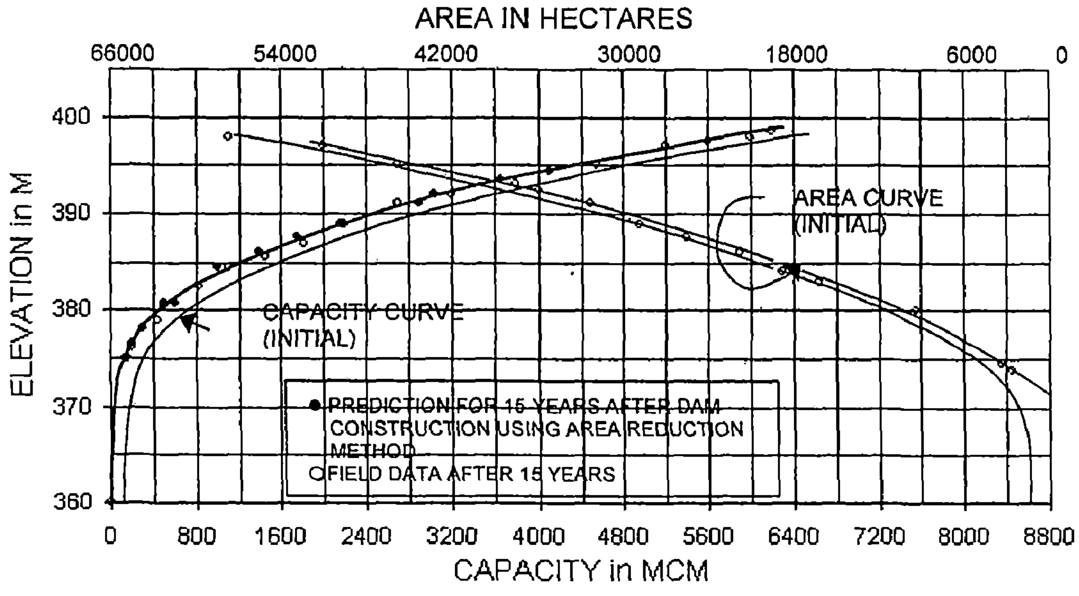


Fig. 2.5 : Predicted and Observed Area Capacity Curves for Gandhisagar

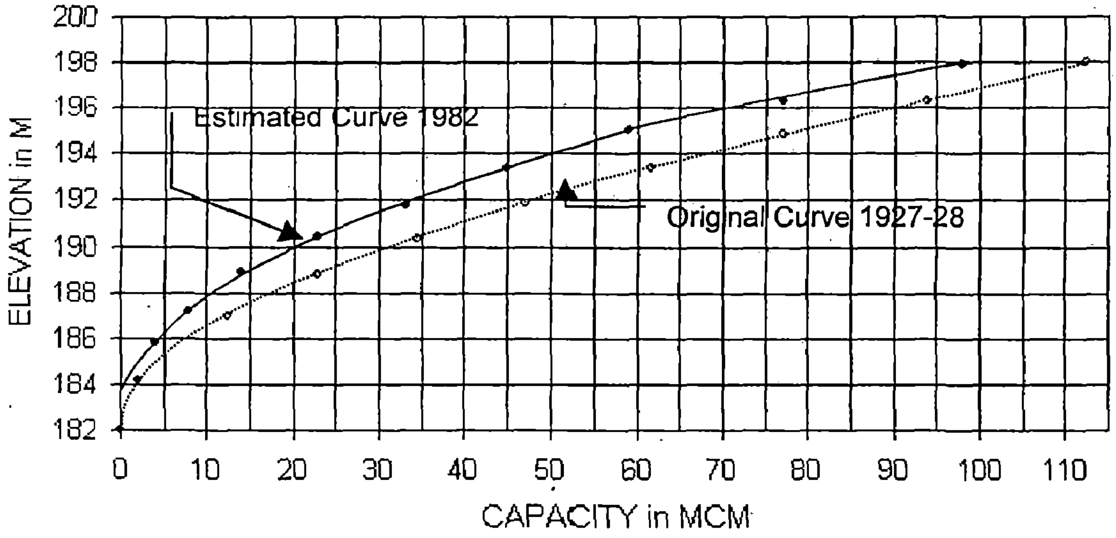


Fig. 2.6 : Predicted and Observed Capacity Curves for Pagara Reservoir

Table 2.2 : Comparison of Observed and Standard Types of Reservoirs

Reservoir	Type as per Borland and Miller	Type as per field data	Effect of adopting type as per *Borland and Miller*
Bhakra	III	I to III	Underestimation of deposition in live storage zone
Gandhisagar	I	I to III	Overestimation of siltation in live storage zone
Panchet	II	I	Underestimation of siltation in live storage zone
Maithon	II	I	Underestimation of siltation in live storage zone
Tungabhadra	I	II to III	Overestimation of siltation in live storage zone

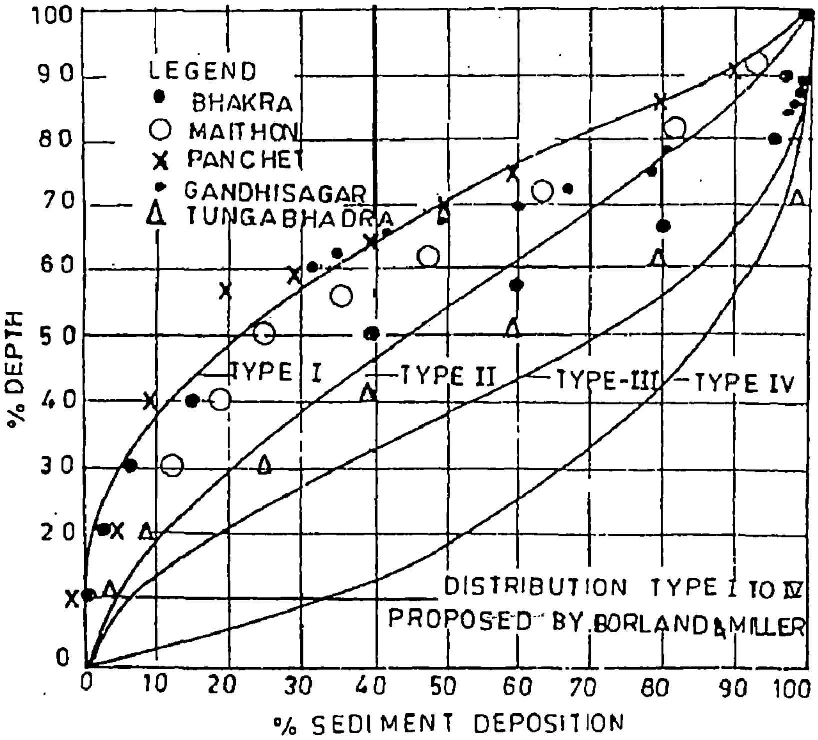


Fig. 2.7 : Comparison of Observed Deposition Patterns with Standard Type

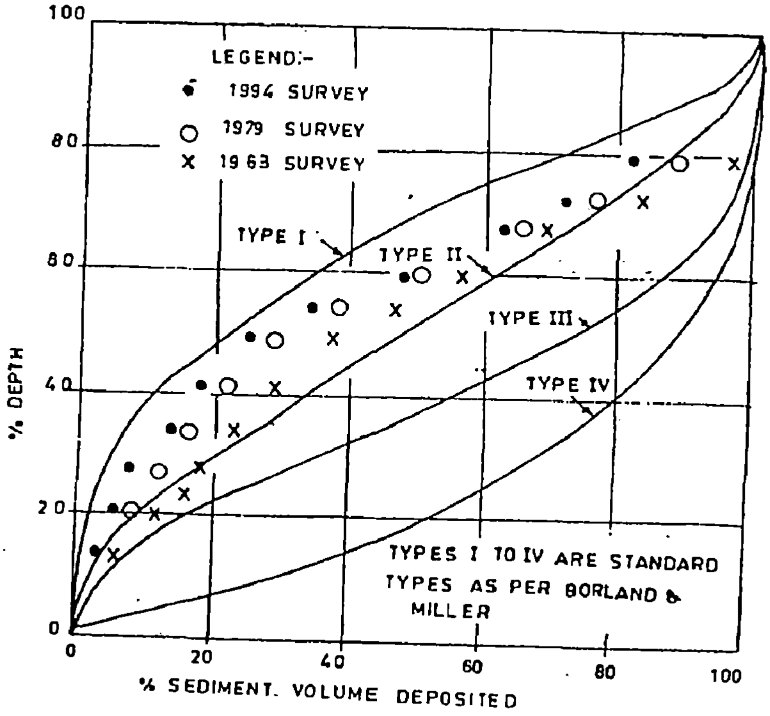


Fig. 2.8 : Progressive Changes in Deposition Patterns of Maithon Reservoir

It is obvious that each reservoir will have its own deposition patterns. In reality, the reservoirs may have mixed characteristics of 2 or more standard types. Other factors such as grain size distribution of sediment reservoir operation pattern, nature of inflow flood hydrograph, trap efficiency of the reservoir, initial water level at the time of arrival of the flood etc. affect directly or indirectly the deposition pattern in the reservoir. For example, if the reservoir is at MDDL at the time of arrival of first flood then not only the incoming sediment but also part of the sediment deposited in live storage will also be carried and deposited into dead storage zone. But with same flood and reservoir at FRL the most of the incoming sediment will be deposited in live storage. Thus, the entire process becomes complex due to large number of governing factors.

2.4 STUDY OF SEDIMENT DISTRIBUTION IN BATUTEGI RESERVOIR

In conventional simulation study the elevation–area–capacity curve as anticipated after half of project life is first derived using Area Reduction Method (or any other appropriate method) and assumed to apply uniformly from first year up to end of project life in the simulation study.

With the availability of computer technology, it is now possible to revise elevation–area–capacity as regular interval say 5 to 10 years and incorporate revised relationship in the long term reservoir simulation study.

Case study of Batutegi Reservoir has been carried out to:

(i.) Evaluate change in standard reservoir type (if any) at 25 years interval, and

(ii.) Compute and compare elevation–area–capacity curves for variation conditions (original, revised after 25 years, 50 years, 75 years and 100 years).

Analysis of Change in Standard Type Classification

The depth-capacity plots based on original elevation–area–capacity curve indicate M = 2.87 i.e. Type II reservoir as shown in Fig. 2.9. Area Reduction

Method is used to obtain revised elevation–area–capacity relation after 25 years. Sediment deposition computation is shown in Table 2.4.

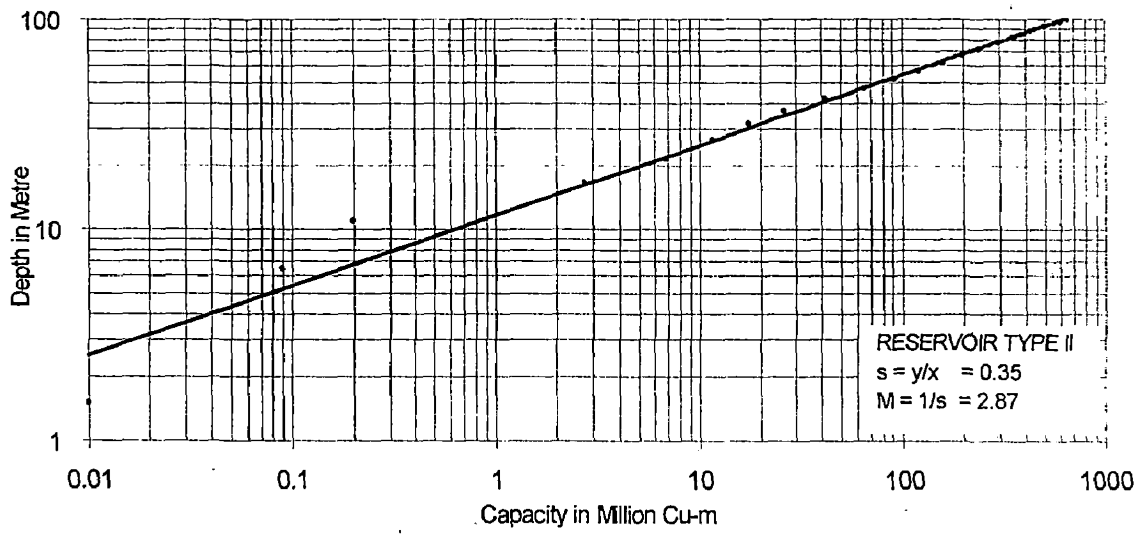


Fig. 2.9 : Original Depth-Volume Relation for Batutegi Reservoir

For next 25 years this revised elevation–area–capacity relationship is used as original elevation–area–capacity curve and M is computed (M = 2.52). Depth –capacity relation is shown in Fig. 2.10. The reservoir is still Type II reservoir.

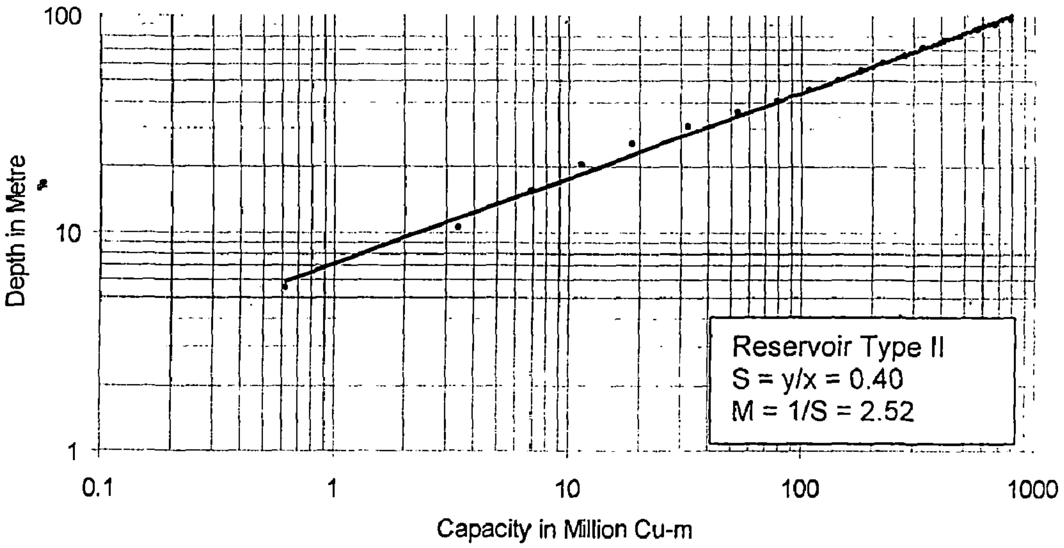


Fig. 2.10 : Depth-Volume Relation Revised After 25 Years – Batutegi Reservoir

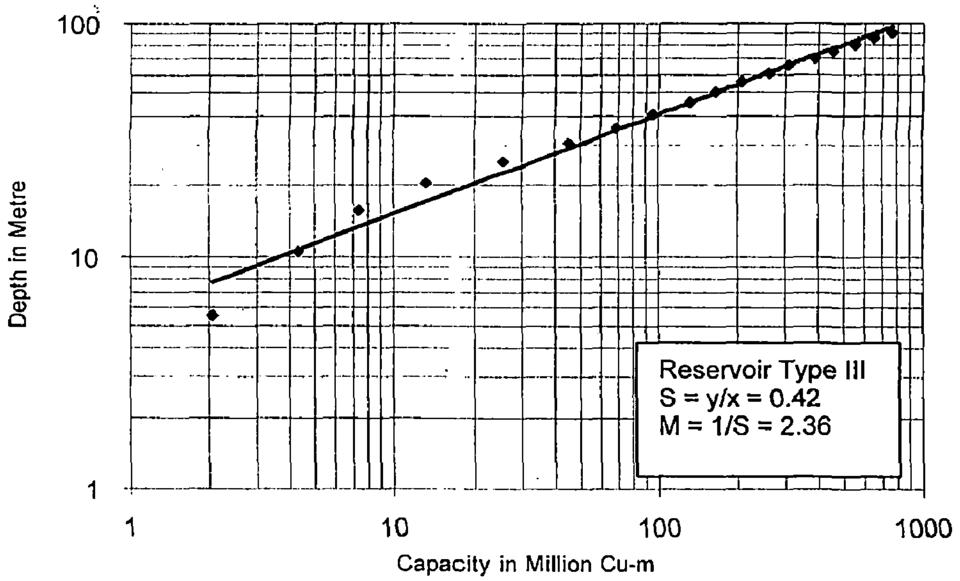


Fig. 2.11 : Depth-Volume Relation Revised After 50 Years – Batutegi Reservoir

For next 25 years i.e. from 51st to 75th years, same procedure is repeated. Computed M is 2.36 as shown by depth–capacity relation (Fig. 2.11). Now, reservoir becomes Type III.

For the next 25 years i.e. 76th to 100th year, computed M is 2.55 i.e. reservoir becomes Type II again. Fig. 2.12 shows depth–capacity relation.

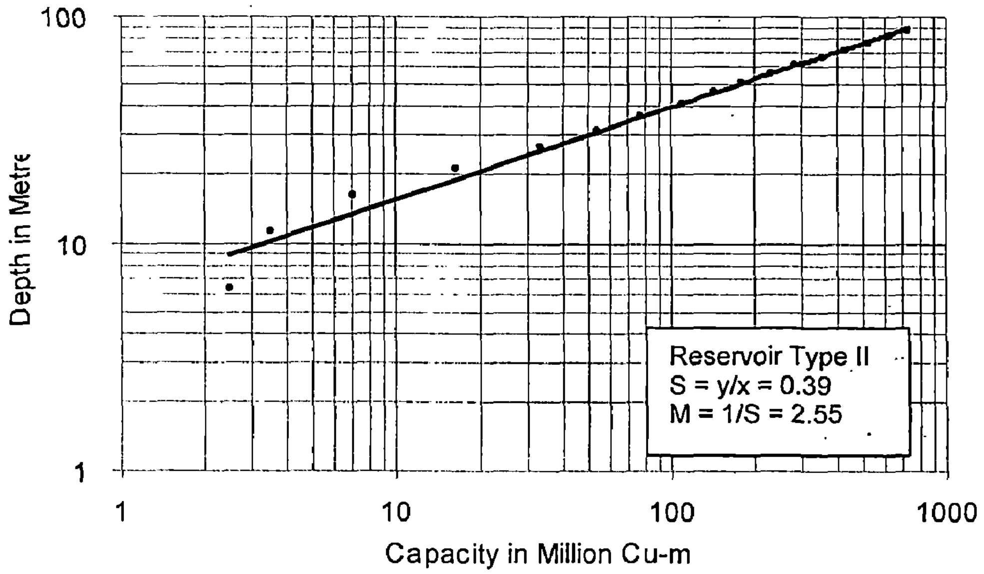


Fig. 2.12 : Depth-Volume Relation Revised After 75 Years – Batutegi Reservoir

After 100 years, M value is 2.56 indicating Type II reservoir as shown by depth – capacity relation in Fig. 2.13. If every 25 years change is not considered, then M value is 2.39 i.e. Type III reservoir (Fig. 2.14). This value is obtained directly from original curve (based on initial M value = 2.87 and initial zero elevation = elevation of stream bed) revised to curve after 100 years without considering change in every 25 years.

Table 2.4 shows the computation of revision in elevation-area-capacity relation after 25 years. Computation of revision in elevation-area-capacity relation after 50 years, 75 years and 100 years are calculated by similar procedure as in Table 2.4, as shown in Appendix 1.

Table 2.3 shows M value, reservoir type and new zero elevation during 100 years project life. Fig. 2.15 shows variation in M value and Fig. 2.16 shows variation in new zero elevation.

Elevation–area–capacity curves are compared in Fig. 2.17. Also, it is compared with estimated sediment pattern after 100 years as given in project report in Fig. 2.18.

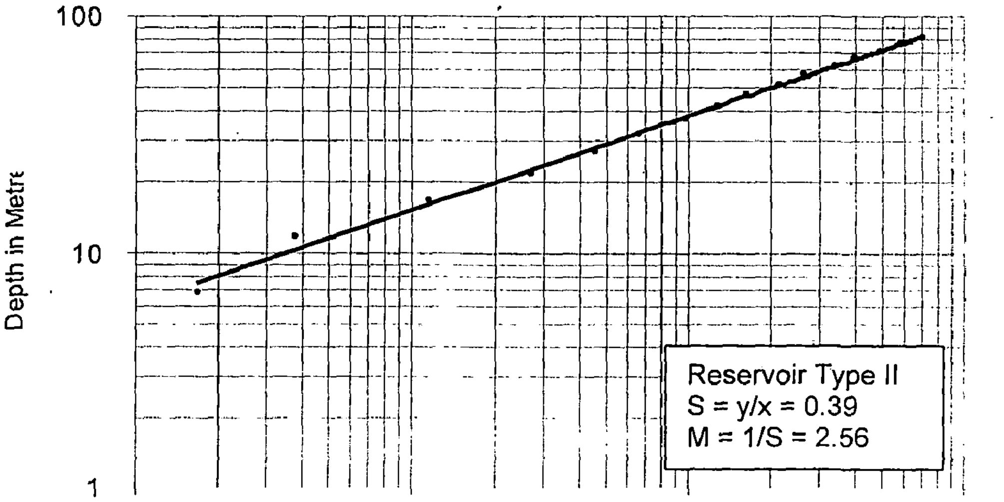


Fig. 2.13 : Depth-Volume Relation Revised After 100 Years – Batutegi Reservoir

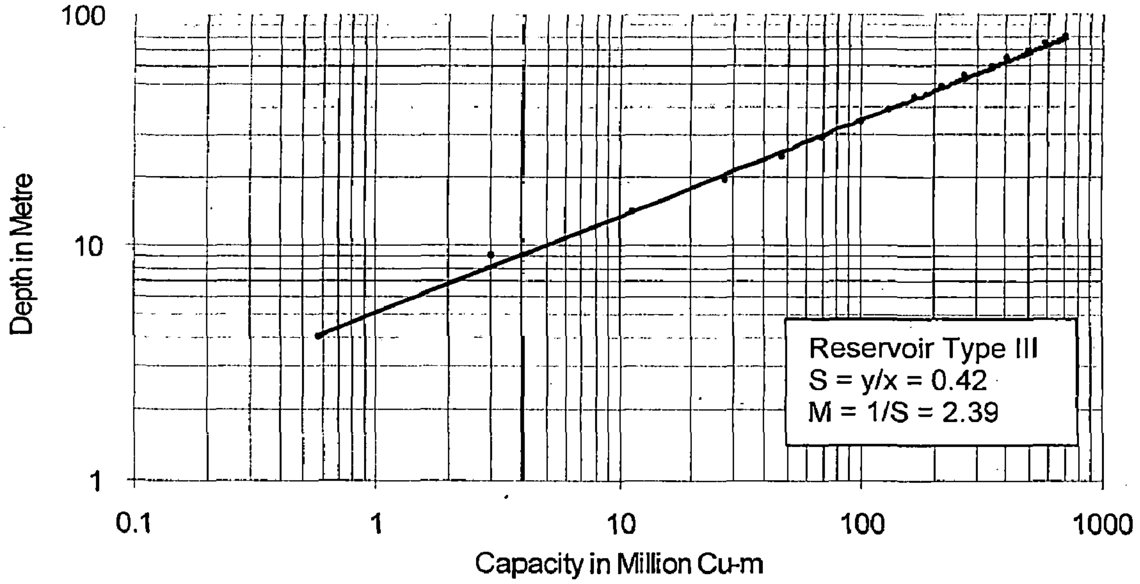


Fig. 2.14 : Depth-Volume Relation Revised After 100 Years Without Change Every 25 Years– Batutegi Reservoir

Table 2.3. M Value, Reservoir Type and New Zero Elevation during 100 years

Elevation Area Capacity Curve	M Value	Reservoir Type	Zero Elevation
Original Curve	2.87	II	173.50
Revised after 25 yr	2.52	II	184.50
Revised after 50 yr	2.36	III	189.50
Revised after 75 yr	2.55	II	193.75
Revised after 100 yr	2.56	II	198.25
Revised after 100 yr (if no change every 25 yr)	2.39	III	201.00

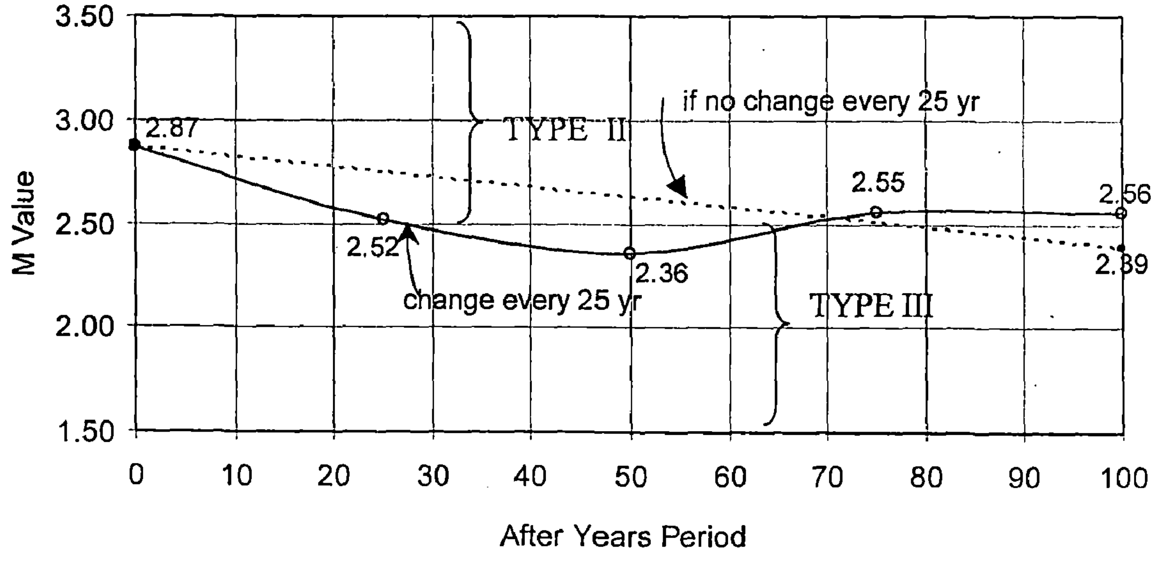


Fig. 2.15 : M Value Variation during 100 Years – Batutegi Reservoir

Table 2.3 and Figure 2.15 show the change in standard classification of reservoir and new zero elevation during 100 years period. Analysis shows that the standard classification of a reservoir is not constant. Based on original elevation-area-capacity curve, the standard classification of reservoir is Type II. This type is not constant during 100 years. Up to 25 years from beginning, it is Type II (same as in Project design), then it is Type III from 25 years to 75 years and again it just becomes Type II from 75 years to 100 years.

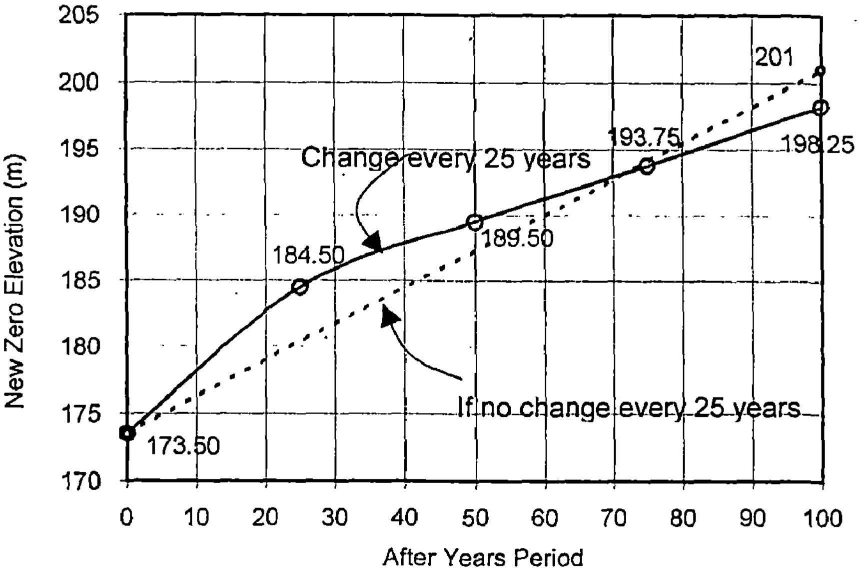


Fig. 2.16 : New Zero Elevation during 100 years – Batutegi Reservoir

Due to change in standard classification, the distribution pattern also changes. New zero elevation is revised based on change in elevation-area-capacity curve every 25 years. This study suggests that the new zero elevation will be at elevation 198.25 m after 100 years. Compared with the analysis in which standard classification is kept constant during 100 years, new zero elevation after 100 years will be at elevation 201 m. In other words, it means live storage capacity is expected to be more than proposed in project design over the project life.

Analysis of sediment distribution in the Batutegi reservoir by Area Reduction Method highlight the following important aspects:

(i.) Standard type classification of a reservoir is not constant over entire project life. Due to change in standard type classification, sediment distribution pattern will also change as per method of Borland and Miller. From beginning and up to 25 years, reservoir behaves as Type II (same as considered in project design) and then it is Type III from 25 years to 75 years and it just becomes Type II again from 75 years to 100 years. In otherwords, there is over estimation of siltation from 25 years to 75 years. Even if standard type classification does not change during a period, elevation–area–capacity curve will still undergo revision due to variation new zero elevation, it is therefore, necessary to consider progressive change in elevation–area–capacity relationship in long-term simulation study of a reservoir

(ii.) In the conventional procedure as followed in India, the reservoir would have been designed considering revised elevation-area-capacity curve obtained after sediment deposition during 50 years and assumed to apply uniformly over the entire project life (100 years). With the likely change in new zero elevation and elevation-area-capacity curve at regular interval say 25 years as shown in Fig. 2.16 and Fig. 2.17, the use of conventional procedure would result in underestimation or overestimation of silt deposition in different time interval.

Table 3.4. Computation for Sediment Distribution Pattern after 25 Years Based On M Value of Original Elevation-Capacity Curve by Area Reduction Method

Maximum Water Level = 280.0
Original Stream Bed Level = 173.5
Est. of Sediment Vol during 25 Y = 28.0 Mm^3

New Zero elevation = **184.50**
Area = 0.19 Km^2
Relative depth p = 0.10
Ap = 0.72
K = Area/Ap = 0.27

Sl No	Elevation (m)	Original area (Km^2)	Original capacity (Mm^3)	Depth (2)-173.5 (m)	Relative depth p (5)/106.5	Ap Type II	Sediment area Kap 0.27x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 1 area (3)-(8) (Km^2)	Revised 1 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.60	820.00	106.5	1.000	0.200	0.054	0.582	28.00	28.00	23.55	792.00
2	275.0	21.15	700.00	101.5	0.953	0.667	0.179	1.024	27.42	27.42	20.97	672.58
3	270.0	19.10	605.00	96.5	0.906	0.859	0.230	1.235	26.39	26.39	18.87	578.61
4	265.0	17.00	505.00	91.5	0.859	0.983	0.264	1.379	25.16	25.16	16.74	479.84
5	260.0	15.40	435.00	86.5	0.812	1.073	0.288	1.483	23.78	23.78	15.11	411.22
6	255.0	13.50	355.00	81.5	0.765	1.139	0.305	1.559	22.30	22.30	13.19	332.70
7	250.0	11.95	300.00	76.5	0.718	1.187	0.318	1.614	20.74	20.74	11.63	279.26
8	245.0	10.50	242.50	71.5	0.671	1.220	0.327	1.651	19.12	19.12	10.17	223.38
9	240.0	9.00	198.50	66.5	0.624	1.241	0.333	1.671	17.47	17.47	8.67	181.03
10	235.0	7.70	160.87	61.5	0.577	1.251	0.336	1.678	15.80	15.80	7.36	145.07
11	230.0	6.50	121.74	56.5	0.531	1.251	0.336	1.671	14.12	14.12	6.16	107.62
12	225.0	5.35	92.39	51.5	0.484	1.241	0.333	1.651	12.45	12.45	5.02	79.94
13	220.0	4.00	65.22	46.5	0.437	1.221	0.327	1.617	10.80	10.80	3.67	54.42
14	215.0	3.00	41.85	41.5	0.390	1.191	0.319	1.570	9.18	9.18	2.68	32.66
15	210.0	2.30	26.50	36.5	0.343	1.150	0.309	1.508	7.61	7.61	1.99	18.89
16	205.0	1.75	17.50	31.5	0.296	1.099	0.295	1.430	6.11	6.11	1.46	11.39
17	200.0	1.20	11.65	26.5	0.249	1.034	0.277	1.333	4.68	4.68	0.92	6.97
18	195.0	0.76	6.80	21.5	0.202	0.954	0.256	1.213	3.34	3.34	0.50	3.46
19	190.0	0.43	2.75	16.5	0.155	0.855	0.229	1.158	2.13	2.13	0.21	0.62
20	**184.5**	**0.19**	**0.20**	**11.0**	**0.103**	**0.715**	**0.192**	**0.657**	**0.97**	**0.20**	**0.00**	**0.00**
21	180.0	0.10	0.09	6.5	0.061	0.560	0.100	0.300	0.32	0.09	0.00	0.00
22	175.0	0.02	0.01	1.5	0.014	0.274	0.020	0.015	0.02	0.01	0.00	0.00
23	173.5	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00

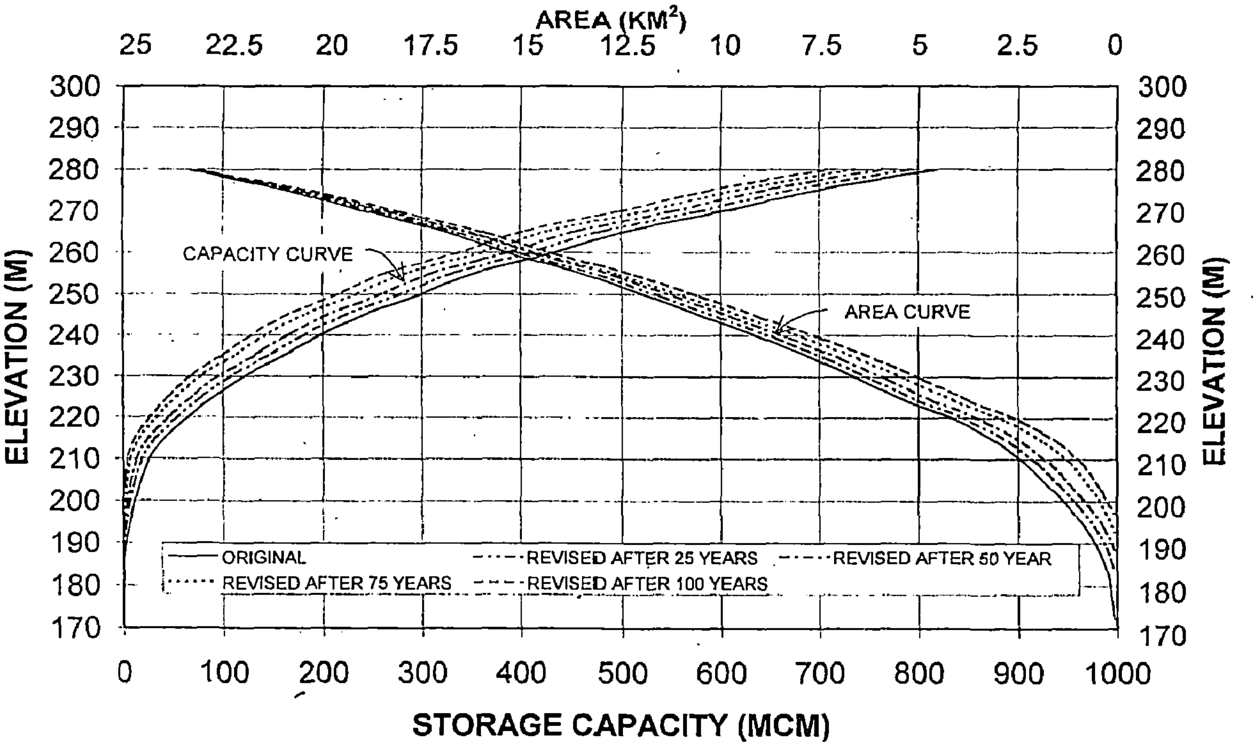


Fig. 2.17 :Change in Elevation - Area - Capacity Curve after every 25 years during 100 years

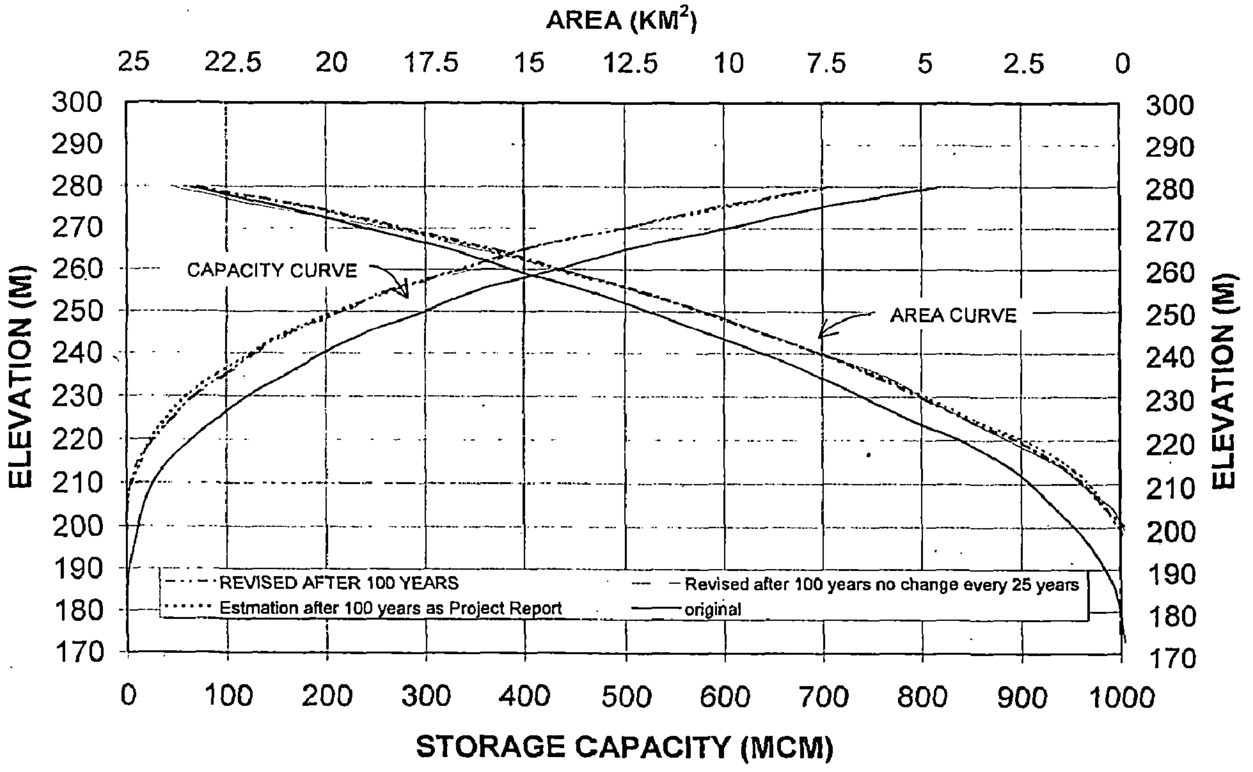


Fig. 2.18 : Comparison of Elevation - Area - Capacity Curve after 100 years as per Present Study and Project Report

CHAPTER 3

PRELIMINARY DESIGN OF RESERVOIR

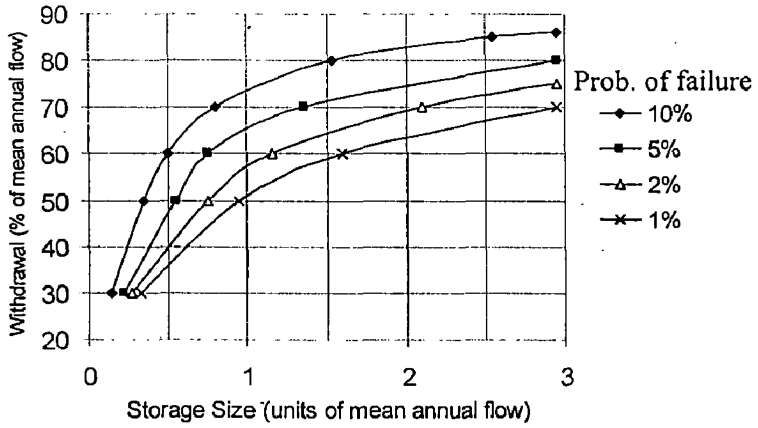
3.1 GENERAL

For surface water reservoirs, a two-step design process is generally adopted. In the first step, simple and quick techniques are used to establish reservoir capacity–yield relationship. Such methods are called preliminary design techniques. In these preliminary techniques, simplifying assumptions are normally made. Reservoir releases are assumed constant (i.e. demand is assumed to be uniform), evaporation is ignored. In India, dependability criteria are fixed as 75 % for irrigation and 90 % for hydropower generation. Thus, no attempt is made to explore capacity – yield relationship particularly in preliminary design.

Uncertainty is a major element in the design process. This is inherent not only in the flow records but also in the forecasts of demand particularly irrigation water demand. Irrigation demand depends on several variables such as cropping pattern, rainfall, irrigation system, efficiency, which are not deterministic. Cropping pattern changes with farmers behavior, market prices, socio-economic condition, reliability of water supply and so on. Thus, variability which should be a key factor in the design process is often ignored by making simplifying assumptions. With availability of computer technology and analytical tools, even preliminary design can be made more realistic and informative for the planner to take appropriate decisions.

One of the earlier methods for estimating size of storage to meet a given draft is Rippl's method, which is equivalent to the computer based sequent peak algorithm. However, the procedure does have several deficiencies, especially where variable drafts, evaporation losses, and multi reservoir systems are involved. Because of these limitations, the mass curve procedure is not recommended as a design technique. However, it should be noted that the capacity of many reservoirs might have estimated using this technique, and analysis reviewing the yield of older storages should be aware of its limitations.

A useful summary result of either a preliminary or final design analysis is illustrated in Fig. 3.1, where draft or withdrawal (or regulated outflow) from the reservoir, expressed as a percentage of mean annual flow, is plotted against the required storage for several levels of probability of failure. From such a diagram, the storage at a specific site required to meet a given draft and probability of failure can be obtained. Alternatively, for a fixed reservoir size, the relationship of withdrawal of firm yield to probability of failure (or reliability) can be depicted.



For one unit of storage size

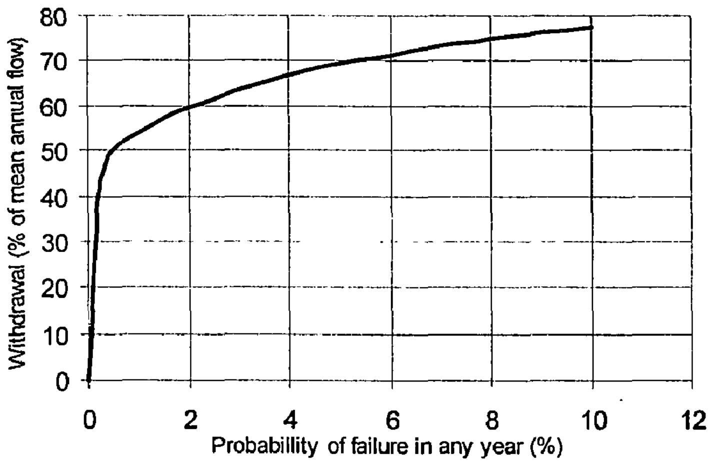


Fig. 3.1 Example of the Relationship between Storage Size, Withdrawal and Probability of Failure

This chapter explores possible improvements in preliminary design procedure.

3.2 DEFINITION OF TERMS:

Terms often used in storage capacity-yield-reliability analysis are defined below.

Within - year storage: is the storage capacity required to smooth out season fluctuations in stream flow within a year. In humid regions, only sufficient capacity is required to meet within – year fluctuations in stream flow and demand.

Carry-over storage: it refers to the additional capacity of a reservoir to compensate for year-to-year variations in stream flow and demand for reservoirs that do not refill every year. Reservoirs located in more arid climates are normally of this type.

The terms *yield*, *release, draft, withdrawal, outflow*, and *regulation* are used synonymously and refer to the regulated outflow from a reservoir. *Yield* is often expressed as a percentage of mean flow during the project life, with typical values being in the range 50 to 70 percent. In India, yield is often associated with dependability.

Firm yield as used in United States is the draft or withdrawal that lowers the water content in a reservoir from a full condition to a minimum level just once during the critical historical drought. It is essentially the no failure yield. In India, it corresponds to 90 % dependability.

Release or *operating rule*. Usually the water supplied to the consumer is equal to that demanded. However, during periods when the reservoir contents are so low that the water required can not be supplied, or when prudence suggest that only part of the demand should be met from storage, withdrawals may be a function of water stored where the function relating release and storage is the release rule.

Criteria for Assessing Reservoir Performance

A number of definitions are used for *probability of failure* of a reservoir from a hydrologic point of view. A common definition of failure is the ratio of the time the reservoir is unable to meet the full demand, n_f, to the total time period used in the analysis, n.

Hence,

$$P_f = \frac{n_f}{n} \tag{3.1}$$

Reliability is the term used to represent the proportion of time the reservoir is able to meet the consumer demand. Hence, it is the complement of probability of failure:

$$R_f = 1 - P_f \tag{3.2}$$

When n_f and n are in terms of year R_f is called *annual reliability.* When n_f and n are in months or smaller time interval, it is called *time reliability.*

Volumetric reliability is defined as the ratio of the volume of water supplied, Vs, to the volume of water demanded, Vd :

$$Rv = \frac{Vs}{Vd} \tag{3.3}$$

Two other criteria are useful in assessing reservoir performance, namely *resilience* (the rate of recovery from failure) and *vulnerability* (the severity of failure). The probability of recovery from failure to some acceptable state within a specified time interval is defined as resilience. A resilience system is one that is capable of recovering from a deficit state to a normal state in a short time. For mathematical modeling, it is defined as the maximum number of consecutive periods of shortage that occur prior to recovery.

Vulnerability is a measure of the likely magnitude or significance of a failure. It is defined as the largest deficit during the period of operation of a reservoir.

$$\underset{n}{Max}\left[(V_d)_i - (V_s)_i\right] \qquad (3.4)$$

i = 1,2,3,........n

A *critical period* is defined as the period from a full condition through emptiness (or a condition defined as failure) to the next full condition (Fig. 3.2). On the other hand, a *critical drawdown period* is the period during which the reservoir contents fall from an initially full condition to an empty condition, without spilling during the intervening period. In the United States, these terms refer only to the worst historical drought.

In critical drawdown period, only one failure occurs and that signals the end of the period. In Fig. 3.2, two critical drawdown periods are illustrated. In the second one, the period beyond the initial empty point in 1987 is not part of the critical drawdown period. Critical drawdown periods can be as short as a few months or as long as 10 years or more.

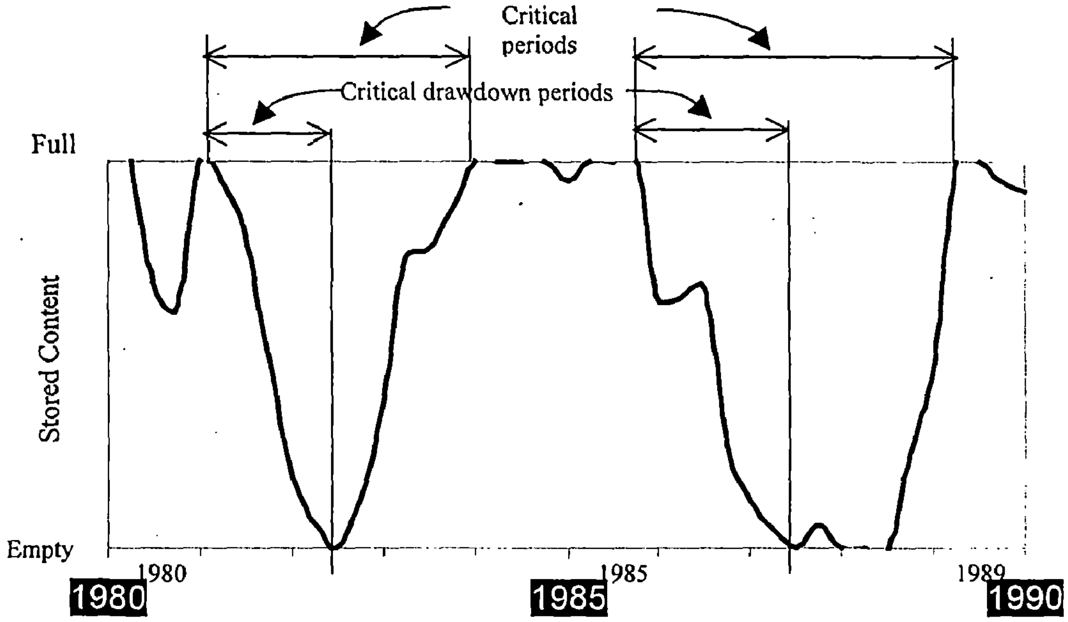


Fig. .3.2 : Behavior Diagram Illustrating Critical Periods.

3.3 GOULD GAMMA METHOD

Following an extensive review of preliminary reservoir capacity–yield techniques and their application to Australian and Malaysian streams (that cover the range of hydrologic characteristics throughout the world), *Teoh and Mc Mahon* recommend the Gould Gamma method for establishing reservoir – draft – probability of failure relationship. It should be noted, however, that the Gould Gamma method applies to reservoirs whose storage volume fluctuates from year to year.

This method uses the fact that, while parameters for the normal distribution are easy to calculate and probability tables for it are readily available, the Gamma distribution usually is a better approximation to the distribution of annual flow data. The procedure is therefore to use the normal distribution for the calculations, and then to apply a correction to approximate the Gamma distribution. Procedure as given in *McMahon and Mein (1978)* is explained in Annexure.

3.4 PRELIMINARY DESIGN OF BATUTEGI RESERVOIR

The storage required on a reservoir to meet a specific demand depends on three factors; the variability of the inflows, the size of the demand, and the reliability of this demand being met. This section deals with estimate of storage for preliminary design using Gould Gamma method and simple simulation/behavior analysis.

3.4.1 Data

The inflow data is available on fortnight basis in unit of cumec, for 25 years. Appendix 2 shows monthly inflow at Batutegi reservoir in million cubic meter (MCM).

3.4.2 Gould Gamma Method Analysis

By Gould Gamma method, storage required is found out for varying withdrawal i.e. for 50%, 75%, 90%, and 95% of mean annual flow and varying probability of failure i.e. for 1%, 2%, and 5%. Probability of failure greater than 5% is not recommended by this method (Table 1 in Annexure).

Estimation of storage capacity by Gould Gamma method is illustrated below:

- Withdrawal = 90 % of mean annual flow
- Probability of failure = 5 %

For above condition, the parameter as in Eq. E.13 is obtained as below :

D = 0.9 i.e. percentage of mean annual flow

z_p = 1.64 i.e. standard distribution corresponding to p = 5% (Table 1 in Annexure)

d = 0.6 i.e. from Table 1 (Annexure) corresponding to z_p = 1.64

C_v = 0.21 i.e. coefficient of variation

$$= \frac{\text{standard deviation}}{\text{mean annual flow}} = \frac{142.79}{690.88} = 0.21$$

Hence, using Eq. E.13

$$\tau = \left[\frac{1.64^2}{4(1-0.9)} - 0.6\right] x 0.21^2$$

$$= 0.27$$

Therefore, storage capacity

C = τ x mean annual flow

= 0.27 x 690.88

= 186.58 MCM

3.4.3 Adjustment for Evaporation Loss

Evaporation from a reservoir needs to be taken into account using Equation E.20 ;

$$\Delta SE = c\, A_F\, \Delta E\, CP$$

C = constant taken as 0.7

A_F = 10.2 km^2 taken from elevation–area–capacity curve revised after 50 years (Fig. 2.17 in previous chapter) corresponding to storage size of 186.58 MCM

ΔE = net evaporation loss or gain/loss from reservoir is assumed to be equal to the average annual rainfall less the average annual runoff. Table 3.1 shows that the annual gain/loss reservoir is 142.1 mm/year or 0.142 m/year

CP = critical drawdown period is obtained from Equation E.7

$$CP = \frac{z_p^{\;2}}{4(1-D)^2} C_v^{\;2} = \frac{1.64^2}{4(1-0.9)^2} x 0.21^2$$

$$= 2.97 \text{ years}$$

Therefore, adjustment for evaporation loss is computed as below :

ΔSE = 0.7 x (10.2x10^6 m^2) x 0.142 m/year x 2.97 year
= 3.01 MCM

Hence,

Storage Required = C + ΔSE
= 186.58 MCM + 3.01 MCM
= 189.59 MCM

Table 3.1. Mean Annual Gain/Loss from Reservoir

NO	YEAR	ANNUAL RAINFALL (mm)	ANNUAL EVAPORATION (mm)	ANNUAL GAIN/LOSS RESERVOIR (mm)
1	1969	1,384.0	1,433.0	(49.0)
2	1970	1,607.5	1,427.0	180.5
3	1971	1,162.0	1,419.0	(257.0)
4	1972	1,313.2	1,419.0	(105.8)
5	1973	1,114.9	1,415.0	(300.1)
6	1974	1,031.3	1,431.0	(399.7)
7	1975	1,120.9	1,431.0	(310.1)
8	1976	978.3	1,431.0	(452.7)
9	1977	1,279.3	1,412.0	(132.7)
10	1978	1,500.1	1,417.0	83.1
11	1979	1,758.5	1,417.0	341.5
12	1980	1,207.3	1,417.0	(209.7)
13	1981	1,729.3	1,417.0	312.3
14	1982	1,194.4	1,417.0	(222.6)
15	1983	1,084.1	1,417.0	(332.9)
16	1984	1,034.6	1,417.0	(382.4)
17	1985	1,633.8	1,417.0	216.8
18	1986	1,282.8	1,417.0	(134.2)
19	1987	1,583.7	1,417.0	166.7
20	1988	1,223.9	1,417.0	(193.1)
21	1989	1,112.0	1,417.0	(305.0)
22	1990	937.2	1,417.0	(479.8)
23	1991	981.3	1,417.0	(435.7)
24	1992	1,199.5	1,417.0	(217.5)
25	1993	1,484.5	1,417.0	67.5
TOTAL				(3,551.3)
MEAN ANNUAL GAIN/LOSS				(142.1)

3.4.4 Withdrawal, Storage Size and Probability of Failure Relationship

Now, storage required (storage size) with varying withdrawal and probability of failure are computed to establish relationship between withdrawal, storage size and probability of failure. Table 3.2 is summary of storage size estimated using Gould Gamma method with variation in withdrawal and probability of failure, and Fig. 3.3 shows the relation.

Table 3.2. Calculation of Storage Size, Withdrawal and Probability of Failure Relation using Gould Gamma method

Mean Annual Flow (x)	=	690.88 MCM
Standart Deviation (SD)	=	142.79
Coeffisien of Variation (Cv)	=	0.21

No	Parameter	Storage Size with any different prob. of failure											
		prob. of failure 1 %				prob. of failure 2 %				prob. of failure 5 %			
		50 % of An. Flow	75 % of An. Flow	90 % of An. Flow	95 % of An. Flow	50 % of An. Flow	75 % of An. Flow	90 % of An. Flow	95 % of An. Flow	50 % of An. Flow	75 % of An. Flow	**90 % of An. Flow**	95 % of An. Flow
	Storage Size Estimated												
1	Gould Gama Method												
	z_p	2.33	2.33	2.33	2.33	2.05	2.05	2.05	2.05	1.64	1.64	**1.64**	1.64
	D	50%	75%	90%	95%	50%	75%	90%	95%	50%	75%	**90%**	95%
	d	1.50	1.50	1.50	1.50	1.10	1.10	1.10	1.10	0.60	0.60	**0.60**	0.60
	C_v	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	**0.21**	0.21
	τ	0.05	0.17	0.53	1.13	0.04	0.14	0.41	0.88	0.03	0.09	**0.27**	0.57
	Storage Size = $\tau \times \bar{x}$	37.00	119.70	367.81	781.33	30.51	94.53	286.59	606.69	22.69	63.67	**186.58**	391.45
2	Adjusment for Net Evaporation												
	c	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	**0.70**	0.70
	A_F	3.20	7.65	15.60	23.60	3.10	6.70	13.40	20.25	2.35	5.05	**10.20**	15.85
	ΔE	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	**0.14**	0.14
	CP	0.24	0.96	5.99	23.94	0.19	0.74	4.63	18.53	0.12	0.47	**2.97**	11.86
	$\Delta S_E = c\ A_F\ \Delta E\ CP$	0.08	0.73	9.29	56.20	0.06	0.49	6.18	37.33	0.03	0.24	**3.01**	18.70
	Storage after Adjustment	37.08	120.43	377.10	837.53	30.56	95.02	292.76	644.02	22.72	63.90	**189.59**	410.15

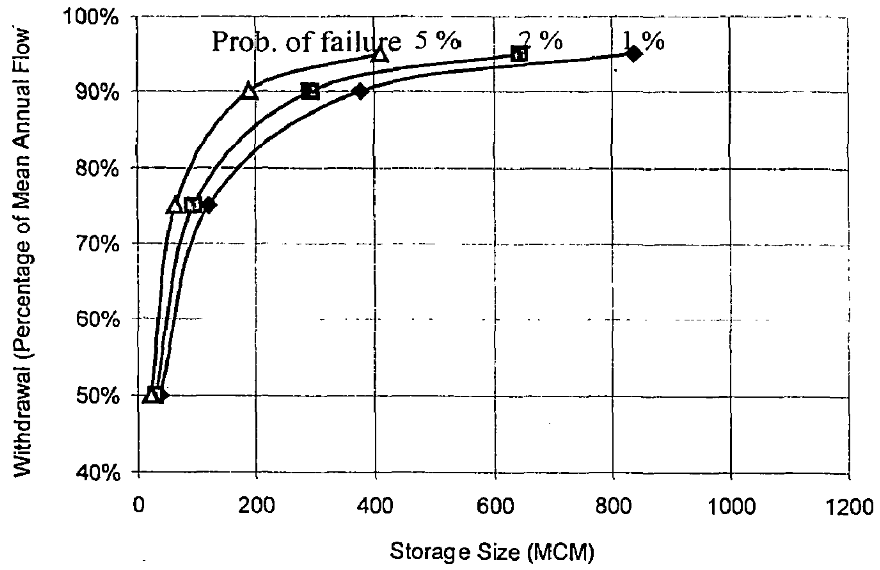


Fig. 3.3 Relationship between Withdrawal, Storage Size and Probability using Gould Gamma Method

Fig 3.3 shows, that for withdrawal being 50% of mean flow, the storage size is not significant different being 22.72 MCM, 30.56 MCM and 37.08 MCM for 5 %, 2%, and 1% probability of failure respectively.

3.4.5 Simple Behavior/Simulation Analysis

Even for preliminary design simulation analysis can be carried out with simplifying assumptions to establish storage size-withdrawal-probability of failure (or reliability) relationship as discussed below:

In behavior/simulation analysis, the changes in storage content of a finite reservoir are calculated using equations:

$$Z_{t+1} = Z_t + Q_t - D_t - \Delta E_t$$

Subject to $0 \leq Z_{t+1} \leq C$ (3.5)

Where, Z_{t+1} = storage at end of the t^{th} time period

(= storage at the beginning of $t+1^{th}$ period)

Z_t = storage at the beginning of t^{th} time period

Q_t = inflow during t^{th} time period

ΔE_t = net evaporation loss from reservoir during t^{th} time period

C = active storage capacity

Time period is in one month. For preliminary design, sedimentation during the life of the reservoir and net evaporation loss are ignored. Withdrawal is fixed at 50%, 75%, 90%, 95 % of mean annual flow.

The steps in a simple simulation analysis are as follows:

i. Arbitrarily choose a reservoir of active capacity C, and assume that it is initially full, that is, z_0 = C.
ii. Apply equation 3.5 month by month for the whole historical record. Dt is assumed to be constant.
iii. Compute the probability of failure by dividing the number of time periods for which the reservoir is empty by the total number of time periods.
iv. If the probability of failure is unacceptable, choose a new value of C and repeat the steps above.

Appendix 3 shows a simple simulation analysis for case of withdrawal being 90 % of mean annual flow and probability of failure being 5 % in time reliability analysis (monthly basis).

By trial and error, storage capacity for different withdrawal levels and probability of failure are obtained easily. The results of simulation are shown in Table 3.3 and Table 3.4. The relation between withdrawal, storage size and probability of failure on monthly basis and annual basis are shown in Fig 3.4.a and Fig. 3.4.b respectively.

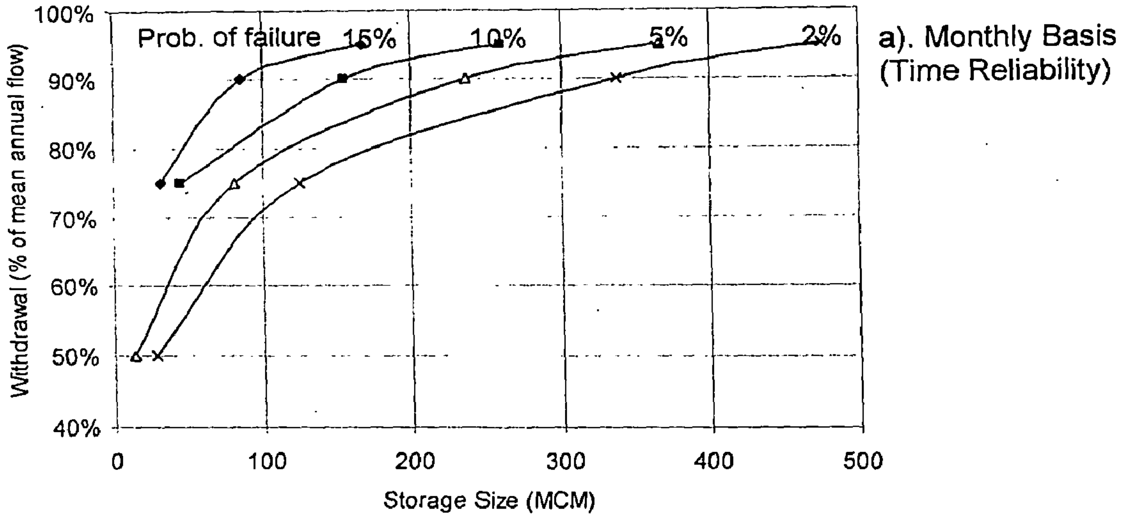
In this study, simple simulation analysis has been used to estimate storage size with probability of failure 2%, 5%, 10%, and 15% on monthly basis (time reliability) and 5%, 12.5 %, 17 %, 21 % and 25 % on annual basis (annual reliability). Probability of failure of exactly 10 %, 15 % and 20 % on annual basis cannot be considered. For example 10% of 24 years is 2.4 years failure, therefore 3 years failure or 12.5% probability of failure is considered.

Table 3.3 : Result of simple simulation study (storage size-withdrawal-reliability relation) for monthly basis (time reliability)

Case No	Storage Size in MCM	Probability of failure
I	Withdrawal 50 %	
1	0	10%
2	14	5%
3	30.0	2%
II	Withdrawal 75 %	
1	31.6	15%
2	45.0	10%
3	85.0	5%
4	120.0	2%
III	Withdrawal 90 %	
1	85.0	15%
2	160.0	10%
3	225.0	5%
4	325.0	2%
IV	Withdrawal 95 %	
1	160.0	15%
2	265.0	10%
3	370.0	5%
4	470.0	2%

Table 3.4: Result of simple simulation study (storage size-withdrawal-reliability relation) for annual basis (annual reliability)

Case No	Storage Size in MCM	Probability of failure
I	Withdrawal 50 %	
1	20.0	25%
2	23.0	21%
3	30.0	17%
4	46.0	12.5%
5	50.0	5%
II	Withdrawal 75 %	
1	80.0	25%
2	95.0	21%
3	115.0	17%
4	125.0	12.5%
5	158.0	5%
III	Withdrawal 90 %	
1	200.0	25%
2	210.0	21%
3	225.0	17%
4	240.0	12.5%
5	390.0	5%
IV	Withdrawal 95 %	
1	295.0	25%
2	305.0	21%
3	315.0	17%
4	375.0	12.5%
5	510.0	5%



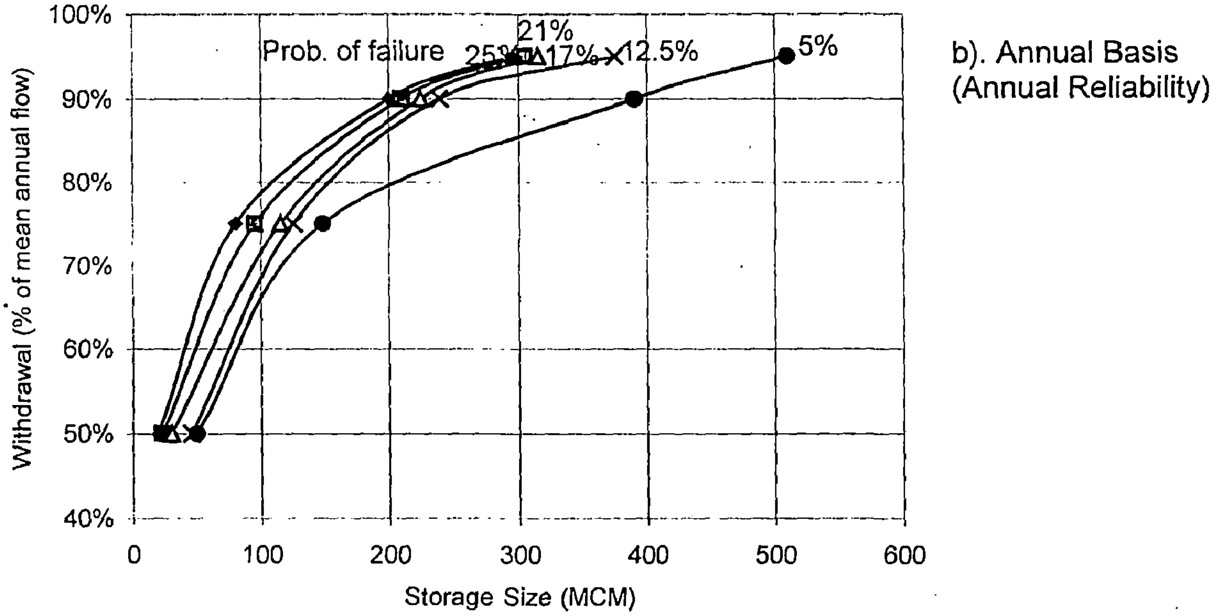


Fig. 3. 4. Relationship between Withdrawal, Storage Size and Probability of Failure of Batutegi reservoir

Following are the conclusions from preliminary design of Batutegi reservoir:

(i.) Storage size estimation using simple simulation method is higher than estimation using Gould Gamma method for 5% probability of failure (annual basis) as shown in Table 3.5 for varying withdrawal from 50% to 90% of mean annual flow.

Table 3.5. Storage Size Estimation by Gould Gamma Method and Simple Simulation Analysis for 5% Probability of Failure

Withdrawal	Storage Size Estimation (MCM)		Deviation	
	Gould Gamma Method	Simple Simulation	MCM	% of by Simple Simulation
50%	23	50	27	54
75%	64	158	94	59
90%	190	390	200	51
95%	410	510	100	20

(ii.) Preliminary design using simple simulation (withdrawal-storage size-probability of failure relationship) is more flexible and informative than the preliminary design by Gould Gamma method. Withdrawal-storage size-probability of failure relationship on annual basis can be developed for probability of failure greater than 5% also.

CHAPTER 4

IMPROVEMENTS IN SIMULATION STUDY FOR HYDROPOWER

4.1. REVIEW OF PLANNING APPROACH

Irrigation and hydroelectric generation are the two main purposes for which a river valley project is generally taken up. However, concepts, basis and approach followed in planning for irrigation water supply and hydroelectric generation from the same river valley project are observed to be different as discussed in Chapter 1. Based on review of prevalent approach in planning of river valley projects, following comments are made:

(i.) A reservoir provides capacity to store water similar to generation units, which provide capacity to generate power. While generated electricity cannot be stored, the power potential in terms of flow and head, which cause power generation, can definitely be stored.

(ii.) It is well known that in developing country such as India, annual, seasonal and daily demand for electricity is much higher than available supply. Electricity production system consists of a mix of hydro, thermal, gas, and atomic power plants. Further, electricity distribution is made through grid and not directly from a single producer to consumer. Therefore, production at a particular hydroelectric project need not match with consumer demand instant by instant.

(iii.) In single purpose power generation projects, releases from storage would depend upon system requirements. In multipurpose projects, where major benefit is irrigation, the releases are made primarily in the interest of irrigation and power generation follow the pattern of irrigation. But if installed capacity is based on 90% dependable power, possibility of higher power generation during periods of keen irrigation demand is lost. On the other hand, demand for electricity is high during this period of keen demand for tube well and lift irrigation. It results a paradoxical situation wherein energy demand is high, power generation potential is also available (through storage head and irrigation releases) but power generation is restricted, by installed capacity, which has been based on 90% dependable power.

(iv.) Power component of a multipurpose storage project is also a component of energy generation system as stated in item (ii) above. As the system grows to match increasing power demand, releases from storage have to be changed. Similarly irrigation component is part of irrigation water supply system including ground water. As irrigation development scenario in the command area changes due to change in cropping pattern etc. The irrigation demand pattern will also change in future. Conflicts usually arise in operational requirements for irrigation and power. Adjustment in power releases also have to be made during any day to afford power matching to day - night variation in power demand.

(v.) Farmers generally avoid night irrigation. Thus, power releases made in night require additional storage in downstream for irrigation only. In a designed cultural command area of storage type irrigation project, there is no alternate supply source if conjunctive use of surface and ground water has not been planned. Also even if groundwater use is planned at project level, this would have to be based on reliable power supply. In other words, storage type irrigation (single or multipurpose projects) are generally planned to serve an area as stand alone projects. There are only a few multi reservoir systems for irrigation alone.

(vi.) Discussion in item (iv) to (v) leads to the necessity of improving the planning procedure. Irrigation and power supply have to be viewed as serving common higher-level goal. It is first necessary to appreciate and accept the shortcomings in traditional approach for planning of irrigation and power projects.

(vii.) In U.S.A., reservoirs have been planned as carry over storage (over year storage), which means the reservoir capacity is more than what is required for within year storage. This results in higher utilization of river flows both for irrigation and power generation. In India, irrigation reservoirs are planned as within year storage to achieve 75% reliability in water supply. This means available flows are under utilized in three out of four years. Similarly 90% dependability of hydropower means under utilization in nine out of ten years which developing country such as India can ill afford when irrigation is a top priority sector of development and there is acute shortage of power (a key input in country's development) *(IWRS, 1999)*. The prevalent criteria do not appear to have a sound basis and analytical depth. Similarly decision on within year or over year storage should be based on long-term simulation study. Making irrigation and power projects as part of larger supply systems, reliability of over year storage can be increased. In the case of irrigation, it can be (i). Conjunctive use of surface and ground water (ii). Multi reservoir integrated planning, and (iii) Inter basin transfer.

4.2. POSSIBLE IMPROVEMENTS IN SIMULATION STUDY

With the availability of long-term hydrologic data, computational software and computer technology, it is possible to carry out detailed analysis and make the analysis more realistic and informative.

(i.) Hydrologic design of a multipurpose reservoir in terms of storage capacity, dependable power, dependable irrigation water supply, installed capacity for power generation, irrigation canal capacity, and dependable area of irrigation should be based on long term simulation study of reservoir performance.

(ii.) Progressive siltation and its impact on elevation – area – capacity relation have been examined in chapter II. It is necessary to incorporate progressive change in live storage capacity in the long-term simulation study.

(iii.) Dependability criteria for irrigation and power generation are empirical in nature. It is necessary to carry out planning studies for different levels of water utilization and for different levels of reliability both for irrigation and power generation. Graphical depiction of relationship between water withdrawal and storage capacity for different levels of reliability provide much more useful information for decision making a simply working out storage capacity for 75% dependable irrigation or 90% dependable power generation.

(iv.) Normally, the minimum draw down level in storage development are fixed on considerations of silting and the safe limit of operating heads on the generating unit. Having arrived at the quantum of gross and effective storage required for regulating the available flows, studies should be carried out for different height of the dam, which would provide the same live capacity but with different minimum draw down levels and full reservoir level to arrive at the most economic solution.

(v.) Irrigation demand is traditionally assumed to be constant over the period of simulation though its variation within a year is considered. It is a well known fact that irrigation demand changes from year to year depending on farmers choice of crops, effective rainfall, reliability of water supply, physical performance of delivery system and other infrastructure development (market, storage capacity, credit facility seeds, fertilizer, transportation, etc). Therefore, irrigation demand variation over the years should be considered in long-term simulation study.

Unrealistic estimation of irrigation demand and assuming it to be constant over the years may cause over estimation or underestimation of system capacities, and their performance.

4.3. STATISTICAL INDEXES OF PHYSICAL PERFORMANCE

The purpose of long-term simulation study is to permit evaluation of the physical and economic performance of alternative plans for storage capacity, power generation and irrigation water supply. The present study is limited to evaluation of physical performance. Economic performance is measured by the net benefits towards alternative objectives generated by the alternative plans for which sufficient data are not available, for the present study.

The discussion in this chapter is limited to evaluation of physical performance of hydropower generation, which is best undertaken statistically. The term "reliability" is used to describe the expected frequency with which a project attains given physical targets. *Lenton and Strzepek (1977)* have suggested following statistical indexes for evaluation of physical performance of hydropower generation.

T : total number of years of simulation
n : a particular month n = 1, 2, 3....., 12
t : a particular year
Pc : Installed Capacity (MW)
PG(t,n): energy generated in month n of year t

i.) For each of twelve calendar months, draw power duration curve and compute minimum, mean, 90% dependable, 75% dependable power generation and also estimate variance. Compute capacity factor for each month.

$$C_f(n) = \frac{\text{av.monthly energy generation}}{\text{Installed Capacity x no.of hours in a month}}$$

ii.) Draw annual energy duration curve and compute minimum, mean, 90% dependable, 75% dependable energy generation on annual basis and also estimate variance. Compute annual capacity factor

$$C_f = \frac{\text{av.annual energy generation}}{\text{Installed Capacity x no.of hours in a year}}$$

iii.) Estimate firm power (dependable power), which can been guaranteed with a high level of reliability. Usually it is 90% dependable power.

In the following paragraphs, simulation study of Batutegi reservoir has been carried out incorporating some of improvements for hydrologic design of this multipurpose reservoir. This chapter considers only power generation, and joint consideration of irrigation and hydropower is discussed in next chapter.

4.4. THE DATA

4.4.1 Discharge at Batutegi Reservoir

For the simulation study, discharge at Batutegi dam site and at Argoguruh weir are required. In the Sekampung river, four gauging stations are operated namely: Kunyir, Jurak, Pujorahayu and Argoguruh. Their general features are given below:

Runoff Gauging Stations

Station	Catchment Area (km^2)	Data Availability	Data Obtained From
Kunyir	438	Jan.1968-Feb.1994	Puslitbang Air,P2SDA
Jurak	682	Jan.1968-Dec.1993	Puslitbang Air
Pujorahayu	1,743	Jan.1969-Dec.1992	Puslitbang Air
Argoguruh	2,155	Sep.1974-Feb.1994	Cabang Metro

Note: Puslitbang Air : Research Institute for Water Resources Development (Pusat Penelitian dan Pengembangan Pengairan)

P2SDA : Water Resources Research Project (Proyek Pengkajian Sumber Daya Air)

Cabang Metro: Metro District Irrigation Service (Cabang Dinas Pengairan Metro)

The nearest gauging station is Kunyir, about 2 km downstream from Batutegi dam site. The catchment areas at Batutegi and at Kunyir are 424 sq. km, and 438 sq. km respectively. Consequently, discharge at Batutegi is estimated by multiplying the discharge at Kunyir by 424/438.

The order of the priority is from the nearest to the farthest i.e. Jurak is the first station to be converted, Pujorahayu the second and Argoguruh the last.

After the generation of the discharge at Kunyir, the discharge at Batutegi is estimated as:

$$Qb = \frac{424}{438}\, x\, Qk$$

Where, Qb = Discharge at Batutegi (m^3/s)

Qk = Discharge at Kunyir (m^3/s)

The discharge at Batutegi during 24 years is shown in Appendix 2.

4.4.2 Evaporation and Rainfall

The evaporation from reservoir water surface is given as below :

Unit	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

Monthly rainfall during 24 years is given in Appendix 4.

4.5. ANALYSIS OF CHANGE IN ELEVATION, AREA, CAPACITY RELATION

The progressive siltation and its impact on elevation – area – capacity has been examined in chapter II. In this study, analysis of change in elevation – area – capacity after every 10 years is carried out and the live storage revised during period of simulation. Details of calculation on the progressive siltation during project life are given in Appendix 6. Figure in Appendix 5 shows the change in elevation–area–capacity curve after every 10 years. These curves are used in long-term simulation study both for power generation and irrigation simulation, instead of assuming a fixed elevation–area–capacity curve that is used in conventional studies.

4.6. SIMULATION STUDY OF POWER GENERATION

According to the project report *(Department of Public Work, 1994),* the irrigation water will be released from Batutegi reservoir to the Sekampung river through irrigation/power waterway. This waterway will be a circular tunnel with diameter of 3.5 m in the first portion and it branches into two penstocks and power penstock further branches into two penstocks, respectively. In the powerhouse, two units of generators will be installed with capacity of 12 MW each. In the simulation study, irrigation water is to be released through power tunnel as much as allowed and balance required water flows through irrigation outlet. This chapter considers only power generation. The power generation is estimated as per following procedure:

- Tail water level (TWL) is assumed at Elevation 170 m.
- Turbine efficiency is as given in figure 4.3.
- Low water level for power generation is at Elevation 226 m.
- Head Loss is estimated as follows:

  $$HL = 0.001377095\,(q_i)^2 + 0.002574749\,(q_p)^2$$

  Where, HL : head loss (m)

  q_i : discharge through irrigation intake (m^3/s)

  q_p : discharge through power intake (m^3/s)

- Power is estimated by the following equation:

  $$P = 9.8\,\eta\,q_p\,(WL - TWL - HL)$$

  Where, P : generated power (KW)

  WL : reservoir surface water level (El. m)

- If available turbine discharge is less than 40% of the turbine discharge required for one turbine, power generation is stopped.

4.6.1 Regression for Estimation of Average Surface Area of Reservoir

Average area is estimated by developing a linear function relation with area at the beginning of month. The procedure is explained as below:

- Select a power target (Installed Capacity) and set initial storage as average of the range between 460 MCM and 660 MCM i.e. 560 MCM to carry out monthly water balance.
- Carry out preliminary water balance with following assumptions:
    - a) Net head = Water level at beginning – head loss – TWL
      Where, head loss is assumed as 2 m and TWL is set as El. 170.
    - b) Gain/loss from reservoir or net evaporation loss is assumed by multiplying depth of (rainfall – evaporation) with surface area at the beginning.
    - c) Turbine efficiency taken to be constant as 0.814
- Area at end of month is found out corresponding to storage at end of month. Plot surface area at the beginning (abscissa) versus average of surface area at beginning and at end of a month) as obtained from monthly water balance.
- Obtain best-fit linear equation by regression analysis for the selected power target. Repeat process for other power target.
- Hence, Average surface area = function (surface area at the beginning). The results are shown in Fig. 4.1.

The regression relations as shown in Fig. 4.1 are used in detailed simulation study as explained in section 4.6.3.

4.6.2 Regression for Estimation of Average Elevation

Average reservoir elevation is estimated by a similar procedure as in section 4.6.1 above.

- Elevation at end of month is found out corresponding to storage at end of month. Plot elevation at the beginning (abscissa) versus average of elevation.
- Obtain best-fit linear equation by regression analysis.
- Hence, Average elevation = function (elevation at the beginning). The results are shown in Fig. 4.2.

It is observed that scatter of points from best fit regression lines for both (i). *Initial elevation vs. average elevation* and (ii). *Initial area vs. average area* is more when power target is 12 MW. For other power settings, relationships are good.

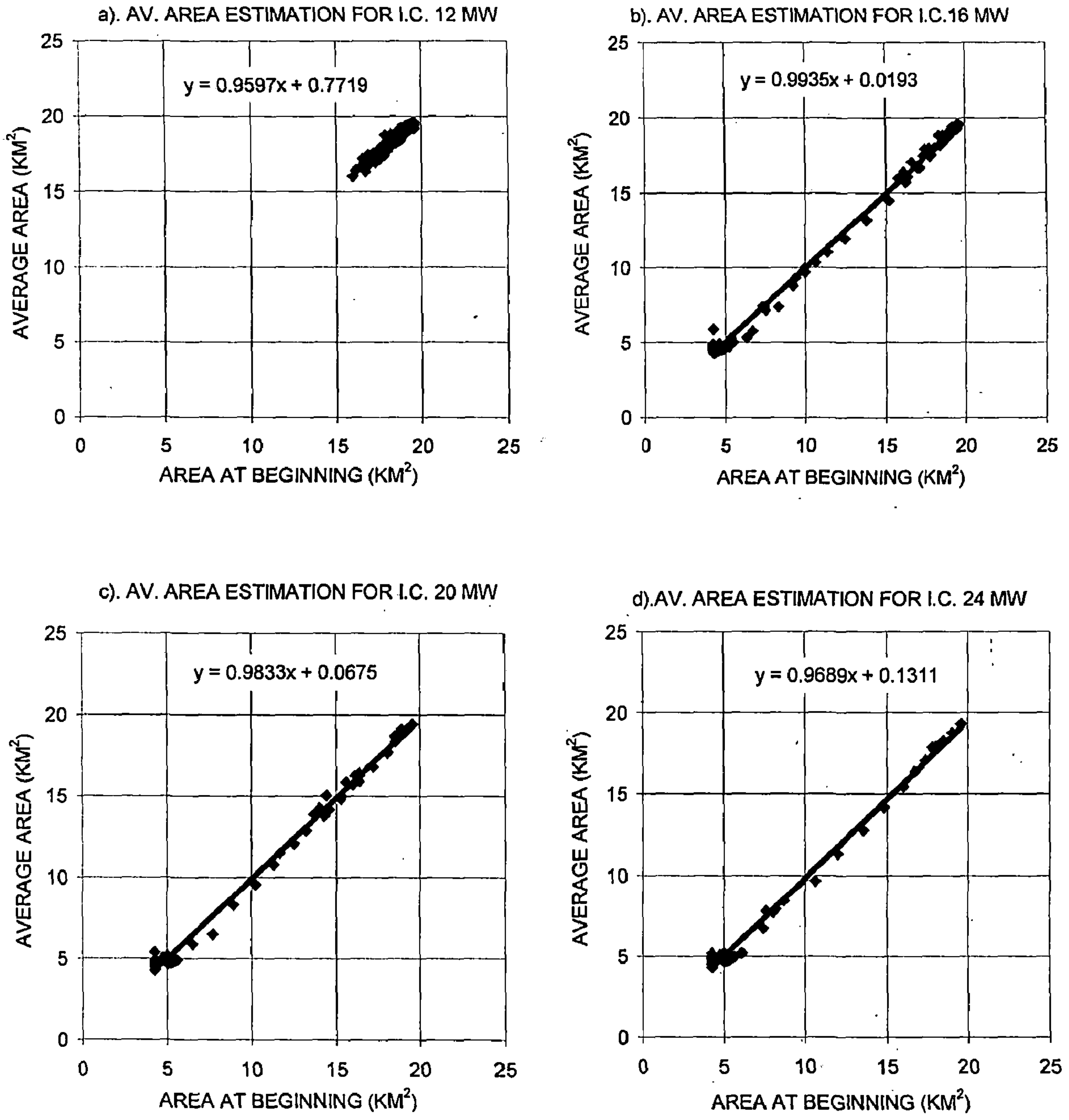


Fig. 4.1 : Linear Regression for Estimation of Average Area with Different Power Target

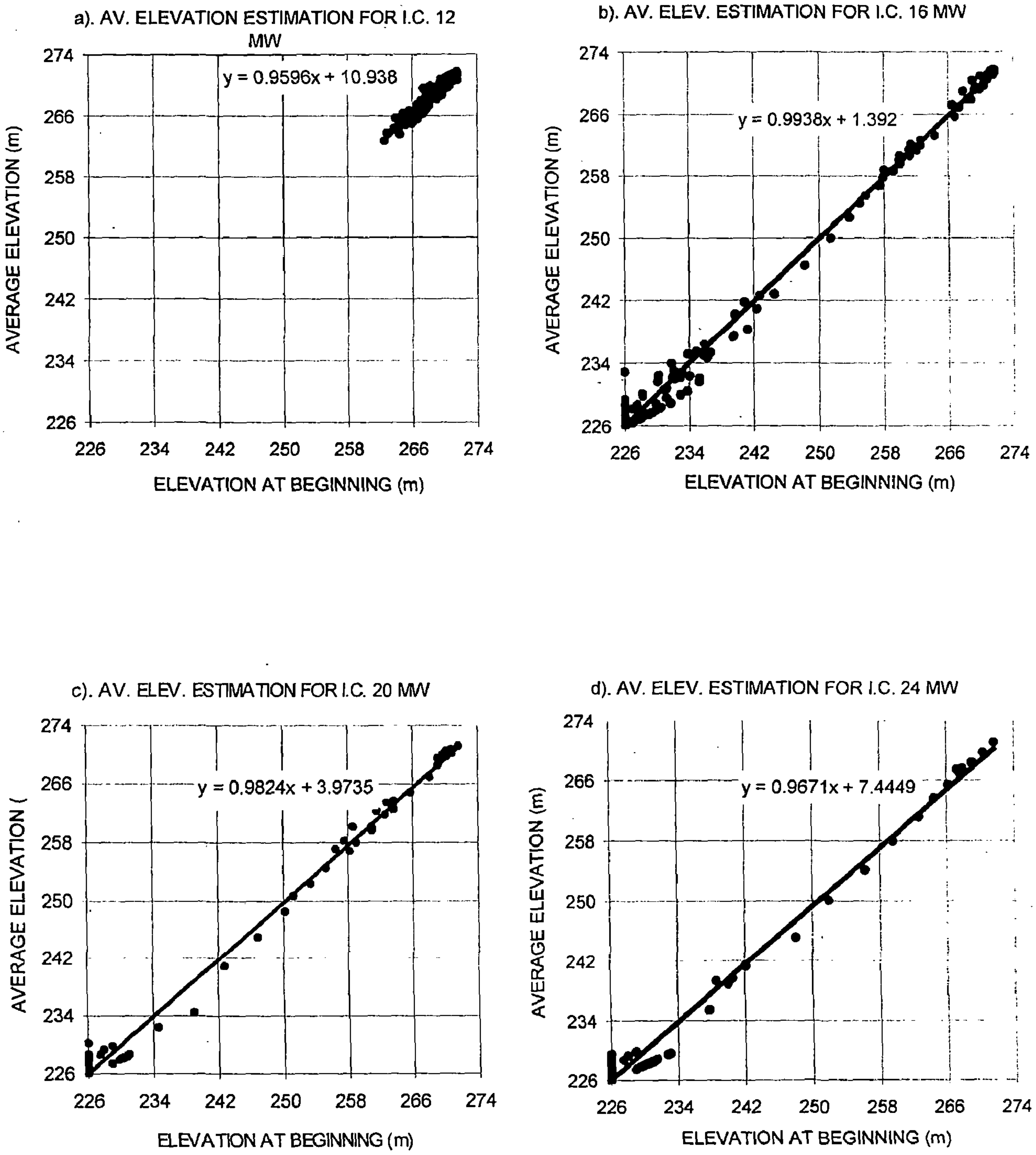


Fig 4.2 : Linear Regression for Estimation of Average Elevation with Different Power Target

4.6.3 Algorithm of Power Simulation Study

Power routing is done using the following sequence of steps. The complete sequence is performed for a calendar month of the simulation.

(i.) Adopt a storage capacity based on preliminary design or any other consideration.

(ii.) Select power target/Installed Capacity and number of units (in number of 4 MW units).

(iii.) Select first month of simulation, which is usually at end of wet season. For this case study, April is the first month. Assume storage at beginning of month. Reservoir can be assumed to be full at end of wet season.

(iv.) Adopt appropriate elevation-area-capacity curve, which is revised in every 10 years during project life. Since the stream flow data is for 24 years, original curve, curve revised after 10 years and curve revised after 20 years are adopted for simulation study. Elevation – area – capacity curves are shown in Appendix 5.

(v.) Calculate the gain/loss from reservoir with following procedure:

- Estimate the average surface area of reservoir for the month corresponding to the surface area at the beginning of month using the linear function (Fig. 4.1) appropriate to the power target.
- Gain/loss from Reservoir is obtained as:

  = Average surface area x depth of gain/loss reservoir x conversion

  = $(\text{km}^2 \times 10^6) \times (\text{mm} \times 10^{-3}) / 10^6$ (in Mm^3 or MCM)

  Where;

  depth of gain/loss = monthly rainfall – monthly evaporation in mm

(vi.) Calculate the water available as:

Gross Water available (WA) = Gross storage at beginning + Inflow + Gain/loss

(vii.) Estimate rated discharge by following formula

$$\text{Rated discharge } (q_{\text{rated}}) = \frac{P}{9.8 x \eta x H} \quad (\text{in m}^3/\text{s})$$

Turbine efficiency is assumed constant (η = 0.814)

H is net head, which is taken as:

= Average water level of reservoir - constant head loss (2 m)-TWL

= (FRL+MDDL)/2 – 2m - TWL

(viii.) Obtained average reservoir elevation for the month from the regression equation.

Av. elevation = fn (elevation at beginning of month)

(ix.) Estimate the discharge required for one unit for generation of P with average reservoir elevation as in previous step.

Discharge required (q_r) (for one unit) $= \dfrac{P}{9.8 x \eta x Hr}$ (in m^3/s)

Where, η = taken as 0.814

Hr = average elevation in a month – 2 – TWL

In Volume, units :

Q r = q_r x 60 x 60 x 24 x no of days in a month/10^6 MCM

(x.) Total release required through power intake

Qpr = (no of units n) x Qr

(xi.) Compute actual discharge (qa) and volume (Qa) for each unit as follow:

if WA $\geq$ Storage below MDDL + Qpr, then

qa = qr for all units

if WA < Storage below MDDL + Qpr, then

Qpa = WA – Storage below MDDL

Qpa is divided into n units such that 0.4 Qr < Qa < Qr , and qa is worked out.

(xii.) Revise Head Loss (HL) based on actual discharge (qa):

HL = $0.002574749 (q_a)^2$ for each unit turbine (xiii.) Revise Net Head (H)

H = Average elevation from step (viii) – Head Loss from step (xii) – TWL

(xiv.) Revise Turbine Efficiency

Using efficiency curve in Fig. 4.3, efficiency is obtained for the actual discharge qa as percentage of rated discharge.

$$\text{Where, percentage discharge} = \frac{q_a}{q_{rated}} \times 100\%$$

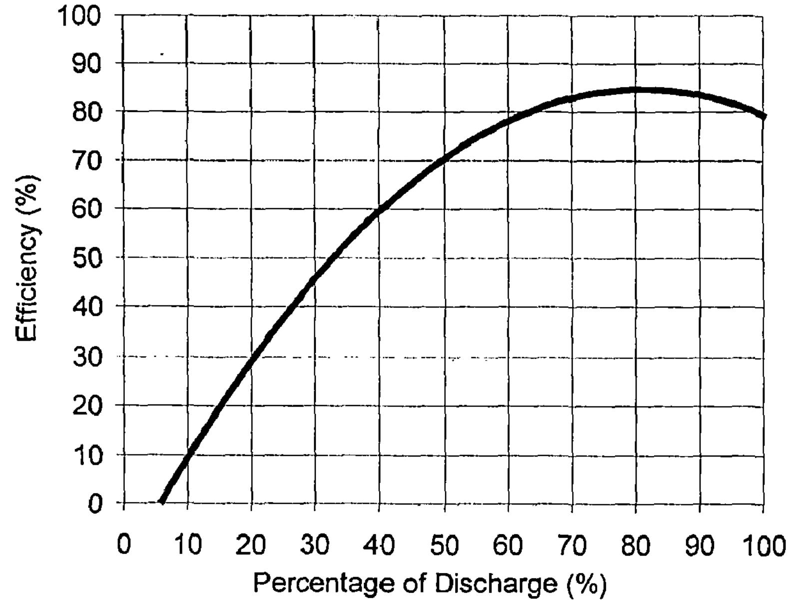


Fig 4.3 : Efficiency Curve

(xv.) Estimate turbine flow for one unit required for generating primary output, with the revised net head and revised efficiency,

$$\text{revised } qr = \frac{P}{9.81 \times \text{revised efficiency} \times \text{revised head}}$$

$$\text{revised } Qr = \text{revised } qr \times \frac{60 \times 60 \times 24 \times \text{no of days in a month}}{10^6}$$

revised Qpr = (no of units n) x revised Qr

Figure 4.4 depictis the estimation of turbine flow in form of flow chart in case of Batutegi reservoir.

Turbine release for each unit (qa discharge, Qa volume) depends on the water available, and how much can be released for power generation. Turbine release (in volume) made for power simulation is found applying following rules:

- If WA $\geq$ Storage below MDDL+ revised Qpr
  Qpa = Qpr , and
  qa = revised qr for all units
- If WA $<$ Storage below MDDL + revised Qpr
  Then, Qpa = WA – Storage below MDDL
  Qpa is divided into n units such that $0.4\ Qr < Qa < Qr$
  And qa is worked out for each turbine
- If (WA – Storage below MDDL) $<$ 0.4 Qpr, then
  Qpa = 0 and qa = 0

(xvi.) Calculate end of month storage

$$S_{i+1} = \min \begin{bmatrix} \text{Si} + \text{Gain/Loss} + \text{Inflow} - \text{Qpa} \\ \text{Smax} \end{bmatrix}$$

(xvii.) Calculate Power Output

$$\text{Power Output} = \sum_{n} 9.8 \text{x} \text{revise d} \eta \text{ x revised head x } q a$$

(xviii.) Repeat the above mentioned procedure sequentially for all the months of simulation period (here 288 months), using revised elevation area capacity curve after 120 months (10 years) and 240 month (20 years).

(xix.) Work out statistical performance parameters.

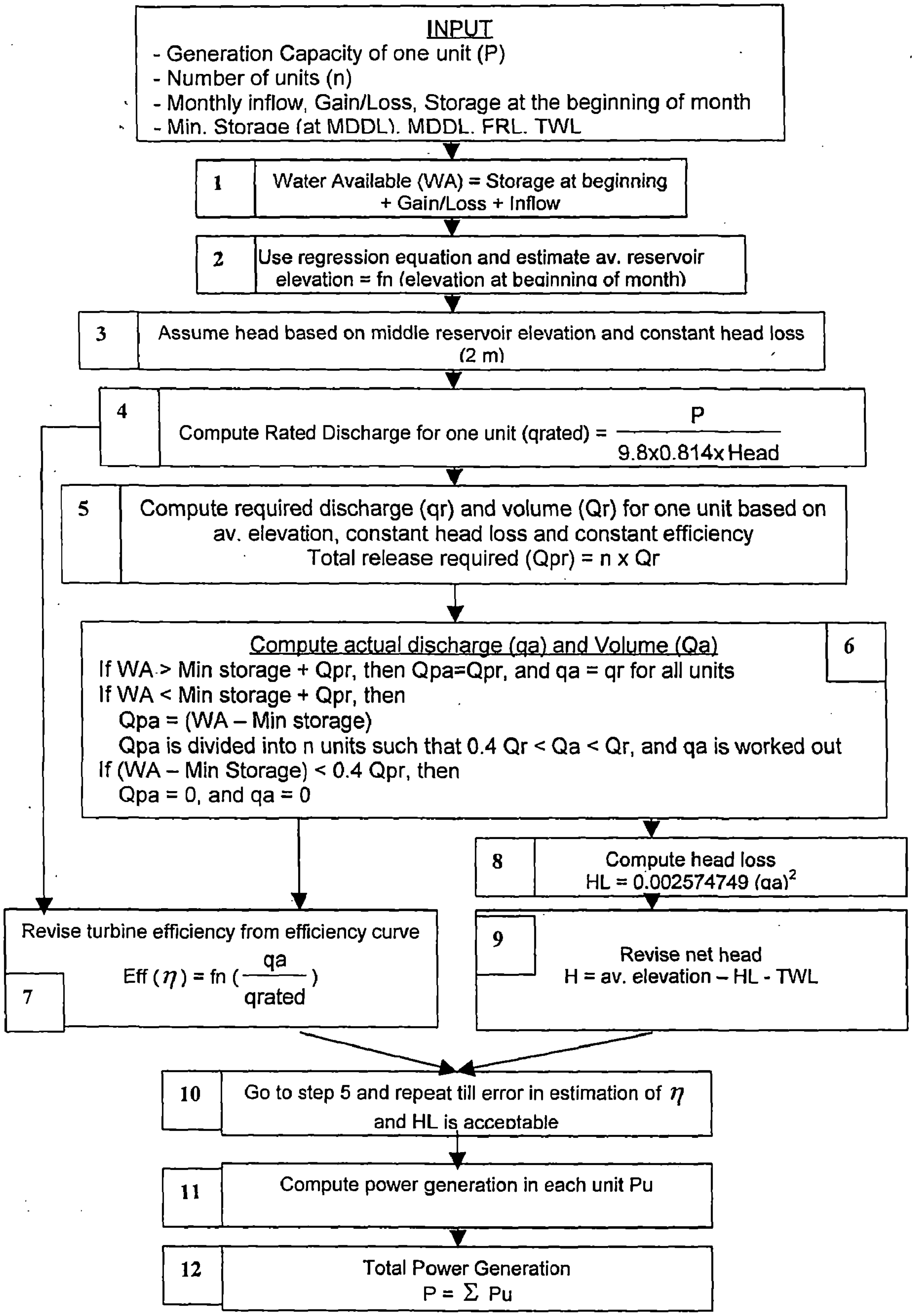


Fig. 4.4 : Flow Chart Depicting Estimation of Unit Turbine Flow and Power

(xx.) Repeat the entire algorithm from step (i) to step (xix) for the following changes in storage capacity and Installed Capacity:

I.C. condition : 12 MW 16 MW 20 MW 24 MW

Storage condition : 460, 500, 540, 580, 620, 660 (in MCM)

Thus there are 24 different combinations of storage size and Installed Capacity for which simulation studies have been carried out.

Table 4.1 shows the results of simulation study in terms of power generation at different dependability levels for 24 different combinations of storage size and Installed Capacity

Table 4.2 shows statistical performance parameters for each month for six different combinations of storage capacity and installed capacity. The statistical parameters of physical performance on monthly basis are: *mean power generation on monthly basis; variance in monthly power generation; average energy generation on monthly basis; capacity factor for each month; 90% dependable power on monthly basis; and 80% dependable power on monthly basis.*

Table 4.3 depicts a sample simulation study in detail for 580 MCM storage capacity and 16 MW installed capacity.

4.7. RELIABILITY ANALYSIS OF POWER SIMULATION STUDY

The present study deals with a multipurpose reservoir for irrigation and hydropower. Concept used in estimation of reliability for irrigation and hydropower are different even though both are related with use of water but in a different manner. Following indexes can be used to evaluate physical performance in relation to power generation.

Failure month = when power target can not be met in a month

Failure year = when power target isn't met in one or month in a year

Annual reliability $= \frac{T - \text{sum of failure year}}{T} \text{x} 100$

Time reliability $= \frac{12T - \text{sum of failure month}}{12T} \text{x} 100$

Av.Annual Generation $= \frac{\text{Total energy generation in Simulation period}}{T}$

Annual Capacity Factor $= \frac{\text{Av.annual energy generation}}{\text{Energy gen. related to Installed Capacity}}$

To establish the relationship between storage size, installed capacity and different levels of dependable power, the storage size is varied in range between 460 MCM to 660 MCM.

For a given storage capacity the installed capacity is varied as 12 MW, 16 MW, 20 MW and 24 MW with the assumption of 4 MW unit turbine.

4.7.1 Storage Size – Power Generation – Dependability Relationship

Storage size – power generation relationship at different levels of reliability are useful in deciding dependable power generation according the given storage capacity or how much storage capacity is required for a specific dependable power generation.

In this study, four alternative installed capacities are analyzed i.e. 12 MW, 16 MW, 20 MW and 24 MW in which the capacity for one turbine is assumed as 4 MW. Table 4.1 shows the summary of storage size-power generation-dependability relationship. Figure 4.5 and figure 4.6 show graphical depiction of results for 12 MW and 16 MW installed capacities.

With installed capacity 12 MW (3 x 4 MW), the power generation at different reliability levels (65%, 75%, 80%, 90%) is constant at 12 MW (Figure 4.5.a), even when gross storage size increases from 460 MCM to 660 MCM. This means increase in storage capacity has no affect on power generation reliability with 12 MW installed capacity.

Table 4.1 Summary of Storage Size - Power Generation - Dependability Relationship Analysis

Gross Storage (MCM)	Installed Capacity (MW)	Dependable Power (MW)					Dependable Annual Energy Generation (GWh)					Annual Capacity Factor (%)
		Mean	65%	75%	80%	90%	Mean	65%	75%	80%	90%	
460	12	11.8	12.0	12.0	12.0	12.0	103.6	105.1	105.1	105.1	105.1	98.5
	16	10.5	7.9	6.9	6.4	5.0	92.1	79.1	69.6	69.1	63.7	65.7
	20	10.0	7.6	6.7	6.0	4.5	87.8	73.8	69.8	67.7	63.6	50.1
	24	10.0	7.6	6.7	6.0	4.7	87.5	74.5	69.8	68.1	64.0	41.6
500	12	12.0	12.0	12.0	12.0	12.0	104.7	105.1	105.1	105.1	105.1	99.6
	16	10.7	7.9	6.9	6.5	5.0	93.3	79.8	69.4	68.9	63.6	66.6
	20	10.2	7.6	6.7	6.0	4.5	89.1	74.2	69.8	67.7	63.6	50.9
	24	10.1	7.6	6.7	6.0	4.7	87.9	74.5	69.8	68.1	64.0	41.8
540	12	12.0	12.0	12.0	12.0	12.0	105.1	105.1	105.1	105.1	105.1	100.0
	16	10.9	8.0	7.0	6.5	5.0	95.1	80.9	69.4	68.9	63.6	67.9
	20	10.3	7.6	6.7	6.0	4.5	90.4	74.2	69.8	67.7	63.6	51.6
	24	10.1	7.6	6.7	6.0	4.7	88.4	74.5	69.8	68.1	64.0	42.0
580	12	12.0	12.0	12.0	12.0	12.0	105.1	105.1	105.1	105.1	105.1	100.0
	16	11.0	8.2	7.0	6.5	5.0	96.1	82.0	72.4	68.9	63.6	68.6
	20	10.5	7.7	6.8	6.1	4.5	92.0	74.2	69.8	67.7	63.6	52.5
	24	10.2	7.6	6.7	6.0	4.7	89.0	74.5	69.8	68.1	64.0	42.3
620	12	12.0	12.0	12.0	12.0	12.0	105.1	105.1	105.1	105.1	105.1	100.0
	16	11.1	8.6	7.2	6.6	5.0	97.2	88.1	72.4	68.9	63.6	69.4
	20	10.7	7.8	6.8	6.1	4.5	93.3	74.2	69.8	67.7	63.6	53.3
	24	10.3	7.6	6.7	6.0	4.7	90.1	74.6	69.8	68.1	64.0	42.9
660	12	12.0	12.0	12.0	12.0	12.0	105.1	105.1	105.1	105.1	105.1	100.0
	16	11.2	8.7	7.3	6.6	5.0	98.3	88.1	72.4	68.9	63.7	70.1
	20	10.9	7.8	6.8	6.2	4.5	95.3	78.8	71.9	69.2	63.7	54.4
	24	10.4	7.6	6.7	6.0	4.7	91.1	74.6	69.8	68.1	64.0	43.3

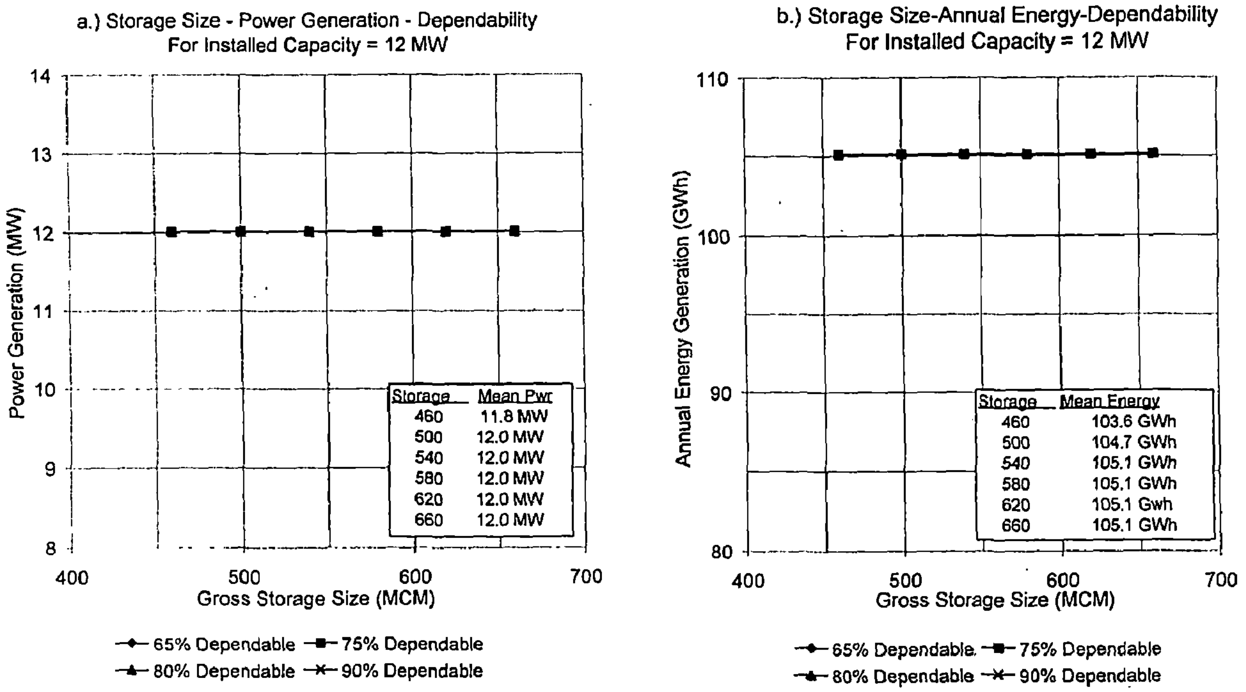


Fig. 4.5 : Storage Size - Power and Energy Generation - Dependability Relationship (12 MW)

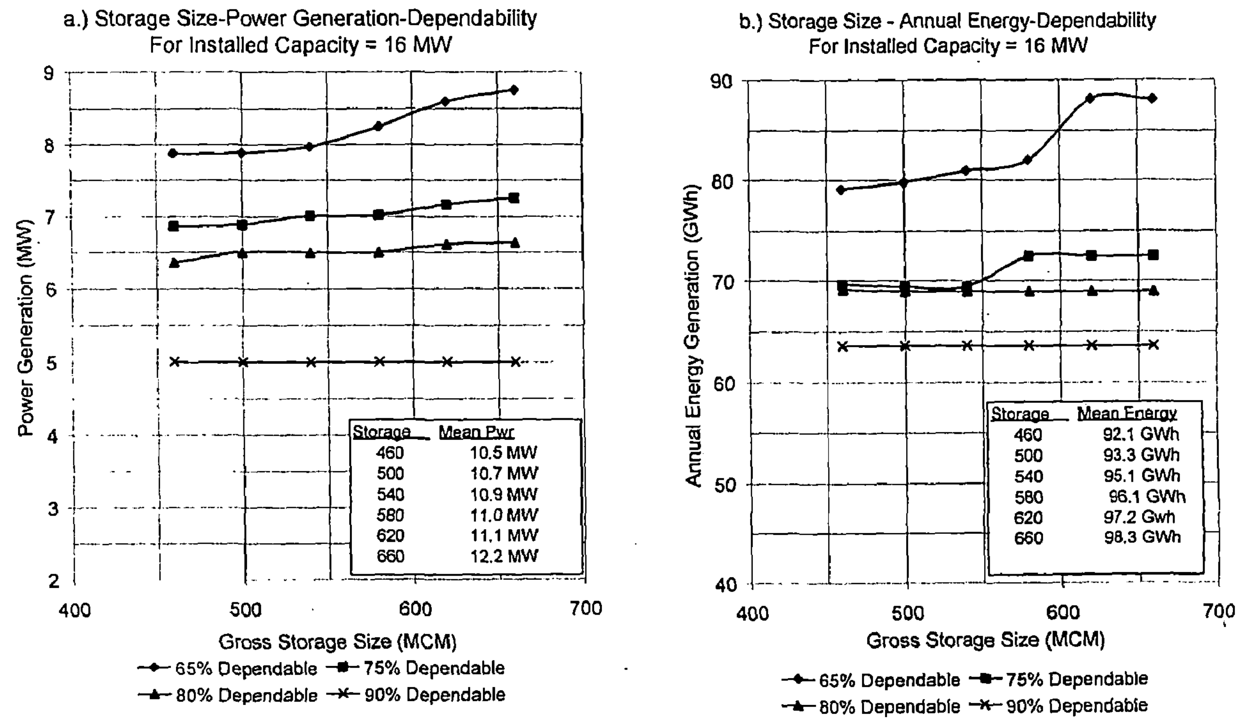


Fig. 4.6 : Storage Size - Power and Energy Generation - Dependability Relationship (16 MW)

Storage size–power generation relationship for 12 MW and 16 MW installed capacities are shown in Fig. 4.5.a and 4.6.a. Installed capacity greater than 16 MW is not necessary if only hydropower generation is considered. Power simulation study in Table 4.3 and Figure 4.10.b show that for gross storage size 580 MCM and installed capacity of 16 MW, after 4 years period of simulation, the storage is gradually going down, and at end of 5th year the water level achieves the bottom level at MDDL. The draw down period occurs almost along the remaining 19 years period of study. The reservoir behaves like a *run of river scheme*. Similarly for higher installed capacities, the reservoir is found to behave like a run of river scheme.

4.7.2 Storage Size – Annual Energy – Dependability Relationship

With increase in storage capacity, average annual energy generation for a given installed capacity increases. Figure 4.5.b and 4.6.b show the relationship between storage size and annual energy generation at different dependability for 12 MW and 16 MW installed capacity. These figures provide useful information in deciding installed capacity and storage size for meeting annual energy demand and desired dependability.

4.7.3 Monthly Power Generation Analysis

Table 4.2 shows performance parameters for each month and for six different combinations of storage capacity and installed capacity. These parameters give useful information in deciding fixing power generation targets in different months.

i.) Monthly power duration curves were drawn to develop the monthly dependable power for different installed capacity. Figures in Appendix 7 show the monthly power duration curves for 12 MW and 16 MW installed capacity and storage size 580 MCM. These power duration curves can be used for deciding dependable generation on monthly basis. Fig. 4.7 shows 90% dependable power on monthly basis when storage capacity is 580 MCM and installed capacity are 12 MW and 16 MW. Figure 4.8 shows mean monthly power generation when storage capacity is 580 MCM and installed capacity are 12 MW and 16 MW.

ii.) Increasing gross storage from 580 MCM to 660 MCM does not give significantly different power generation.

Fig. 4.7 : 90% Monthly Dependable Power
Storage Size = 580 MCM

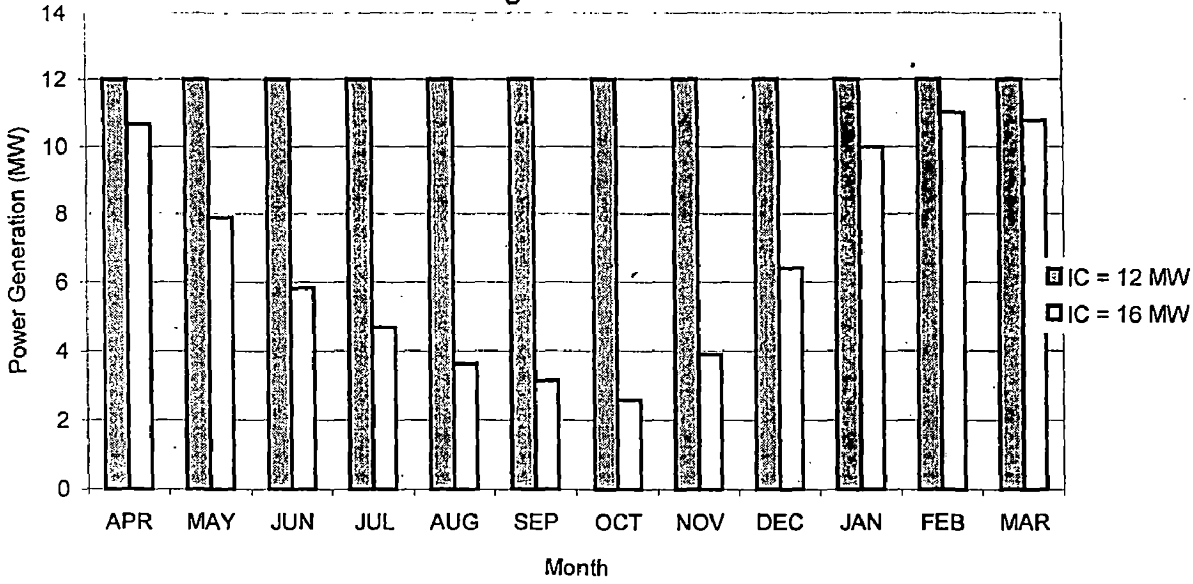


Fig. 4.8 : Mean Monthly Power Generation
Storage Size = 580 MCM

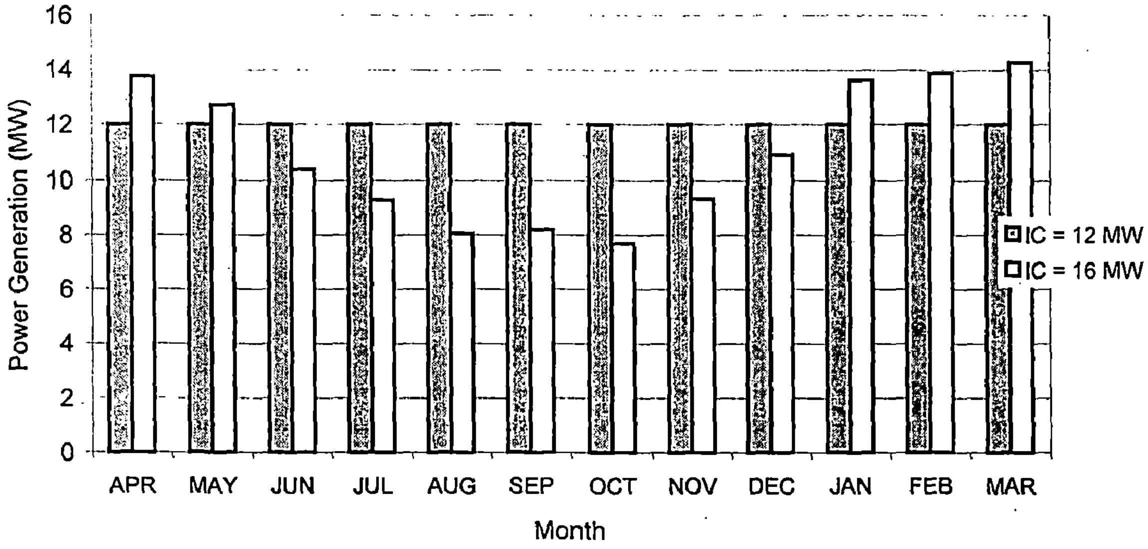


TABLE 4.2 Monthly Power Generation Analysis

Smax MCM	I.C. MW	Power	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual Energy
580	12	Mean	12	12	12	12	12	12	12	12	12	12	12	12	105.1
		Variance	0	0	0	0	0	0	0	0	0	0	0	0	0.0
		Av. Energy	8.64	8.93	8.64	8.93	8.93	8.64	8.93	8.64	8.93	8.93	8.06	8.93	105.1
		Cap. Factor	100	100	100	100	100	100	100	100	100	100	100	100	100.0
		90%	12	12	12	12	12	12	12	12	12	12	12	12	105.1
		80%	12	12	12	12	12	12	12	12	12	12	12	12	105.1
	16	Mean	13.8	12.7	10.4	9.3	8.0	8.2	7.7	9.3	10.9	13.6	13.9	14.3	96.1
		Variance	6.8	12.8	19.6	24.1	21.1	22.6	25.4	21.8	15.3	7.6	6.8	5.4	781.3
		Av. Energy	9.9	9.4	7.5	6.9	6.0	5.9	5.7	6.7	8.1	10.1	9.3	10.6	96.1
		Cap. Factor	85.9	79.4	64.8	57.8	50.2	51.0	47.9	58.1	68.2	85.2	86.7	89.1	68.6
		90%	10.6	7.9	5.8	4.7	3.6	3.1	2.6	3.9	6.4	10.0	11.0	10.8	63.6
		80%	11.0	8.8	6.6	5.6	4.7	3.8	3.9	6.2	7.7	11.2	11.4	11.4	68.9
	20	Mean	13.5	12.1	9.7	8.5	7.5	7.4	6.8	8.7	10.8	13.2	13.9	14.2	92.0
		Variance	12.9	16.6	21.6	28.0	23.6	22.0	23.6	23.8	20.6	12.8	13.6	14.0	988.8
		Av. Energy	9.7	9.0	7.0	6.3	5.6	5.3	5.0	6.3	8.0	9.8	9.3	10.5	92.0
		Cap. Factor	67.6	60.4	48.7	42.5	37.4	36.9	33.8	43.4	53.9	66.1	69.5	70.8	52.5
		90%	10.1	7.9	5.7	4.7	3.6	3.1	2.5	3.8	6.0	8.8	9.7	10.3	63.6
		80%	10.8	8.6	6.6	5.2	4.6	3.8	3.8	5.3	7.2	10.4	11.2	11.0	67.7
660	12	Mean	12	12	12	12	12	12	12	12	12	12	12	12	105.1
		Variance	0	0	0	0	0	0	0	0	0	0	0	0	0.0
		Av. Energy	8.64	8.93	8.64	8.93	8.93	8.64	8.93	8.64	8.93	8.93	8.06	8.93	105.1
		Cap. Factor	100	100	100	100	100	100	100	100	100	100	100	100	100.0
		90%	12	12	12	12	12	12	12	12	12	12	12	12	105.1
		80%	12	12	12	12	12	12	12	12	12	12	12	12	105.1
	16	Mean	13.7	12.7	10.8	9.7	8.5	8.5	8.1	9.7	11.2	13.8	13.9	14.2	98.3
		Variance	6.9	12.8	19.8	25.2	23.5	25.1	28.2	23.4	15.9	7.6	6.9	5.5	827.4
		Av. Energy	9.9	9.5	7.8	7.2	6.3	6.1	6.0	7.0	8.4	10.3	9.3	10.6	98.3
		Cap. Factor	85.8	79.4	67.6	60.6	52.8	53.3	50.5	60.5	70.2	86.4	86.7	89.0	70.1
		90%	10.6	7.9	6.4	4.7	3.6	3.1	2.6	3.9	6.4	10.0	10.9	10.8	63.5
		80%	11.0	8.8	6.7	5.9	4.7	3.8	3.9	6.2	7.7	11.2	11.3	11.3	68.9
	20	Mean	13.9	12.3	10.2	9.1	7.9	7.9	7.3	9.0	11.0	13.4	14.2	14.5	95.3
		Variance	14.4	19.1	26.0	32.9	27.0	28.6	31.0	28.3	23.7	14.6	15.0	14.9	1199.1
		Av. Energy	10.0	9.2	7.4	6.8	5.9	5.7	5.4	6.5	8.2	10.0	9.5	10.8	95.3
		Cap. Factor	69.4	61.7	51.1	45.6	39.7	39.7	36.4	44.8	55.0	67.2	70.9	72.4	54.4
		90%	10.1	7.9	5.7	4.7	3.6	3.1	2.5	3.8	6.0	8.8	9.7	10.3	63.6
		80%	10.8	8.6	6.6	5.6	4.7	3.8	3.8	5.3	7.2	10.4	11.2	11.4	69.2

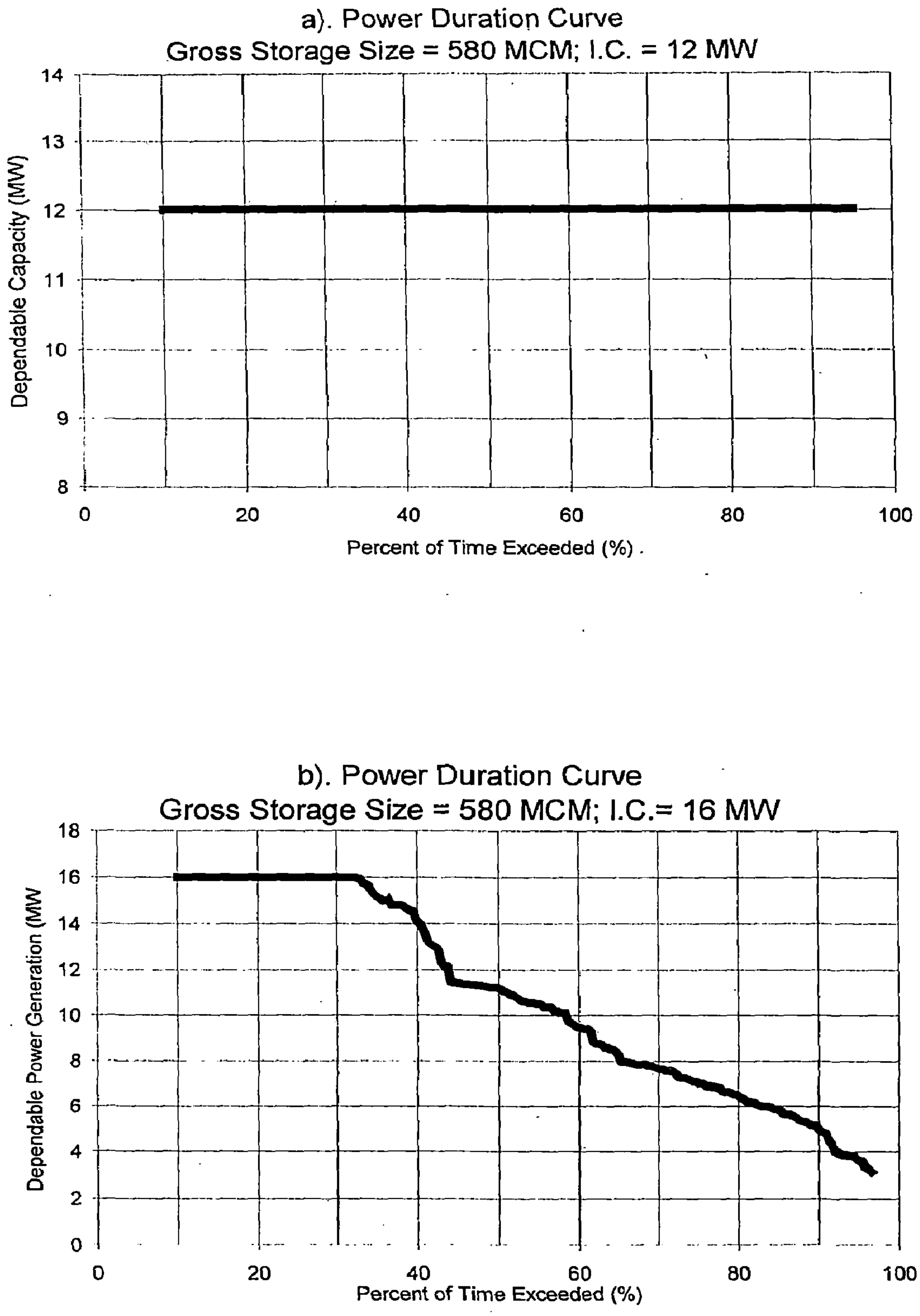
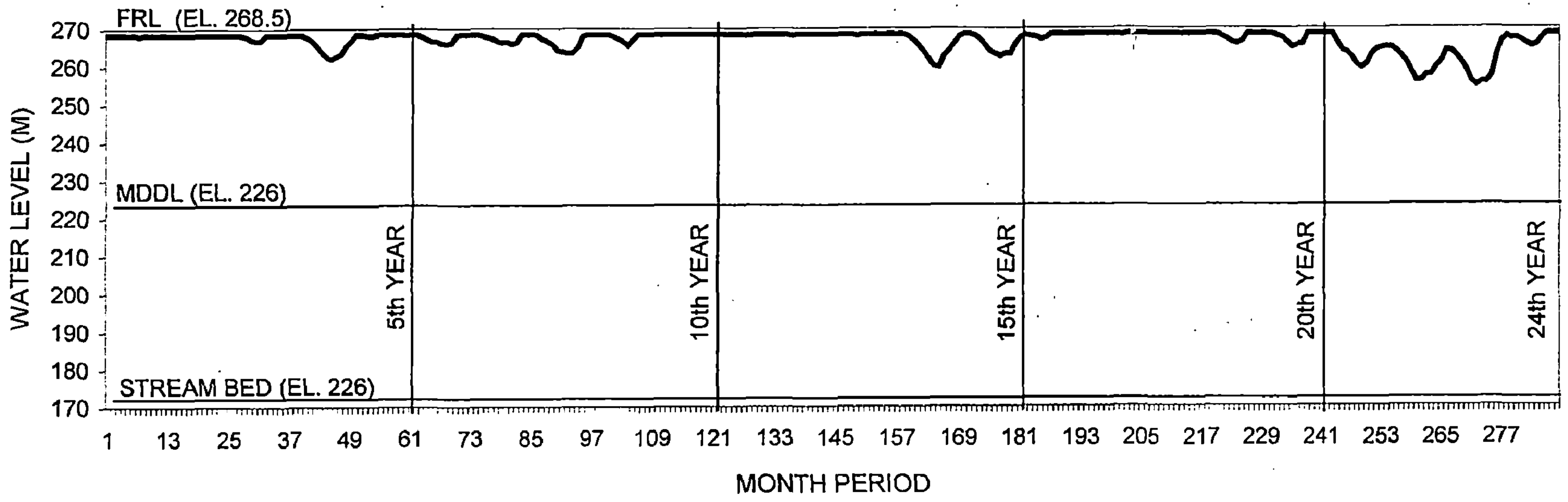


Fig. 4.9 : Power Duration Curve of Batutegi Reservoir

a). Behaviour Diagram of Batutegi Reservoir (Storage Size = 580 MCM; I.C. = 12 MW)



b). Behaviour Diagram of Batutegi Reservoir (Storage Size = 580 MCM; I.C. = 16 MW)

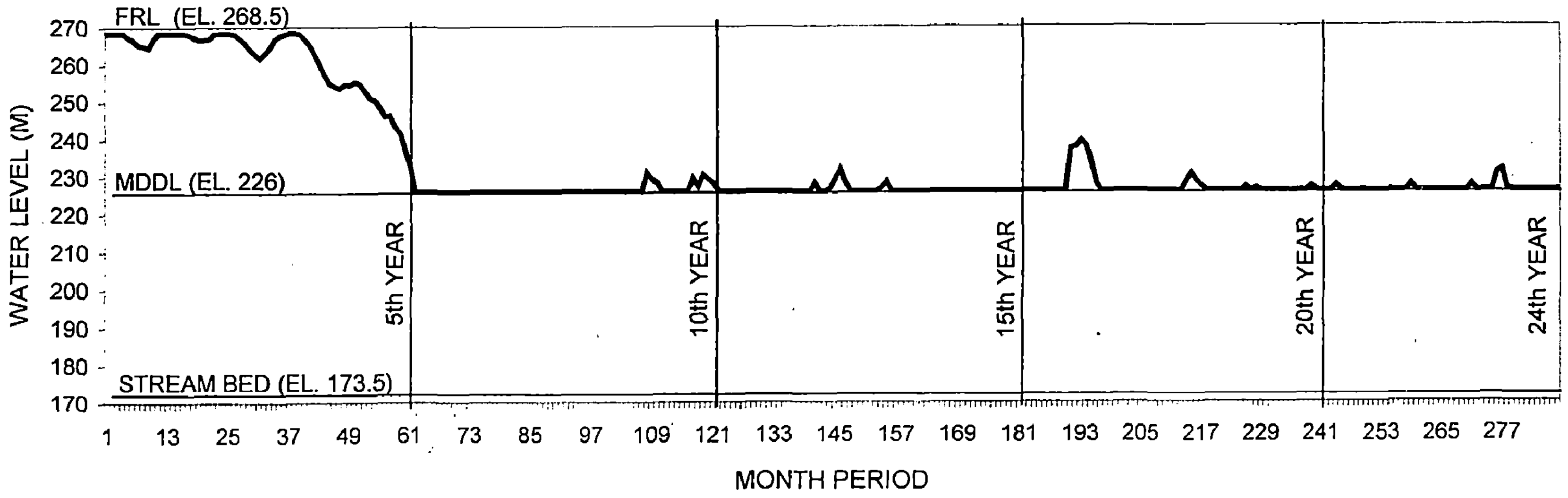


Fig. 4.10 : Behaviour Diagram of Batutegi Reservoir

4.7.4 Reservoir Behaviour Diagram

The power duration curves considering entire series of power generation and with installed capacity as 12 MW and 16 MW are shown in figure 4.9.

Average monthly flow over the entire simulation period is 57.6 MCM/month. The average power generation is 13.01 MW. For generation of 12 MW, 52 MCM/month is required and for generation of 16 MW, 70 MCM/month is required. The reservoir is assumed to be full at the beginning of simulation period in this study.

It is observed that reservoir almost remains full during entire simulation period for 12 MW generation. However, with installed capacity as 16 MW, reservoir depletion occurs and reaches MDDL at end of 5th year. The project behaves as run of river scheme for the remaining 19 years period of simulation (Figure 4.10.b).

4.9. CONCLUSIONS

In this chapter, improvements have been made in long-term simulation algorithm and demonstrated through a case study of Batutegi reservoir. Even though Batutegi reservoir serves the purposes of irrigation and hydropower, only hydropower generation has been considered in this chapter for the purpose of illustrating the simulation procedure. Results on power generation – reliability in relation to variation in storage size and installed capacity show that the installed capacity of 24 MW as given in Project report is on higher side. Only 12 MW capacity is found to be sufficient.

i.) Progressive sediment deposition and consequent change in storage capacity as well as change in elevation-area-capacity relation have been taken into account in the long-term simulation study.

ii.) Regression analysis has been used to develop best-fit relationship between a). *Initial and average elevation* and b). *Initial area and average area* for different power targets to estimate average elevation and average area.

iii.) Net/gain loss from reservoir has been considered to vary over entire simulation period by using monthly rainfall data for the entire period.

iv.) Power generation has been based on turbine flow for each unit of turbine and related efficiency and then summing it thus making it more realistic.

v.) Instead of assuming constant power plant efficiency, it has been considered as a variable.

vi.) Instead of using conventional procedure of finding 90% dependable power, following relationships have been developed :

1). Storage size-power generation-dependability

2). Storage size-annual energy generation-dependability

3). Monthly dependable power

Such studies provide much more useful information compared to conventional studies particularly when a reservoir is to be planned as multipurpose project.

vii.) Statistical indexes of physical performance such as (i) *mean and variance of monthly power and annual energy*, (ii) *dependable capacity and energy in each month*, (iii) *monthly and annual capacity factor*, are useful in deciding power/energy supply targets.

Table 4.3 Power Generation Simulation Study Using Monthly Data in Unit of Volume

FULL RESERVOIR LEVEL 268.5 M

TAIL WATER LEVEL 170.0 M

RATED DISCHARGE FOR 1 TURBINE 6.7 M^3/S

	0-10yr	10-20yr	20-24yr
MDDL	226.0	226.0	226.0
STORAGE BELOW MDDL (MCM)	98.4	93.3	88.5
GROSS STORAGE SIZE	580.0	569.6	559.3
LIVE STORAGE (MCM)	481.6	476.4	470.8

INSTALLED CAPACITY (4 units of 4 MW) 16.00 MW

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Rated volume for 1 unit (MCM)	Estimate Discharge Req. (m^3/s)	Head Loss Revised (m)	Net Head Revised (m)	Turbine Efficiency Revised	Req. Flow Qreq (MCM)	Actual Flow Qp (MCM)	Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)
			Elevation (m)	Area (km^2)	Storage (MCM)												Storage (MCM)	Elevation (m)	Area (km^2)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Using Original Elevation - Area - Capacity Curve (from 1968 to 1978)																			
1	1969-70	April	268.5	18.53	580.0	86.8	0.79	667.6	17.3	20.9	1.12	97.1	0.79	54.9	54.9	32.7	580.0	268.5	18.53	16.0
2		May	268.5	18.53	580.0	61.2	0.00	641.2	17.8	20.9	1.12	97.1	0.79	56.8	56.8	4.4	580.0	268.5	18.53	16.0
3		June	268.5	18.53	580.0	56.1	-0.45	635.6	17.3	20.9	1.12	97.1	0.79	54.9	54.9	0.7	580.0	268.5	18.53	16.0
4		July	268.5	18.53	580.0	58.6	-0.30	638.3	17.8	20.9	1.12	97.1	0.79	56.8	56.8	1.5	580.0	268.5	18.53	16.0
5		August	268.5	18.53	580.0	40.6	-0.86	619.7	17.8	20.9	1.12	97.1	0.79	56.8	56.8	0.0	563.0	267.4	18.15	16.0
6		September	267.4	18.15	563.0	43.2	-0.62	605.6	17.3	21.1	1.15	96.0	0.79	55.5	55.5	0.0	550.1	266.6	17.85	16.0
7		October	266.6	17.85	550.1	38.3	-0.65	587.7	17.8	21.3	1.16	95.2	0.79	57.9	57.9	0.0	529.9	265.4	17.39	16.0
8		November	265.4	17.39	529.9	51.9	-0.24	581.5	17.3	21.5	1.20	93.9	0.79	56.8	56.8	0.0	524.7	265.1	17.28	16.0
9		December	265.1	17.28	524.7	51.5	-0.44	575.8	17.8	21.6	1.20	93.6	0.79	58.8	58.8	0.0	517.0	264.6	17.10	16.0
10		January	264.6	17.10	517.0	99.3	0.82	617.1	17.8	21.7	1.22	93.1	0.79	59.2	59.2	0.0	558.0	267.1	18.03	16.0
11		February	267.1	18.03	558.0	91.8	0.67	650.4	16.1	21.2	1.15	95.7	0.79	52.0	52.0	18.4	580.0	268.5	18.53	16.0
12		March	268.5	18.53	580.0	129.0	1.96	711.0	17.8	20.9	1.12	97.1	0.79	56.8	56.8	74.2	580.0	268.5	18.53	16.0
13	1970-71	April	268.5	18.53	580.0	99.3	1.18	680.5	17.3	20.9	1.12	97.1	0.79	54.9	54.9	45.6	580.0	268.5	18.53	16.0
14		May	268.5	18.53	580.0	91.2	0.93	672.1	17.8	20.9	1.12	97.1	0.79	56.8	56.8	35.4	580.0	268.5	18.53	16.0
15		June	268.5	18.53	580.0	80.1	0.59	660.7	17.3	20.9	1.12	97.1	0.79	54.9	54.9	25.8	580.0	268.5	18.53	16.0
16		July	268.5	18.53	580.0	63.7	-0.22	643.5	17.8	20.9	1.12	97.1	0.79	56.8	56.8	6.8	580.0	268.5	18.53	16.0
17		August	268.5	18.53	580.0	52.5	-0.49	632.0	17.8	20.9	1.12	97.1	0.79	56.8	56.8	0.0	575.3	268.2	18.43	16.0
18		September	268.2	18.43	575.3	42.4	-0.80	616.9	17.3	20.9	1.13	96.8	0.79	55.1	55.1	0.0	561.8	267.4	18.12	16.0
19		October	267.4	18.12	561.8	46.7	-0.51	608.0	17.8	21.1	1.15	95.9	0.79	57.4	57.4	0.0	550.5	266.7	17.86	16.0
20		November	266.7	17.86	550.5	58.7	-0.04	609.2	17.3	21.3	1.16	95.2	0.79	56.0	56.0	0.0	553.2	266.8	17.92	16.0
21		December	266.8	17.92	553.2	61.2	0.03	614.4	17.8	21.2	1.16	95.4	0.79	57.7	57.7	0.0	556.7	267.0	18.00	16.0
22		January	267.0	18.00	556.7	79.5	0.39	636.6	17.8	21.2	1.15	95.6	0.79	57.6	57.6	0.0	579.0	268.4	18.51	16.0
23		February	268.4	18.51	579.0	53.4	-0.54	631.9	16.1	20.9	1.12	97.0	0.79	51.3	51.3	0.6	580.0	268.5	18.53	16.0
24		March	268.5	18.53	580.0	62.4	-0.22	642.2	17.8	20.9	1.12	97.1	0.79	56.8	56.8	5.4	580.0	268.5	18.53	16.0
25	1971-72	April	268.5	18.53	580.0	66.6	0.02	646.6	17.3	20.9	1.12	97.1	0.79	54.9	54.9	11.7	580.0	268.5	18.53	16.0
26		May	268.5	18.53	580.0	52.6	-0.27	632.4	17.8	20.9	1.12	97.1	0.79	56.8	56.8	0.0	575.6	268.2	18.43	16.0
27		June	268.2	18.43	575.6	39.4	-0.67	614.3	17.3	20.9	1.13	96.8	0.79	55.1	55.1	0.0	559.3	267.2	18.06	16.0
28		July	267.2	18.06	559.3	37.6	-0.72	596.1	17.8	21.1	1.15	95.8	0.79	57.5	57.5	0.0	538.6	265.9	17.59	16.0
29		August	265.9	17.59	538.6	31.3	-1.16	568.7	17.8	21.4	1.18	94.5	0.79	58.3	58.3	0.0	510.4	264.2	16.95	16.0
30		September	264.2	16.95	510.4	37.3	-0.88	546.8	17.3	21.8	1.23	92.7	0.79	57.5	57.5	0.0	489.3	262.9	16.47	16.0
31		October	262.9	16.47	489.3	43.9	-0.67	532.6	17.8	22.1	1.26	91.4	0.79	60.3	60.3	0.0	472.3	261.9	16.09	16.0
32		November	261.9	16.09	472.3	77.6	0.38	550.3	17.3	22.4	1.29	90.3	0.79	59.0	59.0	0.0	491.3	263.0	16.52	16.0
33		December	263.0	16.52	491.3	87.7	0.77	579.8	17.8	22.1	1.26	91.5	0.79	60.2	60.2	0.0	519.6	264.8	17.16	16.0
34		January	264.8	17.16	519.6	93.0	0.95	613.5	17.8	21.7	1.21	93.3	0.79	59.0	59.0	0.0	554.5	266.9	17.95	16.0
35		February	266.9	17.95	554.5	66.8	0.01	621.2	16.1	21.2	1.16	95.5	0.79	52.1	52.1	0.0	569.1	267.8	18.29	16.0
36		March	267.8	18.29	569.1	64.8	-0.18	633.7	17.8	21.0	1.14	96.4	0.79	57.2	57.2	0.0	576.6	268.3	18.45	16.0

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Rated volume for 1 unit	Estimate Discharge Req.	Head Loss Revised	Net Head Revised	Turbine Efficiency Revised	Req. Flow Qreq	Actual Flow Qp	Spill Out	Reservoir at end of month			Power Generation
			Elevation (m)	Area (km^2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(m^3/s)	(m)	(m)		(MCM)	(MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km^2)	(MW)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
37	1972-73	April	268.3	18.45	576.6	68.3	-0.04	644.8	17.3	20.9	1.13	96.9	0.79	55.0	55.0	9.7	580.0	268.5	18.53	16.0
38		May	268.5	18.53	580.0	78.0	0.37	658.4	17.8	20.9	1.12	97.1	0.79	56.8	56.8	21.6	580.0	268.5	18.53	16.0
39		June	268.5	18.53	580.0	51.3	-0.31	631.0	17.3	20.9	1.12	97.1	0.79	54.9	54.9	0.0	576.1	268.2	18.44	16.0
40		July	268.2	18.44	576.1	31.8	-0.91	606.9	17.8	20.9	1.13	96.8	0.79	56.9	56.9	0.0	550.0	266.6	17.85	16.0
41		August	266.6	17.85	550.0	30.4	-0.92	579.5	17.8	21.3	1.16	95.2	0.79	57.9	57.9	0.0	521.6	264.9	17.21	16.0
42		September	264.9	17.21	521.6	22.9	-1.38	543.2	17.3	21.7	1.21	93.4	0.79	57.1	57.1	0.0	486.1	262.7	16.40	16.0
43		October	262.7	16.40	486.1	18.1	-1.38	502.8	17.8	22.2	1.27	91.2	0.79	60.4	60.4	0.0	442.4	260.0	15.41	16.0
44		November	260.0	15.41	442.4	21.2	-1.22	462.3	17.3	22.9	1.35	88.5	0.79	60.3	60.3	0.0	402.0	257.2	14.43	16.0
45		December	257.2	14.43	402.0	34.5	-0.70	435.8	17.8	23.6	1.44	85.5	0.79	64.4	64.4	0.0	371.4	255.0	13.68	16.0
46		January	255.0	13.68	371.4	55.6	-0.10	426.9	17.8	24.2	1.51	83.3	0.79	66.1	66.1	0.0	360.8	254.3	13.43	16.0
47		February	254.3	13.43	360.8	52.6	-0.17	413.2	16.1	24.4	1.54	82.6	0.79	60.3	60.3	0.0	353.0	253.7	13.24	16.0
48		March	253.7	13.24	353.0	80.0	0.30	433.3	17.8	24.6	1.56	82.0	0.79	67.2	67.2	0.0	366.1	254.7	13.56	16.0
49	1973-74	April	254.7	13.56	366.1	62.2	-0.19	428.0	17.3	24.3	1.52	82.9	0.79	64.3	64.3	0.0	363.8	254.5	13.50	16.0
50		May	254.5	13.50	363.8	79.0	0.21	442.9	17.8	24.4	1.53	82.8	0.79	66.6	66.6	0.0	376.4	255.4	13.81	16.0
51		June	255.4	13.81	376.4	56.3	-0.22	432.5	17.3	24.1	1.50	83.7	0.79	63.7	63.7	0.0	368.8	254.8	13.62	16.0
52		July	254.8	13.62	368.8	39.1	-0.51	407.4	17.8	24.3	1.52	83.1	0.79	66.3	66.3	0.0	341.1	252.9	12.95	16.0
53		August	252.9	12.95	341.1	39.6	-0.47	380.2	17.8	24.9	1.59	81.1	0.79	67.9	67.9	0.0	312.3	250.9	12.25	16.0
54		September	250.9	12.25	312.3	60.6	-0.01	372.9	17.3	25.5	1.67	79.0	0.79	67.5	67.5	0.0	305.5	250.4	12.08	16.0
55		October	250.4	12.08	305.5	48.6	-0.45	353.7	17.8	25.7	1.69	78.5	0.79	70.2	70.2	0.0	283.5	248.4	11.47	16.0
56		November	248.4	11.47	283.5	46.7	-0.42	329.8	17.3	26.3	1.78	76.4	0.79	69.7	69.7	0.0	260.1	246.1	10.79	16.0
57		December	246.1	10.79	260.1	76.4	0.15	336.7	17.8	27.1	1.90	74.0	0.79	74.4	74.4	0.0	262.2	246.3	10.85	16.0
58		January	246.3	10.85	262.2	44.6	-0.35	306.5	17.8	27.1	1.89	74.3	0.79	74.2	74.2	0.0	232.3	243.3	9.98	16.0
59		February	243.3	9.98	232.3	51.0	-0.15	283.2	16.1	28.2	2.04	71.2	0.79	69.9	69.9	0.0	213.3	241.5	9.43	16.0
60		March	241.5	9.43	213.3	39.9	-0.32	252.9	17.8	28.9	2.16	69.2	0.79	79.6	79.6	0.0	173.3	236.7	8.18	16.0
61	1974-75	April	236.7	8.18	173.3	52.3	-0.20	225.3	17.3	31.0	2.48	64.2	0.79	83.1	83.1	0.0	142.2	232.7	7.17	16.0
62		May	232.7	7.17	142.2	48.3	-0.27	190.2	17.8	33.1	2.82	59.8	0.79	92.1	91.8	0.0	98.4	226.0	5.59	16.0
63		June	226.0	5.59	98.4	32.6	-0.35	130.6	17.3	37.1	0.40	55.6	0.82	93.1	32.2	0.0	98.4	226.0	5.59	5.5
64		July	226.0	5.59	98.4	32.1	-0.32	130.2	17.8	37.1	0.36	55.7	0.80	97.9	31.8	0.0	98.4	226.0	5.59	5.2
65		August	226.0	5.59	98.4	35.2	-0.24	133.4	17.8	37.1	0.44	55.6	0.83	94.9	35.0	0.0	98.4	226.0	5.59	5.9
66		September	226.0	5.59	98.4	41.2	-0.19	139.4	17.3	37.1	0.65	55.4	0.84	90.5	41.0	0.0	98.4	226.0	5.59	7.3
67		October	226.0	5.59	98.4	35.6	-0.24	133.7	17.8	37.1	0.45	55.6	0.83	94.6	35.3	0.0	98.4	226.0	5.59	6.0
68		November	226.0	5.59	98.4	38.9	-0.30	137.0	17.3	37.1	0.57	55.4	0.85	90.2	38.6	0.0	98.4	226.0	5.59	6.8
69		December	226.0	5.59	98.4	49.8	-0.17	148.0	17.8	37.1	0.88	55.1	0.80	99.8	49.6	0.0	98.4	226.0	5.59	8.0
70		January	226.0	5.59	98.4	73.9	0.05	172.4	17.8	37.1	3.55	52.5	0.80	104.4	74.0	0.0	98.4	226.0	5.59	11.3
71		February	226.0	5.59	98.4	72.3	0.08	170.7	16.1	37.1	3.55	52.5	0.85	88.9	72.3	0.0	98.4	226.0	5.59	13.0
72		March	226.0	5.59	98.4	55.6	-0.04	153.9	17.8	37.1	1.11	54.9	0.84	94.8	55.5	0.0	98.4	226.0	5.59	9.4

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Rated volume for 1 unit (MCM)	Estimate Discharge Req. (m^3/s)	Head Loss Revised (m)	Net Head Revised (m)	Turbine Efficiency Revised	Req. Flow Qreq (MCM)	Actual Flow Qp (MCM)	Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)
			Elevation (m)	Area (km^2)	Storage (MCM)												Storage (MCM)	Elevation (m)	Area (km^2)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
73	1975-76	April	226.0	5.59	98.4	77.8	0.17	176.4	17.3	37.1	3.55	52.5	0.85	95.3	78.0	0.0	98.4	226.0	5.59	13.1
74		May	226.0	5.59	98.4	57.6	-0.08	155.9	17.8	37.1	1.19	54.8	0.84	94.5	57.5	0.0	98.4	226.0	5.59	9.8
75		June	226.0	5.59	98.4	37.9	-0.31	136.0	17.3	37.1	0.54	55.5	0.85	90.2	37.6	0.0	98.4	226.0	5.59	6.7
76		July	226.0	5.59	98.4	35.5	-0.32	133.6	17.8	37.1	0.44	55.6	0.83	94.7	35.2	0.0	98.4	226.0	5.59	6.0
77		August	226.0	5.59	98.4	36.6	-0.28	134.7	17.8	37.1	0.47	55.5	0.84	94.1	36.3	0.0	98.4	226.0	5.59	6.2
78		September	226.0	5.59	98.4	30.8	-0.29	128.9	17.3	37.1	0.36	55.7	0.80	95.1	30.5	0.0	98.4	226.0	5.59	5.1
79		October	226.0	5.59	98.4	38.3	-0.22	136.4	17.8	37.1	0.52	55.5	0.84	93.4	38.0	0.0	98.4	226.0	5.59	6.5
80		November	226.0	5.59	98.4	44.6	-0.16	142.8	17.3	37.1	0.76	55.3	0.83	92.5	44.4	0.0	98.4	226.0	5.59	7.7
81		December	226.0	5.59	98.4	35.1	-0.33	133.2	17.8	37.1	0.43	55.6	0.83	95.0	34.8	0.0	98.4	226.0	5.59	5.9
82		January	226.0	5.59	98.4	51.3	-0.16	149.5	17.8	37.1	0.94	55.1	0.82	96.5	51.1	0.0	98.4	226.0	5.59	8.5
83		February	226.0	5.59	98.4	73.8	0.05	172.3	16.1	37.1	3.55	52.5	0.85	88.9	73.9	0.0	98.4	226.0	5.59	13.3
84		March	226.0	5.59	98.4	65.6	0.02	164.0	17.8	37.1	1.55	54.5	0.84	95.6	65.6	0.0	98.4	226.0	5.59	11.0
85	1976-77	April	226.0	5.59	98.4	60.6	0.01	159.0	17.3	37.1	1.41	54.6	0.85	91.6	60.6	0.0	98.4	226.0	5.59	10.6
86		May	226.0	5.59	98.4	39.6	-0.19	137.8	17.8	37.1	0.56	55.5	0.85	93.2	39.4	0.0	98.4	226.0	5.59	6.8
87		June	226.0	5.59	98.4	25.6	-0.38	123.6	17.3	37.1	0.24	55.8	0.72	105.0	25.2	0.0	98.4	226.0	5.59	3.8
88		July	226.0	5.59	98.4	34.1	-0.34	132.1	17.8	37.1	0.41	55.6	0.82	95.9	33.7	0.0	98.4	226.0	5.59	5.6
89		August	226.0	5.59	98.4	30.8	-0.36	128.8	17.8	37.1	0.33	55.7	0.79	99.8	30.4	0.0	98.4	226.0	5.59	4.9
90		September	226.0	5.59	98.4	18.2	-0.45	116.2	17.3	37.1	0.12	55.9	0.84	90.3	17.8	0.0	98.4	226.0	5.59	3.2
91		October	226.0	5.59	98.4	38.1	-0.22	136.3	17.8	37.1	0.52	55.5	0.84	93.5	37.9	0.0	98.4	226.0	5.59	6.5
92		November	226.0	5.59	98.4	36.3	-0.23	134.4	17.3	37.1	0.50	55.5	0.84	90.7	36.0	0.0	98.4	226.0	5.59	6.4
93		December	226.0	5.59	98.4	47.8	-0.13	146.0	17.8	37.1	0.81	55.2	0.81	97.2	47.6	0.0	98.4	226.0	5.59	7.8
94		January	226.0	5.59	98.4	67.0	-0.04	165.3	17.8	37.1	1.61	54.4	0.84	96.2	66.9	0.0	98.4	226.0	5.59	11.1
95		February	226.0	5.59	98.4	88.0	0.21	186.7	16.1	37.1	3.55	52.5	0.80	93.7	88.3	0.0	98.4	226.0	5.59	15.1
96		March	226.0	5.59	98.4	69.9	0.08	168.4	17.8	37.1	1.76	54.3	0.82	98.0	70.0	0.0	98.4	226.0	5.59	11.4
97	1977-78	April	226.0	5.59	98.4	99.5	0.36	198.2	17.3	37.1	3.55	52.5	0.79	101.6	99.8	0.0	98.4	226.0	5.59	15.7
98		May	226.0	5.59	98.4	60.9	0.00	159.3	17.8	37.1	1.33	54.7	0.85	94.5	60.9	0.0	98.4	226.0	5.59	10.3
99		June	226.0	5.59	98.4	69.9	-0.01	168.3	17.3	37.1	3.55	52.5	0.81	99.6	69.9	0.0	98.4	226.0	5.59	11.2
100		July	226.0	5.59	98.4	51.4	-0.16	149.7	17.8	37.1	0.94	55.1	0.82	96.4	51.3	0.0	98.4	226.0	5.59	8.5
101		August	226.0	5.59	98.4	34.5	-0.32	132.6	17.8	37.1	0.42	55.6	0.82	95.5	34.2	0.0	98.4	226.0	5.59	5.7
102		September	226.0	5.59	98.4	32.9	-0.29	131.0	17.3	37.1	0.41	55.6	0.82	92.8	32.6	0.0	98.4	226.0	5.59	5.6
103		October	226.0	5.59	98.4	30.4	-0.28	128.6	17.8	37.1	0.33	55.7	0.78	100.2	30.2	0.0	98.4	226.0	5.59	4.8
104		November	226.0	5.59	98.4	26.1	-0.32	124.2	17.3	37.1	0.25	55.8	0.73	103.5	25.8	0.0	98.4	226.0	5.59	4.0
105		December	226.0	5.59	98.4	67.7	0.01	166.1	17.8	37.1	1.65	54.4	0.83	96.6	67.7	0.0	98.4	226.0	5.59	11.2
106		January	226.0	5.59	98.4	69.0	-0.02	167.4	17.8	37.1	1.71	54.3	0.83	97.3	69.0	0.0	98.4	226.0	5.59	11.4
107		February	226.0	5.59	98.4	84.2	0.17	182.8	16.1	37.1	3.55	52.5	0.82	91.5	84.4	0.0	98.4	226.0	5.59	14.8
108		March	226.0	5.59	98.4	134.8	0.69	233.9	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	128.9	230.9	6.73	16.0

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss -(MCM)	Gross Water Available (MCM)	Rated volume for 1 unit (MCM)	Estimate Discharge Req. (m^3/s)	Head Loss Revised (m)	Net Head Revised (m)	Turbine Efficiency Revised	Req. Flow Qreq (MCM)	Actual Flow Qp (MCM)	Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)
			Elevation (m)	Area (km^2)	Storage (MCM)												Storage (MCM)	Elevation (m)	Area (km^2)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
109	1978-79	April	230.9	6.73	128.9	80.8	0.22	209.9	17.3	34.1	2.99	57.9	0.79	92.1	92.1	0.0	117.8	229.3	6.34	16.0
110		May	229.3	6.34	117.8	91.0	0.32	209.1	17.8	35.0	3.16	56.1	0.79	98.1	98.1	0.0	110.9	228.2	6.08	16.0
111		June	228.2	6.08	110.9	82.5	0.12	193.5	17.3	35.7	3.29	54.8	0.79	97.2	95.1	0.0	98.4	226.0	5.59	15.7
112		July	226.0	5.59	98.4	61.1	-0.07	159.5	17.8	37.1	1.34	54.7	0.85	94.5	61.1	0.0	98.4	226.0	5.59	10.4
113		August	226.0	5.59	98.4	51.8	-0.16	150.0	17.8	37.1	0.96	55.1	0.83	96.2	51.6	0.0	98.4	226.0	5.59	8.6
114		September	226.0	5.59	98.4	47.9	-0.15	146.2	17.3	37.1	0.88	55.1	0.80	96.2	47.8	0.0	98.4	226.0	5.59	8.0
115		October	226.0	5.59	98.4	46.3	-0.13	144.6	17.8	37.1	0.77	55.2	0.83	95.8	46.2	0.0	98.4	226.0	5.59	7.7
116		November	226.0	5.59	98.4	70.9	0.10	169.4	17.3	37.1	3.55	52.5	0.80	100.5	71.0	0.0	98.4	226.0	5.59	11.3
117		December	226.0	5.59	98.4	123.6	0.53	222.5	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	117.5	229.3	6.33	16.0
118		January	229.3	6.33	117.5	86.6	0.17	204.3	17.8	35.0	3.16	56.1	0.79	98.2	98.2	0.0	106.0	227.3	5.88	16.0
119		February	227.3	5.88	106.0	110.4	0.44	216.9	16.1	36.3	3.39	53.9	0.79	92.3	92.3	0.0	124.6	230.4	6.59	16.0
120		March	230.4	6.59	124.6	88.4	0.30	213.3	17.8	34.4	3.05	57.3	0.79	96.2	96.2	0.0	117.1	229.2	6.32	16.0
	Using Elevation - Area - Capacity Curve Revised after 10 Years																			
121	1979-80	April	229.2	6.32	111.5	89.2	0.30	201.0	17.3	35.1	3.17	56.0	0.79	95.2	95.2	0.0	105.8	228.2	5.96	16.0
122		May	228.2	5.96	105.8	88.0	0.27	194.1	17.8	35.7	3.28	54.9	0.79	100.3	100.3	0.0	93.8	226.1	5.48	16.0
123		June	226.1	5.48	93.8	62.1	-0.08	155.8	17.3	37.1	1.50	54.6	0.84	92.0	62.6	0.0	93.3	226.0	5.46	10.9
124		July	226.0	5.46	93.3	102.0	0.31	195.6	17.8	37.1	3.55	52.5	0.79	105.0	102.3	0.0	93.3	226.0	5.46	15.6
125		August	226.0	5.46	93.3	62.1	-0.06	155.3	17.8	37.1	1.38	54.6	0.85	94.6	62.0	0.0	93.3	226.0	5.46	10.5
126		September	226.0	5.46	93.3	51.3	-0.11	144.4	17.3	37.1	1.00	55.0	0.83	92.6	51.1	0.0	93.3	226.0	5.46	8.8
127		October	226.0	5.46	93.3	39.7	-0.19	132.8	17.8	37.1	0.56	55.5	0.85	93.2	39.5	0.0	93.3	226.0	5.46	6.8
128		November	226.0	5.46	93.3	40.1	-0.18	133.1	17.3	37.1	0.61	55.4	0.85	90.2	39.9	0.0	93.3	226.0	5.46	7.1
129		December	226.0	5.46	93.3	46.9	-0.18	139.9	17.8	37.1	0.78	55.2	0.82	96.2	46.7	0.0	93.3	226.0	5.46	7.8
130		January	226.0	5.46	93.3	93.8	0.21	187.2	17.8	37.1	3.55	52.5	0.82	101.6	94.0	0.0	93.3	226.0	5.46	14.8
131		February	226.0	5.46	93.3	61.6	-0.04	154.9	16.1	37.1	1.67	54.3	0.83	87.4	61.6	0.0	93.3	226.0	5.46	11.3
132		March	226.0	5.46	93.3	59.5	-0.02	152.8	17.8	37.1	1.27	54.7	0.85	94.4	59.5	0.0	93.3	226.0	5.46	10.1
133	1980-81	April	226.0	5.46	93.3	63.9	0.02	157.2	17.3	37.1	1.57	54.5	0.84	92.7	64.0	0.0	93.3	226.0	5.46	11.1
134		May	226.0	5.46	93.3	55.8	-0.05	149.0	17.8	37.1	1.12	54.9	0.84	94.8	55.8	0.0	93.3	226.0	5.46	9.4
135		June	226.0	5.46	93.3	43.6	-0.25	136.6	17.3	37.1	0.72	55.3	0.83	91.7	43.4	0.0	93.3	226.0	5.46	7.6
136		July	226.0	5.46	93.3	37.5	-0.28	130.4	17.8	37.1	0.50	55.5	0.84	93.7	37.2	0.0	93.3	226.0	5.46	6.4
137		August	226.0	5.46	93.3	50.2	-0.17	143.2	17.8	37.1	0.90	55.1	0.82	97.1	50.0	0.0	93.3	226.0	5.46	8.2
138		September	226.0	5.46	93.3	61.0	-0.02	154.2	17.3	37.1	1.43	54.6	0.85	91.7	61.0	0.0	93.3	226.0	5.46	10.6
139		October	226.0	5.46	93.3	47.5	-0.11	140.6	17.8	37.1	0.81	55.2	0.82	96.9	47.4	0.0	93.3	226.0	5.46	7.8
140		November	226.0	5.46	93.3	95.8	0.33	189.4	17.3	37.1	3.55	52.5	0.79	101.5	96.1	0.0	93.3	226.0	5.46	15.2
141		December	226.0	5.46	93.3	117.0	0.46	210.7	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	105.7	228.2	5.95	16.0
142		January	228.2	5.95	105.7	82.3	0.12	188.1	17.8	35.7	3.28	54.9	0.80	99.8	94.9	0.0	93.3	226.0	5.46	15.2
143		February	226.0	5.46	93.3	71.9	0.05	165.2	16.1	37.1	3.55	52.5	0.85	88.9	72.0	0.0	93.3	226.0	5.46	13.0
144		March	226.0	5.46	93.3	109.1	0.44	202.7	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	97.7	226.8	5.64	16.0

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Rated volume for 1 unit	Estimate Discharge Req.	Head Loss Revised	Net Head Revised	Turbine Efficiency Revised	Req. Flow Qreq	Actual Flow Qp	Spill Out	Reservoir at end of month			Power Generation
			Elevation (m)	Area (km^2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(m^3/s)	(m)	(m)		(MCM)	(MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km^2)	(MW)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
145	1981-82	April	226.8	5.64	97.7	112.6	0.49	210.8	17.3	36.6	3.45	53.3	0.79	99.9	99.9	0.0	110.9	229.1	6.16	16.0
146		May	229.1	6.16	110.9	115.9	0.57	227.3	17.8	35.2	3.18	55.9	0.79	98.6	98.6	0.0	128.7	231.7	6.79	16.0
147		June	231.7	6.79	128.7	67.6	-0.04	196.3	17.3	33.6	2.91	58.7	0.79	90.8	90.8	0.0	105.5	228.2	5.95	16.0
148		July	228.2	5.95	105.5	47.9	-0.20	153.2	17.8	35.7	1.29	56.8	0.85	90.9	59.9	0.0	93.3	226.0	5.46	10.6
149		August	226.0	5.46	93.3	35.9	-0.30	128.8	17.8	37.1	0.45	55.6	0.83	94.5	35.6	0.0	93.3	226.0	5.46	6.0
150		September	226.0	5.46	93.3	60.1	-0.03	153.3	17.3	37.1	1.38	54.6	0.85	91.5	60.1	0.0	93.3	226.0	5.46	10.5
151		October	226.0	5.46	93.3	43.8	-0.15	136.9	17.8	37.1	0.68	55.3	0.84	94.0	43.6	0.0	93.3	226.0	5.46	7.4
152		November	226.0	5.46	93.3	40.6	-0.18	133.7	17.3	37.1	0.63	55.4	0.85	90.4	40.4	0.0	93.3	226.0	5.46	7.2
153		December	226.0	5.46	93.3	56.1	-0.10	149.3	17.8	37.1	1.13	54.9	0.84	94.7	56.0	0.0	93.3	226.0	5.46	9.5
154		January	226.0	5.46	93.3	109.6	0.36	203.2	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	98.2	226.9	5.65	16.0
155		February	226.9	5.65	98.2	102.2	0.34	200.8	16.1	36.6	3.44	53.4	0.79	93.1	93.1	0.0	107.6	228.5	6.03	16.0
156		March	228.5	6.03	107.6	84.4	0.23	192.2	17.8	35.5	3.25	55.3	0.79	99.7	99.0	0.0	93.3	226.0	5.46	15.9
157	1982-83	April	226.0	5.46	93.3	62.8	0.01	156.1	17.3	37.1	1.51	54.5	0.84	92.3	62.8	0.0	93.3	226.0	5.46	10.9
158		May	226.0	5.46	93.3	47.8	-0.12	140.9	17.8	37.1	0.81	55.2	0.81	97.2	47.6	0.0	93.3	226.0	5.46	7.8
159		June	226.0	5.46	93.3	31.8	-0.36	124.6	17.3	37.1	0.38	55.6	0.81	94.0	31.4	0.0	93.3	226.0	5.46	5.3
160		July	226.0	5.46	93.3	29.1	-0.36	122.0	17.8	37.1	0.30	55.7	0.77	102.5	28.8	0.0	93.3	226.0	5.46	4.5
161		August	226.0	5.46	93.3	21.2	-0.43	114.0	17.8	37.1	0.15	55.9	0.85	92.5	20.8	0.0	93.3	226.0	5.46	3.6
162		September	226.0	5.46	93.3	16.6	-0.43	109.4	17.3	37.1	0.10	55.9	0.82	92.5	16.2	0.0	93.3	226.0	5.46	2.8
163		October	226.0	5.46	93.3	14.2	-0.42	107.1	17.8	37.1	0.07	55.9	0.75	104.4	13.8	0.0	93.3	226.0	5.46	2.1
164		November	226.0	5.46	93.3	13.9	-0.42	106.8	17.3	37.1	0.07	55.9	0.75	100.4	13.5	0.0	93.3	226.0	5.46	2.2
165		December	226.0	5.46	93.3	42.8	-0.22	135.9	17.8	37.1	0.65	55.4	0.84	93.6	42.6	0.0	93.3	226.0	5.46	7.3
166		January	226.0	5.46	93.3	93.9	0.21	187.3	17.8	37.1	3.55	52.5	0.82	101.7	94.1	0.0	93.3	226.0	5.46	14.8
167		February	226.0	5.46	93.3	62.7	-0.03	156.0	16.1	37.1	1.73	54.3	0.83	88.1	62.7	0.0	93.3	226.0	5.46	11.4
168		March	226.0	5.46	93.3	74.1	0.12	167.5	17.8	37.1	3.55	52.5	0.80	104.7	74.3	0.0	93.3	226.0	5.46	11.4
169	1983-84	April	226.0	5.46	93.3	72.6	0.10	166.0	17.3	37.1	3.55	52.5	0.84	95.8	72.7	0.0	93.3	226.0	5.46	12.2
170		May	226.0	5.46	93.3	78.4	0.16	171.8	17.8	37.1	3.55	52.5	0.85	98.5	78.6	0.0	93.3	226.0	5.46	12.8
171		June	226.0	5.46	93.3	47.2	-0.22	140.3	17.3	37.1	0.85	55.2	0.81	95.2	47.0	0.0	93.3	226.0	5.46	7.9
172		July	226.0	5.46	93.3	36.5	-0.29	129.4	17.8	37.1	0.47	55.5	0.84	94.2	36.2	0.0	93.3	226.0	5.46	6.2
173		August	226.0	5.46	93.3	25.8	-0.39	118.7	17.8	37.1	0.23	55.8	0.71	110.0	25.4	0.0	93.3	226.0	5.46	3.7
174		September	226.0	5.46	93.3	18.1	-0.42	111.0	17.3	37.1	0.12	55.9	0.84	90.3	17.7	0.0	93.3	226.0	5.46	3.1
175		October	226.0	5.46	93.3	19.4	-0.37	112.3	17.8	37.1	0.13	55.9	0.84	92.7	19.0	0.0	93.3	226.0	5.46	3.3
176		November	226.0	5.46	93.3	33.0	-0.25	126.0	17.3	37.1	0.41	55.6	0.82	92.7	32.7	0.0	93.3	226.0	5.46	5.7
177		December	226.0	5.46	93.3	35.7	-0.28	128.7	17.8	37.1	0.45	55.6	0.83	94.6	35.4	0.0	93.3	226.0	5.46	6.0
178		January	226.0	5.46	93.3	56.8	-0.13	149.9	17.8	37.1	1.15	54.9	0.84	94.6	56.7	0.0	93.3	226.0	5.46	9.6
179		February	226.0	5.46	93.3	40.1	-0.24	133.1	16.1	37.1	0.70	55.3	0.84	85.2	39.9	0.0	93.3	226.0	5.46	7.5
180		March	226.0	5.46	93.3	87.3	0.24	180.8	17.8	37.1	3.55	52.5	0.84	99.3	87.6	0.0	93.3	226.0	5.46	14.1

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Rated volume for 1 unit (MCM)	Estimate Discharge Req. (m^3/s)	Head Loss Revised (m)	Net Head Revised (m)	Turbine Efficiency Revised	Req. Flow Qreq (MCM)	Actual Flow Qp (MCM)	Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)
			Elevation (m)	Area (km^2)	Storage (MCM)												Storage (MCM)	Elevation (m)	Area (km^2)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
181	1984-85	April	226.0	5.46	93.3	68.9	0.07	162.2	17.3	37.1	1.82	54.2	0.82	95.7	68.9	0.0	93.3	226.0	5.46	11.5
182		May	226.0	5.46	93.3	52.3	-0.08	145.5	17.8	37.1	0.98	55.0	0.83	95.9	52.2	0.0	93.3	226.0	5.46	8.7
183		June	226.0	5.46	93.3	35.7	-0.32	128.6	17.3	37.1	0.48	55.5	0.84	90.9	35.3	0.0	93.3	226.0	5.46	6.2
184		July	226.0	5.46	93.3	40.3	-0.26	133.3	17.8	37.1	0.58	55.4	0.85	93.2	40.1	0.0	93.3	226.0	5.46	6.9
185		August	226.0	5.46	93.3	33.4	-0.32	126.4	17.8	37.1	0.39	55.6	0.82	96.4	33.1	0.0	93.3	226.0	5.46	5.5
186		September	226.0	5.46	93.3	48.1	-0.14	141.2	17.3	37.1	0.88	55.1	0.80	96.5	48.0	0.0	93.3	226.0	5.46	8.0
187		October	226.0	5.46	93.3	60.2	0.00	153.4	17.8	37.1	1.30	54.7	0.85	94.4	60.2	0.0	93.3	226.0	5.46	10.2
188		November	226.0	5.46	93.3	70.1	0.09	163.4	17.3	37.1	3.55	52.5	0.81	99.8	70.2	0.0	93.3	226.0	5.46	11.3
189		December	226.0	5.46	93.3	69.8	0.03	163.1	17.8	37.1	1.75	54.3	0.82	97.8	69.8	0.0	93.3	226.0	5.46	11.4
190		January	226.0	5.46	93.3	96.1	0.23	189.6	17.8	37.1	3.55	52.5	0.81	102.9	96.3	0.0	93.3	226.0	5.46	15.0
191		February	226.0	5.46	93.3	171.3	0.96	265.5	16.1	37.1	3.55	52.5	0.79	94.8	94.8	0.0	170.6	237.2	8.18	16.0
192		March	237.2	8.18	170.6	88.0	0.37	259.0	17.8	30.8	2.44	64.7	0.79	85.1	85.1	0.0	173.8	237.7	8.28	16.0
193	1985-86	April	237.7	8.28	173.8	93.5	0.45	267.8	17.3	30.6	2.41	65.2	0.79	81.8	81.8	0.0	186.0	239.3	8.68	16.0
194		May	239.3	8.68	186.0	71.7	0.15	257.8	17.8	29.9	2.30	66.9	0.79	82.4	82.4	0.0	175.5	237.9	8.34	16.0
195		June	237.9	8.34	175.5	49.1	-0.30	224.3	17.3	30.5	2.39	65.4	0.79	81.5	81.5	0.0	142.7	233.5	7.25	16.0
196		July	233.5	7.25	142.7	52.2	-0.20	194.7	17.8	32.6	2.74	60.7	0.79	90.7	90.7	0.0	104.0	227.9	5.89	16.0
197		August	227.9	5.89	104.0	44.6	-0.23	148.5	17.8	35.9	1.09	56.8	0.84	91.3	55.2	0.0	93.3	226.0	5.46	9.7
198		September	226.0	5.46	93.3	40.3	-0.21	133.3	17.3	37.1	0.61	55.4	0.85	90.3	40.0	0.0	93.3	226.0	5.46	7.1
199		October	226.0	5.46	93.3	45.3	-0.14	138.4	17.8	37.1	0.73	55.3	0.83	94.9	45.1	0.0	93.3	226.0	5.46	7.6
200		November	226.0	5.46	93.3	37.5	-0.21	130.5	17.3	37.1	0.53	55.5	0.84	90.3	37.3	0.0	93.3	226.0	5.46	6.6
201		December	226.0	5.46	93.3	40.9	-0.23	134.0	17.8	37.1	0.59	55.4	0.85	93.2	40.7	0.0	93.3	226.0	5.46	7.0
202		January	226.0	5.46	93.3	67.4	-0.03	160.6	17.8	37.1	1.63	54.4	0.83	96.4	67.4	0.0	93.3	226.0	5.46	11.2
203		February	226.0	5.46	93.3	58.1	-0.07	151.3	16.1	37.1	1.48	54.5	0.84	85.9	58.0	0.0	93.3	226.0	5.46	10.8
204		March	226.0	5.46	93.3	91.1	0.27	184.6	17.8	37.1	3.55	52.5	0.83	100.5	91.4	0.0	93.3	226.0	5.46	14.6
205	1986-87	April	226.0	5.46	93.3	72.5	0.10	165.9	17.3	37.1	3.55	52.5	0.84	95.8	72.6	0.0	93.3	226.0	5.46	12.1
206		May	226.0	5.46	93.3	61.2	0.00	154.4	17.8	37.1	1.34	54.7	0.85	94.5	61.2	0.0	93.3	226.0	5.46	10.4
207		June	226.0	5.46	93.3	60.0	-0.10	153.2	17.3	37.1	1.38	54.6	0.85	91.5	59.9	0.0	93.3	226.0	5.46	10.5
208		July	226.0	5.46	93.3	61.2	-0.07	154.4	17.8	37.1	1.34	54.7	0.85	94.5	61.1	0.0	93.3	226.0	5.46	10.4
209		August	226.0	5.46	93.3	45.6	-0.21	138.6	17.8	37.1	0.74	55.3	0.83	95.1	45.4	0.0	93.3	226.0	5.46	7.6
210		September	226.0	5.46	93.3	57.7	-0.05	150.9	17.3	37.1	1.27	54.7	0.85	91.3	57.6	0.0	93.3	226.0	5.46	10.1
211		October	226.0	5.46	93.3	56.1	-0.04	149.3	17.8	37.1	1.13	54.9	0.84	94.7	56.1	0.0	93.3	226.0	5.46	9.5
212		November	226.0	5.46	93.3	80.6	0.19	174.1	17.3	37.1	3.55	52.5	0.85	95.4	80.8	0.0	93.3	226.0	5.46	13.6
213		December	226.0	5.46	93.3	96.0	0.27	189.5	17.8	37.1	3.55	52.5	0.81	102.9	96.3	0.0	93.3	226.0	5.46	15.0
214		January	226.0	5.46	93.3	118.5	0.44	212.2	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	107.2	228.5	6.01	16.0
215		February	228.5	6.01	107.2	102.2	0.37	209.7	16.1	35.6	3.26	55.2	0.79	90.2	90.2	0.0	119.5	230.5	6.48	16.0
216		March	230.5	6.48	119.5	83.9	0.25	203.7	17.8	34.3	3.04	57.4	0.79	96.0	96.0	0.0	107.7	228.5	6.03	16.0

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Rated volume for 1 unit (MCM)	Estimate Discharge Req. (m^3/s)	Head Loss Revised (m)	Net Head Revised (m)	Turbine Efficiency Revised	Req. Flow Qreq (MCM)	Actual Flow Qp (MCM)	Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)
			Elevation (m)	Area (km^2)	Storage (MCM)												Storage (MCM)	Elevation (m)	Area (km^2)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
217	1987-88	April	228.5	6.03	107.7	88.7	0.28	196.7	17.3	35.5	3.24	55.3	0.79	96.5	96.5	0.0	100.3	227.2	5.74	16.0
218		May	227.2	5.74	100.3	75.9	0.14	176.3	17.8	36.3	3.40	53.8	0.84	96.2	83.0	0.0	93.3	226.0	5.46	13.8
219		June	226.0	5.46	93.3	70.7	0.00	164.0	17.3	37.1	3.55	52.5	0.80	100.2	70.7	0.0	93.3	226.0	5.46	11.3
220		July	226.0	5.46	93.3	41.1	-0.25	134.1	17.8	37.1	0.60	55.4	0.85	93.2	40.9	0.0	93.3	226.0	5.46	7.0
221		August	226.0	5.46	93.3	31.9	-0.33	124.8	17.8	37.1	0.36	55.7	0.80	98.2	31.5	0.0	93.3	226.0	5.46	5.1
222		September	226.0	5.46	93.3	31.4	-0.29	124.4	17.3	37.1	0.37	55.6	0.81	94.3	31.1	0.0	93.3	226.0	5.46	5.3
223		October	226.0	5.46	93.3	28.4	-0.29	121.4	17.8	37.1	0.28	55.7	0.76	103.8	28.1	0.0	93.3	226.0	5.46	4.3
224		November	226.0	5.46	93.3	38.9	-0.19	132.0	17.3	37.1	0.57	55.4	0.85	90.2	38.7	0.0	93.3	226.0	5.46	6.9
225		December	226.0	5.46	93.3	55.8	-0.10	148.9	17.8	37.1	1.11	54.9	0.84	94.8	55.7	0.0	93.3	226.0	5.46	9.4
226		January	226.0	5.46	93.3	109.9	0.36	203.6	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	98.6	227.0	5.67	16.0
227		February	227.0	5.67	98.6	79.6	0.13	178.3	16.1	36.5	3.43	53.5	0.81	90.8	85.0	0.0	93.3	226.0	5.46	15.0
228		March	226.0	5.46	93.3	108.1	0.43	201.8	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	96.8	226.6	5.60	16.0
229	1988-89	April	226.6	5.60	96.8	57.3	-0.04	154.1	17.3	36.7	1.42	55.2	0.84	90.8	60.8	0.0	93.3	226.0	5.46	10.7
230		May	226.0	5.46	93.3	52.6	-0.08	145.7	17.8	37.1	0.99	55.0	0.83	95.8	52.5	0.0	93.3	226.0	5.46	8.8
231		June	226.0	5.46	93.3	39.0	-0.29	131.9	17.3	37.1	0.57	55.4	0.85	90.2	38.7	0.0	93.3	226.0	5.46	6.9
232		July	226.0	5.46	93.3	36.7	-0.29	129.7	17.8	37.1	0.48	55.5	0.84	94.0	36.4	0.0	93.3	226.0	5.46	6.2
233		August	226.0	5.46	93.3	35.0	-0.31	128.0	17.8	37.1	0.43	55.6	0.83	95.1	34.7	0.0	93.3	226.0	5.46	5.8
234		September	226.0	5.46	93.3	22.1	-0.38	115.0	17.3	37.1	0.18	55.8	0.83	90.8	21.7	0.0	93.3	226.0	5.46	3.8
235		October	226.0	5.46	93.3	23.1	-0.34	116.0	17.8	37.1	0.19	55.8	0.83	94.3	22.8	0.0	93.3	226.0	5.46	3.9
236		November	226.0	5.46	93.3	53.2	-0.06	146.4	17.3	37.1	1.08	54.9	0.84	91.9	53.2	0.0	93.3	226.0	5.46	9.3
237		December	226.0	5.46	93.3	46.7	-0.18	139.8	17.8	37.1	0.78	55.2	0.82	96.1	46.5	0.0	93.3	226.0	5.46	7.8
238		January	226.0	5.46	93.3	93.7	0.21	187.2	17.8	37.1	3.55	52.5	0.82	101.6	93.9	0.0	93.3	226.0	5.46	14.8
239		February	226.0	5.46	93.3	100.6	0.32	194.1	16.1	37.1	3.55	52.5	0.79	94.8	94.8	0.0	99.3	227.1	5.70	16.0
240		March	227.1	5.70	99.3	82.6	0.20	182.1	17.8	36.4	3.42	53.6	0.83	98.0	88.9	0.0	93.3	226.0	5.46	14.5
	Using Elevation - Area - Capacity Curve Revised after 20 Years																			
241	1989-90	April	226.0	5.46	88.4	58.2	-0.03	146.6	17.3	37.1	1.30	54.7	0.85	91.3	58.2	0.0	88.5	226.0	5.32	10.2
242		May	226.0	5.32	88.5	45.6	-0.14	133.9	17.8	37.1	0.74	55.3	0.83	95.2	45.4	0.0	88.5	226.0	5.32	7.6
243		June	226.0	5.32	88.5	39.7	-0.28	127.9	17.3	37.1	0.60	55.4	0.85	90.2	39.5	0.0	88.5	226.0	5.32	7.0
244		July	226.0	5.32	88.5	7.7	-0.54	95.6	17.8	37.1	0.02	56.0	0.52	150.2	0.0	0.0	95.6	227.3	5.61	0.0
245		August	227.3	5.61	95.6	10.8	-0.54	105.8	17.8	36.3	0.11	57.2	0.83	91.8	17.4	0.0	88.5	226.0	5.32	3.0
246		September	226.0	5.32	88.5	35.0	-0.26	123.2	17.3	37.1	0.46	55.6	0.83	91.3	34.7	0.0	88.5	226.0	5.32	6.1
247		October	226.0	5.32	88.5	23.5	-0.33	111.6	17.8	37.1	0.19	55.8	0.82	95.0	23.2	0.0	88.5	226.0	5.32	3.9
248		November	226.0	5.32	88.5	14.3	-0.41	102.3	17.3	37.1	0.07	56.0	0.76	99.0	13.8	0.0	88.5	226.0	5.32	2.2
249		December	226.0	5.32	88.5	35.6	-0.28	123.8	17.8	37.1	0.45	55.6	0.83	94.6	35.4	0.0	88.5	226.0	5.32	6.0
250		January	226.0	5.32	88.5	62.5	-0.07	150.8	17.8	37.1	1.40	54.6	0.85	94.6	62.4	0.0	88.5	226.0	5.32	10.6
251		February	226.0	5.32	88.5	83.0	0.15	171.6	16.1	37.1	3.55	52.5	0.83	91.0	83.2	0.0	88.5	226.0	5.32	14.6
252		March	226.0	5.32	88.5	62.8	0.01	151.2	17.8	37.1	1.42	54.6	0.85	94.7	62.8	0.0	88.5	226.0	5.32	10.6

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Rated volume for 1 unit	Estimate Discharge Req.	Head Loss Revised	Net Head Revised	Turbine Efficiency Revised	Req. Flow Qreq	Actual Flow Qp	Spill Out	Reservoir at end of month			Power Generation
			Elevation (m)	Area (km^2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(m^3/s)	(m)	(m)		(MCM)	(MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km^2)	(MW)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
253	1990-91	April	226.0	5.32	88.5	50.1	-0.10	138.4	17.3	37.1	0.96	55.1	0.83	93.1	50.0	0.0	88.5	226.0	5.32	8.6
254		May	226.0	5.32	88.5	49.1	-0.11	137.4	17.8	37.1	0.86	55.2	0.80	98.9	49.0	0.0	88.5	226.0	5.32	7.9
255		June	226.0	5.32	88.5	37.7	-0.30	125.8	17.3	37.1	0.54	55.5	0.84	90.3	37.4	0.0	88.5	226.0	5.32	6.6
256		July	226.0	5.32	88.5	31.3	-0.33	119.4	17.8	37.1	0.34	55.7	0.79	99.0	30.9	0.0	88.5	226.0	5.32	5.0
257		August	226.0	5.32	88.5	22.8	-0.41	110.8	17.8	37.1	0.18	55.8	0.84	93.8	22.4	0.0	88.5	226.0	5.32	3.8
258		September	226.0	5.32	88.5	20.6	-0.38	108.7	17.3	37.1	0.16	55.9	0.85	89.6	20.2	0.0	88.5	226.0	5.32	3.6
259		October	226.0	5.32	88.5	9.5	-0.45	97.5	17.8	37.1	0.03	56.0	0.55	142.0	0.0	0.0	97.5	227.7	5.69	0.0
260		November	227.7	5.69	97.5	12.8	-0.45	109.9	17.3	36.1	0.18	57.5	0.83	88.7	21.4	0.0	88.5	226.0	5.32	3.9
261		December	226.0	5.32	88.5	50.9	-0.14	139.2	17.8	37.1	0.92	55.1	0.82	96.7	50.7	0.0	88.5	226.0	5.32	8.4
262		January	226.0	5.32	88.5	69.2	-0.01	157.6	17.8	37.1	1.72	54.3	0.83	97.4	69.2	0.0	88.5	226.0	5.32	11.4
263		February	226.0	5.32	88.5	43.2	-0.20	131.4	16.1	37.1	0.81	55.2	0.82	87.8	43.0	0.0	88.5	226.0	5.32	7.8
264		March	226.0	5.32	88.5	75.9	0.13	164.5	17.8	37.1	3.55	52.5	0.84	98.8	76.0	0.0	88.5	226.0	5.32	12.3
265	1991-92	April	226.0	5.32	88.5	65.6	0.04	154.0	17.3	37.1	1.65	54.4	0.83	93.5	65.6	0.0	88.5	226.0	5.32	11.2
266		May	226.0	5.32	88.5	92.4	0.28	181.2	17.8	37.1	3.55	52.5	0.83	101.0	92.7	0.0	88.5	226.0	5.32	14.7
267		June	226.0	5.32	88.5	40.9	-0.27	129.1	17.3	37.1	0.63	55.4	0.85	90.4	40.7	0.0	88.5	226.0	5.32	7.2
268		July	226.0	5.32	88.5	25.2	-0.39	113.3	17.8	37.1	0.22	55.8	0.79	98.7	24.8	0.0	88.5	226.0	5.32	4.0
269		August	226.0	5.32	88.5	19.8	-0.43	107.8	17.8	37.1	0.13	55.9	0.84	92.6	19.3	0.0	88.5	226.0	5.32	3.3
270		September	226.0	5.32	88.5	14.0	-0.44	102.0	17.3	37.1	0.07	56.0	0.75	100.2	13.6	0.0	88.5	226.0	5.32	2.2
271		October	226.0	5.32	88.5	9.0	-0.46	97.0	17.8	37.1	0.03	56.0	0.52	149.4	0.0	0.0	97.0	227.6	5.67	0.0
272		November	227.6	5.67	97.0	31.6	-0.27	128.3	17.3	36.1	0.61	56.9	0.84	88.0	39.9	0.0	88.5	226.0	5.32	7.3
273		December	226.0	5.32	88.5	59.3	-0.07	147.7	17.8	37.1	1.26	54.8	0.85	94.4	59.2	0.0	88.5	226.0	5.32	10.1
274		January	226.0	5.32	88.5	48.1	-0.20	136.4	17.8	37.1	0.82	55.2	0.81	97.5	47.9	0.0	88.5	226.0	5.32	7.9
275		February	226.0	5.32	88.5	66.6	0.01	155.1	16.1	37.1	3.55	52.5	0.80	94.1	66.6	0.0	88.5	226.0	5.32	11.3
276		March	226.0	5.32	88.5	131.3	0.63	220.4	17.8	37.1	3.55	52.5	0.79	105.0	105.0	0.0	115.4	230.6	6.39	16.0
277	1992-93	April	230.6	6.39	115.4	98.4	0.40	214.2	17.3	34.2	3.02	57.6	0.79	92.6	92.6	0.0	121.6	231.5	6.60	16.0
278		May	231.5	6.60	121.6	63.6	0.03	185.2	17.8	33.8	2.93	58.5	0.79	94.2	94.2	0.0	91.1	226.5	5.43	16.0
279		June	226.5	5.43	91.1	34.3	-0.33	125.1	17.3	36.8	0.51	56.0	0.84	89.6	36.6	0.0	88.5	226.0	5.32	6.5
280		July	226.0	5.32	88.5	44.8	-0.21	133.1	17.8	37.1	0.71	55.3	0.84	94.6	44.6	0.0	88.5	226.0	5.32	7.6
281		August	226.0	5.32	88.5	32.6	-0.32	120.8	17.8	37.1	0.37	55.6	0.81	97.3	32.3	0.0	88.5	226.0	5.32	5.3
282		September	226.0	5.32	88.5	29.1	-0.31	117.3	17.3	37.1	0.32	55.7	0.78	97.4	28.8	0.0	88.5	226.0	5.32	4.7
283		October	226.0	5.32	88.5	32.9	-0.24	121.1	17.8	37.1	0.38	55.6	0.81	97.0	32.6	0.0	88.5	226.0	5.32	5.4
284		November	226.0	5.32	88.5	50.8	-0.08	139.1	17.3	37.1	0.98	55.0	0.83	92.8	50.7	0.0	88.5	226.0	5.32	8.7
285		December	226.0	5.32	88.5	73.5	0.06	162.0	17.8	37.1	3.55	52.5	0.80	104.0	73.5	0.0	88.5	226.0	5.32	11.3
286		January	226.0	5.32	88.5	100.8	0.27	189.5	17.8	37.1	3.55	52.5	0.79	105.0	101.1	0.0	88.5	226.0	5.32	15.4
287		February	226.0	5.32	88.5	78.4	0.11	167.0	16.1	37.1	3.55	52.5	0.84	89.5	78.5	0.0	88.5	226.0	5.32	14.1
288		March	226.0	5.32	88.5	93.8	0.29	182.6	17.8	37.1	3.55	52.5	0.82	101.7	94.1	0.0	88.5	226.0	5.32	14.8

No of Month Failure	=	3	MONTH
Time Reliability	=	99	%
No of Year Failure	=	3	YEAR
Annual Reliability	=	88	%

90% Dependable Power	5.00	MW
80% Dependable Power	6.50	MW
75% Dependable Power	7.02	MW
65% Dependable Power	8.24	MW
Mean Power Generation	11.00	MW

90% Annual Energy Generation	63.65	GWh
80% Annual Energy Generation	68.94	GWh
75% Annual Energy Generation	72.42	GWh
65% Annual Energy Generation	82.00	GWh
Average Annual Energy Generation	96.13	GWh
Annual Capacity Factor	68.59	%

CHAPTER 5

RESERVOIR SIMULATION STUDY FOR IRRIGATION AND HYDROPOWER

5.1. GENERAL

This chapter is an extension of analysis carried out in chapter IV in which concepts and basis for hydropower planning and irrigation planning were examined and certain improvements in planning procedure were discussed. The long-term simulation study and performance evaluation were limited to the purpose of hydropower in chapter IV. This chapter deals with improvements in reservoir simulation study for the purpose of irrigation and for multipurpose of irrigation and hydropower.

5.2. IMPROVEMENTS

5.2.1. *Variation in Irrigation Demand*

In the conventional simulation study for irrigation system planning, a design cropping pattern is evolved and it is assumed to be fixed i.e. variation from year to year is not considered. In the present study, different scenarios of target irrigation area and different cropping intensities are considered. Irrigation release requirements at the Batutegi reservoir have been considered to vary not only from month to month but also from year to year due to randomness of flow contribution from interim catchment between Batutegi reservoir and Argoguruh weir.

5.2.2. Consideration of Group System of Irrigation

Each irrigation project has its own specific water distribution plan to achieve project target. The water balance simulation study of irrigation has to be done according to the water distribution plan.

A water distribution plan is based on the assessment of irrigation demand and dependable flow at head of canal. Rotation of water supply to different areas depends upon available water and demand.

In Indonesia, water distribution plan is based on group system. Concept of *Golongan* (Group) system of irrigation has been introduced and applied in determining irrigation demand in time and space framework. The peak irrigation demand is reduced due to staggering of crop calendar in *Golongans*. Thus the concept of *Golongan* is useful both in irrigation system design and in irrigation system operation. Use of *Golongan* concept in system design results in lower capacities of canal network at head and helps in equitable sharing of deficit water supplies.

The study mainly concentrates on water balance simulation study with priority to meet irrigation demand under different scenarios and also generates power to the extent possible. Target energy generation can be fixed based on trade off between irrigation and power generation as discussed in later.

Sensitivity analysis is also carried out by considering different cropping intensities for dry season paddy only.

5.2.3. Consideration of Storage Capacity-Yield-Reliability on Annual and Seasonal Basis

In the conventional procedure, storage capacity of an irrigation reservoir is planned to meet annual irrigation demand on 75% dependable basis. Instead of considering a fixed dependability criteria, it is considered to be more useful to work out storage capacity requirement for different dependability levels of irrigation water utilization. Further, instead of considering dependability on annual basis only, dependability has been considered on crop seasonal basis also. Such analysis between storage capacity water with withdrawal and reliability provides more useful information in fixing size of live storage and irrigation water utilization.

5.2.4. Estimation of Net Gain or Loss from Reservoir

As storage during a period varies due to inflows and withdrawal from the reservoir, the reservoir area also varies. Therefore, average reservoir area should be considered in estimation of gain due to rainfall and loss due to evaporation from the reservoir. However, average area during a time interval is not known at the beginning. As already explained in chapter IV, it is possible to develop a relationship between initial reservoir area and average area based on trial simulation study.

5.2.5. Trade off between Irrigation Water Supply and Power Generation

It is necessary to workout trade off between irrigation water supply and power generation at different reliability levels in case of a multipurpose reservoir. In conventional procedure, usually priorities between irrigation and power generation are predecided and "as available" energy or "as available" irrigation supply are computed. Simulation study can be used to work out trade off between irrigation and power generation at different reliability levels from the storage-yield-reliability curves for irrigation and power.

The above mentioned improvements have been applied in case study of Batutegi reservoir.

5.3. 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, leaching requirement etc.; and (iv) conveyance efficiencies.

5.3.1. Different Scenarios of Irrigation Development

Simulation is carried out considering the following scenarios of irrigation development :

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

  Scenario I → 76,789 ha (70,999 ha + West Rumbia)
  Scenario II → 81,355 ha (Scenario I + Rumbia II)
  Scenario III → 88,565 ha (Scenario II + Rumbia III)
  Scenario IV → 94,123 ha (Scenario 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 scenario. Thus, there are twenty conditions of simulation analysis as shown in Table 5.1.

Thus different scenarios of irrigation development are as on Table 5.1.

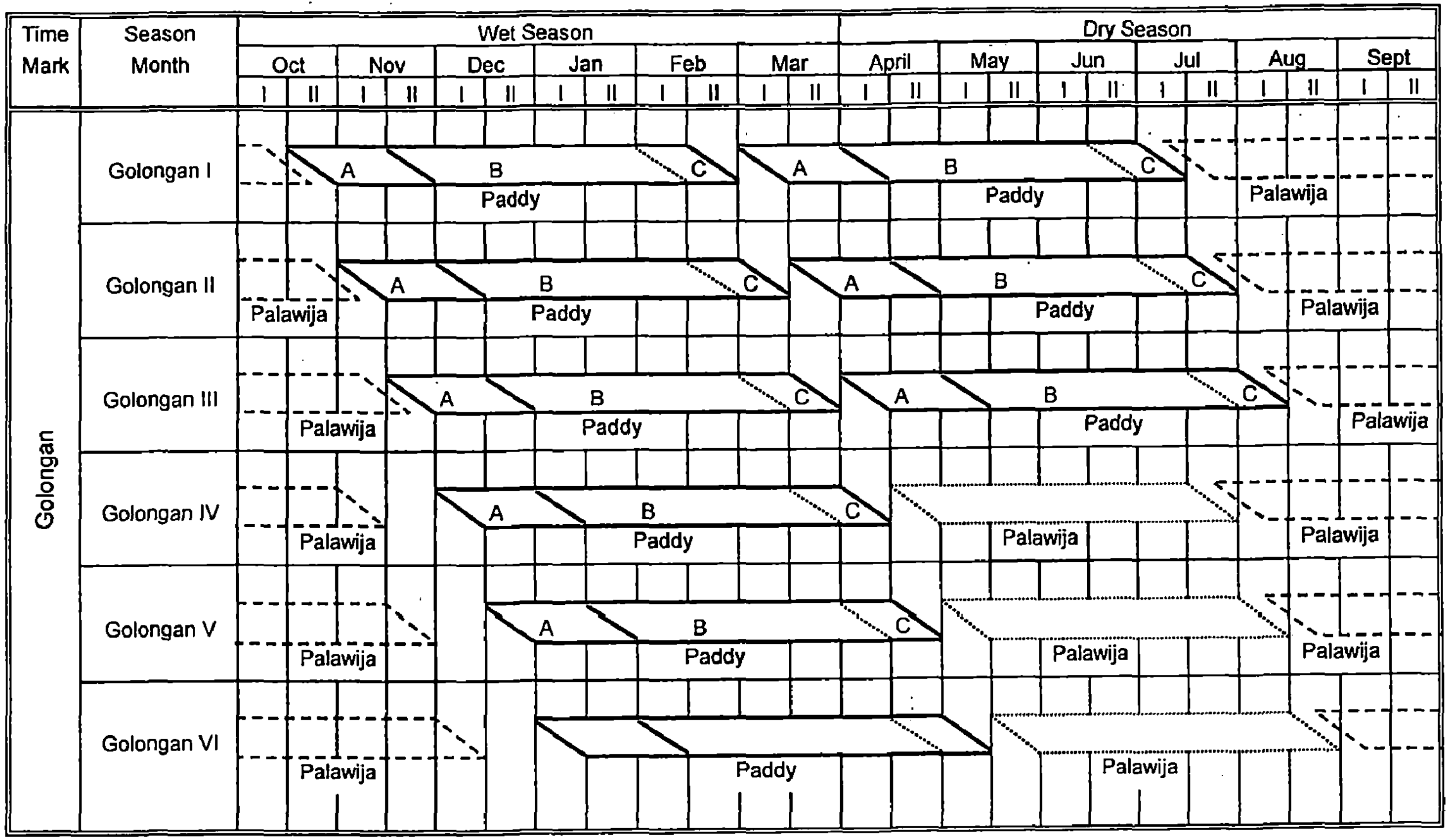
5.3.2. Crop Calendar and *Golongans*

Figure 5.1 shows the crop calendar and staggering of *golongans* to lower the peak water requirement. It also helps in lowering the peak labor requirement.

In the rainy season, the land preparation in *golongans* 1 starts in the second half of October and with time lag of half a month, the other golongan start one by one. In the 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 a 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 (palawija) such as cassava, maize, soybeans, etc. are planted in the single paddy cropping field. Even in the double paddy cropping fields, upland crop are planted between the two paddy cropping seasons, however, they are not provided with irrigation water.



Notes :
A : Nursery + Land Preparation (1 month)
B : Planting + Growing (2.5 month)
C : Graining (0.5 month)

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	3686
MAY	3888	3243
JUN	3188	3110
JUL	0	1157
AUG	0	0
SEP	0	0

Fig. 5.1 : Proposed Crop Calender and Golongan

Table 5.1. Different Scenarios of Irrigation Development

Condi-tion	Zone	Total Irrigation Area (Ha)	Crop Intensity %	Irrigation Area (HA)			
				Rainy Season		Dry Season	
				Direct Divertion	Return Flow	Direct Divertion	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	54447	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

5.3.3. Irrigation Diversion Requirement at Argoguruh Weir (IWD)

Following model has been used to estimate irrigation diversion requirement at Argoguruh weir in each month.

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

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

IWR (mm/day) = ETc + LP + P – Re

Where,

IWR : Irrigation Water Requirement (mm/day)
ETc : Consumptive Use (mm/day)
: kcxETo
LP : Land Preparation Water Requirement (mm/day)
: $\frac{M.e^k}{e^k - 1}$
M : Water requirement to compensate for evaporation and percolation, M = Eo + P
Eo : Open water evaporation during land preparation
k : $\frac{M.T}{S}$
T : Land preparation period (day)
S : Pre-saturation requirement
P : Percolation rate (mm/day)
Re : Effective Rainfall (mm/day)

Required water allowance on monthly basis at Argoguruh weir for each of the six *golongans* are given in Table 5.2, and Table 5.3 is the computation result of annual water requirement for each of the six *golongans* as per scenarios irrigation area. These have been taken from Engineering Report, Way Sekampung Irrigation Report, *Department of Public Work in Indonesia (1994).*

The water requirement is significantly reduced by consideration of shift in crop calendar for each Golongan. As shown in Fig. 5.1, 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.

Table 5.2 : 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	1.30	0.33	1.37	1.60	1.50	1.23	0.00	0.00	0.00
II	0.00	1.56	1.37	1.27	1.00	0.44	1.96	1.44	1.65	0.41	0.00	0.00
III	0.00	0.51	1.66	1.21	1.35	0.36	1.64	1.60	1.63	1.22	0.00	0.00
IV	0.00	0.00	1.31	1.33	1.31	1.06	0.00	0.00	0.00	0.00	0.00	0.00
V	0.00	0.00	0.42	1.62	1.25	1.39	0.38	0.00	0.00	0.00	0.00	0.00
VI	0.00	0.00	0.00	1.33	1.34	1.36	1.16	0.00	0.00	0.00	0.00	0.00

Table 5.3 : Annual Water Requirement for Each Condition

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	
1	2	3	4	5	6	7	8	9	10	11
I	76789	160	68789	41273	13758	13758	13758	13758	13758	1568
II	76789	170	68789	48152	16051	16051	16051	10318	10318	1678
III	76789	180	68789	55031	18344	18344	18344	6879	6879	1788
IV	76789	190	68789	61910	20637	20637	20637	3439	3439	1897
V	76789	200	68789	68789	22930	22930	22930	0	0	2007
VI	81355	160	73355	44013	14671	14671	14671	14671	14671	1672
VII	81355	170	73355	51349	17116	17116	17116	11003	11003	1789
VIII	81355	180	73355	58684	19561	19561	19561	7336	7336	1906
IX	81355	190	73355	66020	22007	22007	22007	3668	3668	2023
X	81355	200	73355	73355	24452	24452	24452	0	0	2140
XI	88565	160	77782	46669	15556	15556	15556	15556	15556	1773
XII	88565	170	77782	54447	18149	18149	18149	11667	11667	1897
XIII	88565	180	77782	62226	20742	20742	20742	7778	7778	2021
XIV	88565	190	77782	70004	23335	23335	23335	3889	3889	2145
XV	88565	200	77782	77782	25927	25927	25927	0	0	2270
XVI	94123	160	83340	50004	16668	16668	16668	16668	16668	1900
XVII	94123	170	83340	58338	19446	19446	19446	12501	12501	2033
XVIII	94123	180	83340	66672	22224	22224	22224	8334	8334	2166
XIX	94123	190	83340	75006	25002	25002	25002	4167	4167	2299
XX	94123	200	83340	83340	27780	27780	27780	0	0	2432

5.3.4. Irrigation Demand at Batutegi Dam Site (DWD)

Part of the irrigation diversion requirements can be met by interim catchment run off between Batutegi dam and Argoguruh weir. Therefore, downstream releases to be made from the Batutegi are :

$$\mathrm{DWD} = \frac{\mathrm{IWD} - \mathrm{Qa}}{e}$$

Where;IWD = irrigation diversion water requirement at Argoguruh weir
Qa = run off at Argoguruh weir
e = conveyance efficiency from Argoguruh weir to Batutegi dam

5.4. RIVER MAINTENANCE FLOW

After construction of reservoir dam, the environmental situation in downstream changes especially for aquatic life. From the environmental and ecological considerations, dam operation should be made so that negative effect in downstream is as little as possible.

In general, the river maintenance flow (called also duty flow, compensation flow or minimum flow) below the dam is as the 10 years probable drought discharge. Annual minimum daily mean discharge at Batutegi dam were analyzed and the obligation river maintenance flow downstream of Batutegi dam was set at 2.0 m^3/s.

5.5. SIMULATION ALGORITHM

Figure 5.2 depicts the sequential steps of simulation study in form of flow chart. The input data and various component and model are highlighted in the flow chart. The steps involved are further explained in following paragraphs.

(i.) Adopt a storage capacity based on preliminary design or any other consideration.

(ii.) - Select power target/installed capacity and number of units.

- Select irrigation scenario condition depicting irrigation area, wet and dry season cropping intensity and *Golongans* (Groups).
- Select first month of simulation. It is usually end of wet season.

(iii.) Estimate irrigation diversion requirement at Argoguruh weir (IWD)

IWD = irrigation area x requirement water allowance x conversion

= ha x (l/s/ha)x10^{-3}x(24x60x60xno of day in a month)x10^{-6} MCM
Where, irrigation area is divided as per *golongan* (Table 5.3) and required water allowance is different for each *golongan* as given in Table 5.2.

(iv.) Compute irrigation demand at Batutegi dam (DWD)

if IWD $\geq$ Runoff at Argoguruh (Qa)

DWD = (IWD – Qa)/η where, η is conveyance efficiency

if IWD < Qa

DWD = maintenance flow = 2 m^3/s x conversion (in MCM)

(v.) Adopt appropriate elevation-area-capacity curve, which is revised in every 10 years during project life. Since the stream flow data is for 24 years, original curve, curve revised after 10 years and revised after 20 years are adopted for simulation study. Elevation–area–capacity curves are shown in Appendix 5.

(vi.) Calculate the gain/loss from reservoir with following procedure :

- Estimate the average surface area of reservoir for the month corresponding to the surface area at the beginning of month using the linear function as shown in Fig. 4.1.
- Gain/loss in volume units from Reservoir is obtained as :

  = Average surface area x depth of gain/loss reservoir x conversion

  = (km^2 x 10^6) x (mm x 10^{-3}) / 10^6 (in Mm^3 or MCM)

  Where ;

  depth of gain/loss = (monthly rainfall – monthly evaporation) in mm

(vii.) Estimate maximum turbine flow (Qp.max) to generate power target

Maximum turbine flow is estimated by same procedure as for power simulation study in chapter IV (step (vi) to (xv), in section 4.6.3).

(viii.) Calculate the water available as :

Water available = Gross storage at beginning+Inflow+Gain/loss reservoir

(ix.) Compute water release (water balance)

Fig. 5.3 depicts the operation rules model of Batutegi reservoir in form of flow chart.

FOR WATER LEVEL AT FRL

$$\left.\begin{array}{ll} \text{- IF} & DWD \le (Qb \pm \text{Gain/loss}) \\ & \text{and } 0.4\,(Qp.max1) \le (Qb \pm \text{Gain/loss}) < Qp.max \end{array}\right\} \begin{array}{l} Qp = Qb \pm \text{Gain/loss} \\ Qi = 0 \end{array}$$

$$\left.\begin{array}{ll} \text{- IF} & DWD \le (Qb \pm \text{Gain/loss}) \\ & \text{and } (Qb \pm \text{Gain/loss}) \ge Qp.max \end{array}\right\} \begin{array}{l} Qp = Qp.max \\ Qi = 0 \end{array}$$

$$\left.\begin{array}{ll} \text{- IF} & DWD > (Qb \pm \text{Gain/loss}) \\ & \text{and } 0.4\,(Qp.max1) \le DWD < Qp.max \end{array}\right\} \begin{array}{l} Qp = DWD \\ Qi = 0 \end{array}$$

$$\begin{array}{ll} \text{- IF} & Qp.max \le DWD > (Qb \pm \text{Gain/loss}) \end{array} \rightarrow \begin{array}{l} Qp = Qp.max \\ Qi = DWD - Qp.max \end{array}$$

FOR WATER LEVEL BELOW FRL

$$\left.\begin{array}{ll} \text{- IF} & DWD \ge Qp.max \\ & \text{and } W.A. \ge (DSp + Qp.max) \end{array}\right\} \begin{array}{l} Qp = Qp.max \\ Qi = DWD - Qp \end{array}$$

$$\left.\begin{array}{ll} \text{- IF} & DWD \ge Qp.max \\ & \text{and } W.A. < (DSp + Qp.max) \end{array}\right\} \begin{array}{l} Qp = WA - DSp \\ Qi = DWD - Qp \end{array}$$

$$\left.\begin{array}{ll} \text{- IF} & 0.4\,(Qp.max1) \le DWD \le Qp.max \\ & \text{and } W.A. \ge (DSp + DWD) \end{array}\right\} \begin{array}{l} Qp = DWD \\ Qi = 0 \end{array}$$

$$\left.\begin{array}{lll} \text{- IF} & DWD < 0.4\,(Qp.max1) & \text{OR} \\ & W.A \le DSp & \text{OR} \\ & DWD = 2\ m3/s & \end{array}\right\} \begin{array}{l} Qp = 0 \\ Qi = DWD \end{array}$$

Where, W.A. = Water Available

DSp = Dead Storage (storage below MDDL)

Qi = Water release through irrigation intake at El. 208

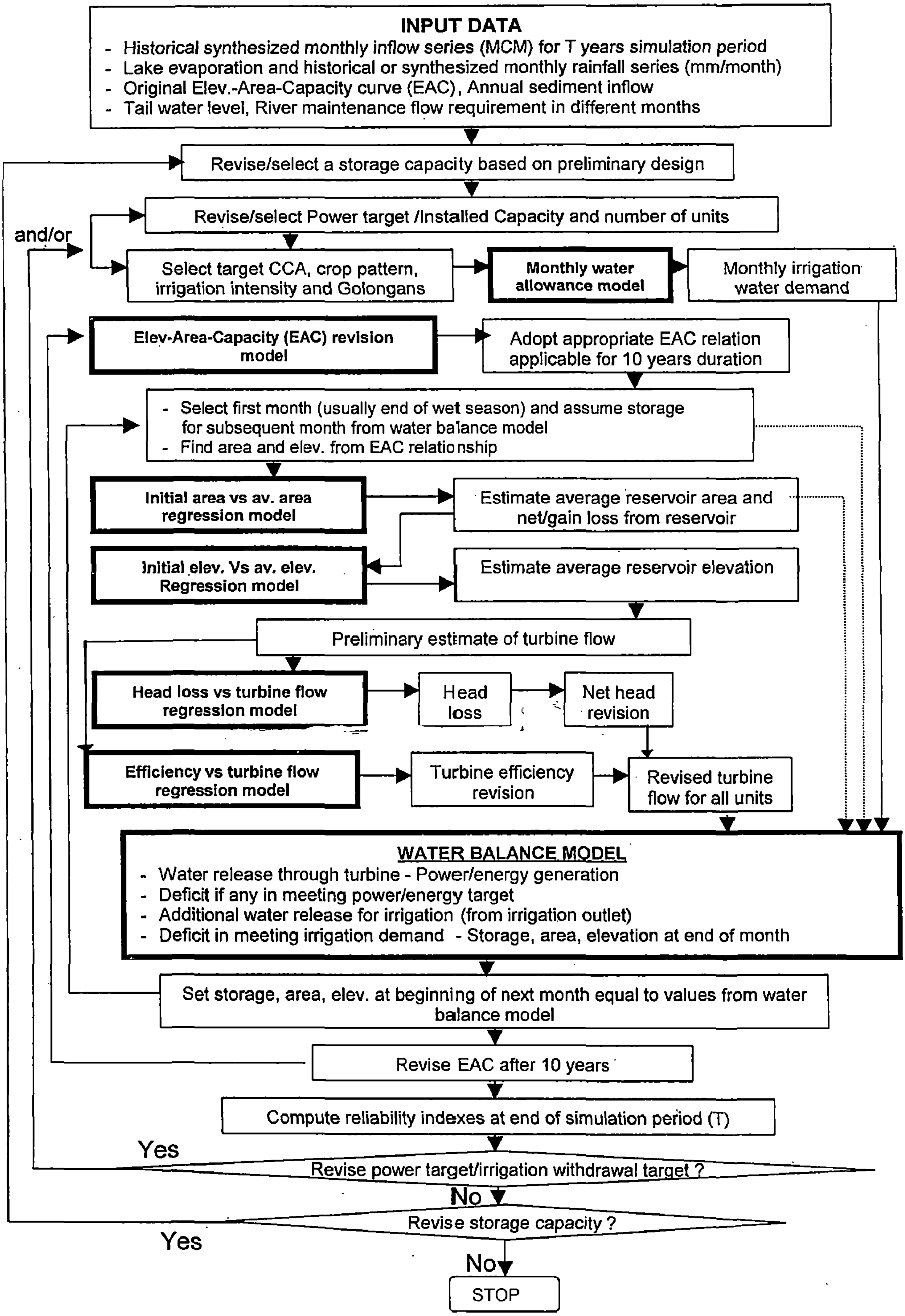


Fig. 5.2 : Simulation Algorithm for Irrigation and Hydropower

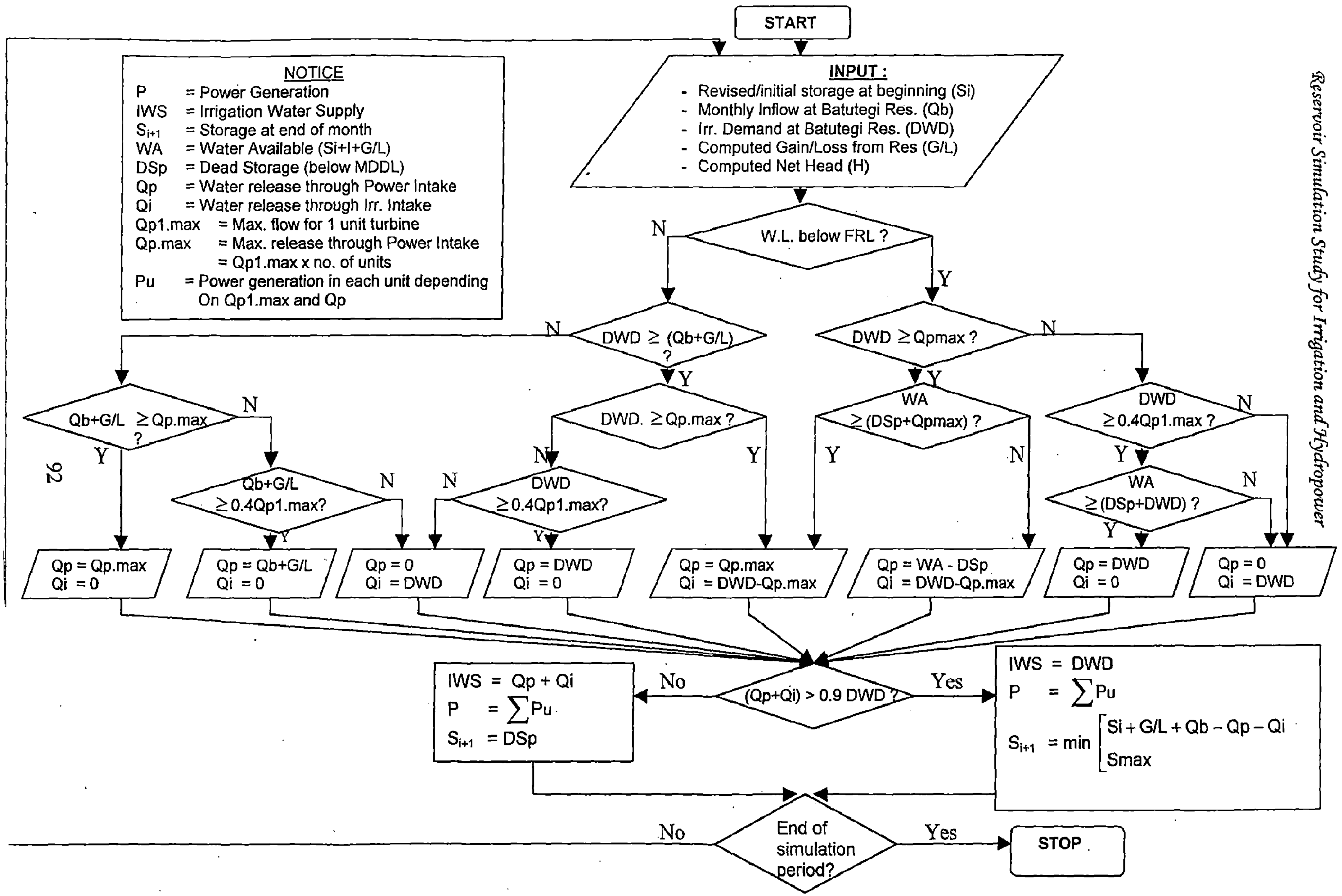


Fig. 5.3 : Operation Rules Model of Batutegi Reservoir with Irrigation Priority

(x.) Compute power generation

Power Output = $9.81 \times \eta \times Qp \times H$

(xi.) Compute energy generation (MWh)

Power energy = Power output x 24 x number of days in a month

(xii.) Carry out the classification of deficit (not meet the demand) with the evaluation criteria: irrigation water shortage less than 10% of demand is allowable. Water shortage more than 10% of monthly demand is considered as water deficit (failure) in the month.

(xiii.) Repeat the above mentioned procedure sequentially for all the months of simulation period (here 288 months).

(xiv.) Work out statistical performance parameters.

As an illustrative example Appendix 8 shows simulation study for the following condition:

Gross Storage Size	= 580 MCM
Total Irrigation Area	= 88565 ha
Crop Intensity	= 180%
Zone	= up to Rumbia II

The above mentioned simulation procedure was applied for twenty different demand patterns corresponding to twenty scenarios of irrigation areas given in Table 5.1.

5.6. RESULTS OF SIMULATION STUDY FOR VARIOUS CONDITIONS

5.6.1 Irrigation Reliability and Available Power Generation

In case of multipurpose development where the major benefit is for irrigation, the releases are made primarily in the interest of irrigation and power generation follows the pattern of irrigation. In this project, evaluation criteria is that irrigation water shortage more than 10% may not occur more than 5 years for the simulation period of 24 years as per prevalent dependability criteria.

The main objective of reservoir operation is to store water during wet season and to regulate water during dry season. Seasonal reliability is computed to evaluate irrigation shortage during different season (wet season and dry season). Table 5.4 shows that in dry season, the irrigation reliability remain constant at 96% (only 1 year irrigation water shortage) when storage size is varied from 460 MCM to 580 MCM and wet season reliability increases from 79% to 88%.

Table 5.4 Irrigation Reliability and Available Power for Condition VIII

Storage Size (MCM)	Irrigation Reliability (%)			Available Energy (GWh)	Annual Cap.Factor (%)	Mean Pwr Gen. (MW)
	Dry Season	Wet Season	Annual			
460	96	79	79	95.1	45.3	10.9
500	96	79	79	96.4	45.9	11.0
540	96	83	83	97.4	46.3	11.1
580	96	88	88	99.3	47.2	11.4

Available annual energy and mean power generation have also worked out with priority use for given irrigation withdrawal. Tables 5.4 shows that increasing in storage capacity, both available energy generation and mean power increase but not significantly.

For a fixed storage capacity 580 MCM, irrigation and available power generation for each condition/scenario have been simulated and summary results are shown in Table 5.5. Based on this table, the relationship between (i) *withdrawal – irrigation reliability*; (ii) *withdrawal – average annual energy generation*; and (iii) *withdrawal – annual capacity factor* are developed as shown in Fig. 5.4 to Fig. 5.7 for different irrigation area conditions. These relationships give useful information in selecting the condition/scenario of irrigation development with the required power generation as well as required irrigation reliability.

With increase in annual water requirement, mean power generation decreases. Annual and seasonal irrigation reliabilities also decrease.

Table 5.5 : Irrigation reliability and power analysis for each condition/scenario with Gross Storage Size 580 MCM

Zone	Condition	Annual Water Req. MCM	Irrigation Reliability			Av. Annual Available Energy GWh	Annual Capacity Factor %	Mean Power Generation MW
			Dry Season (Apr-Sep) %	Wet Season (Oct-Mar) %	Annual %			
	I	1568	100	100	100	124.1	59.0	14.2
	II	1678	100	100	100	117.6	55.9	13.4
	III	1788	96	96	96	108.0	51.4	12.3
	IV	1897	96	79	79	96.8	46.0	11.1
	V	2007	88	71	71	87.1	41.4	10.0
	VI	1672	100	100	100	120.4	57.2	13.7
	VII	1789	96	96	96	107.7	51.2	12.3
	VIII	1906	96	88	88	99.3	47.2	11.4
	IX	2023	88	75	75	89.0	42.3	10.2
	X	2140	79	67	63	78.8	37.5	9.0
	XI	1773	100	96	96	115.4	54.9	13.2
	XII	1897	96	96	96	104.7	49.8	12.0
	XIII	2021	92	79	79	94.2	44.8	10.8
	XIV	2145	79	71	67	83.4	39.7	9.5
	XV	2270	63	63	54	73.7	35.0	8.4
	XVI	1900	96	96	96	108.6	51.6	12.4
	XVII	2033	96	88	88	96.5	45.9	11.0
	XVIII	2166	88	71	71	86.3	41.0	9.9
	XIX	2299	71	67	58	73.8	35.1	8.4
	XX	2432	58	50	42	67.9	32.3	7.8

Trade offs between annual irrigation water supply and average annual energy generation at different levels of seasonal and annual irrigation reliabilities can be selected from results given in Table 5.5. For example condition XVII pertains to total irrigation area of 94,123 ha with 160% crop intensity (100% in wet season and 60% in dry season). This area can be served with 88% reliability in wet season, 96% reliability in dry season and 88% annual reliability. In addition 96.5 GWh average annual energy (11 MW average power) will also be available.

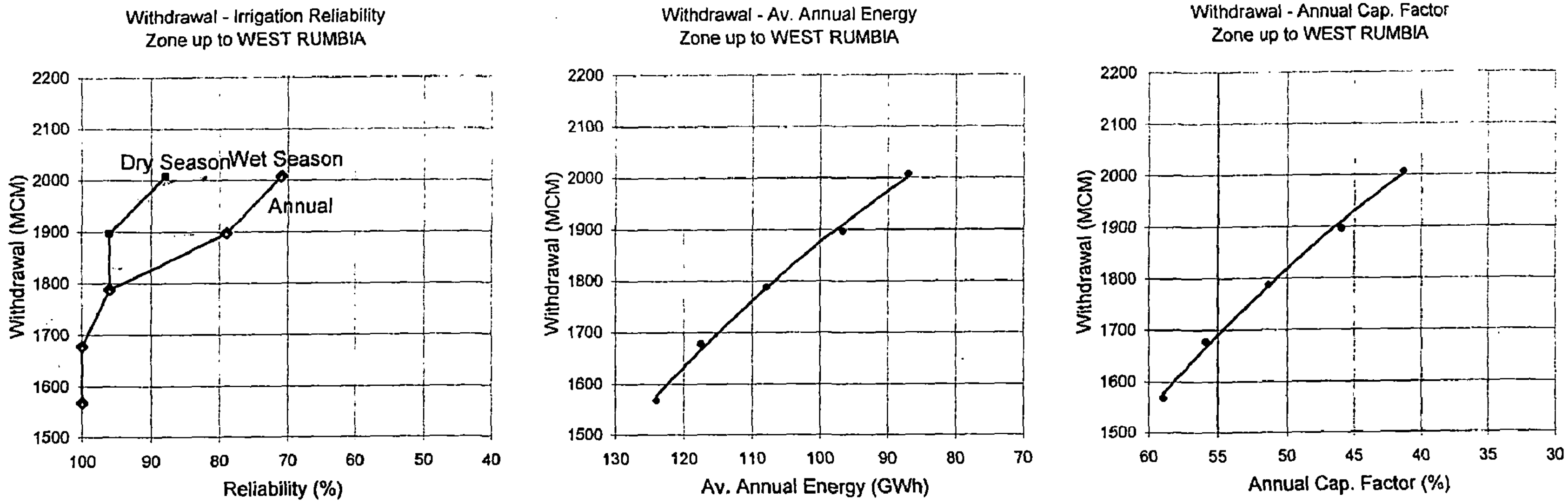


Fig. 5.4 Relationship between Withdrawal and Irrigation Reliability and Power Generation for Zone up to RUMBIA (5 conditions withdrawal)

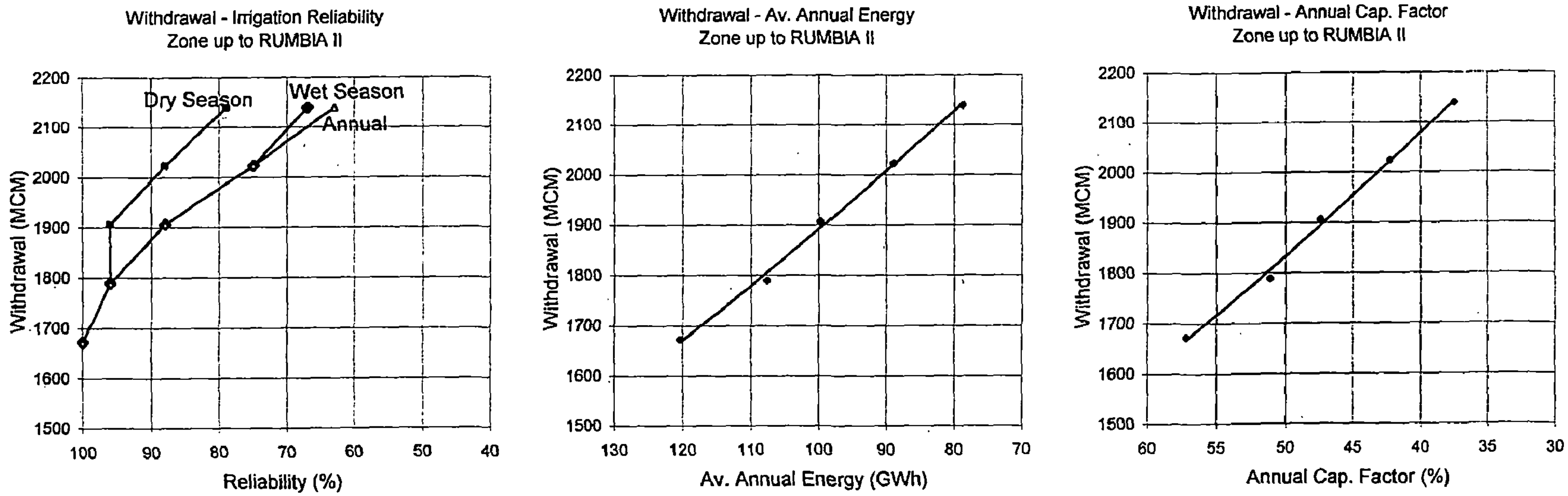


Fig. 5. 6. Relationship between Withdrawal and Irrigation Reliability and Power Generation for Zone up to RUMBIA II (5 conditions withdrawal)

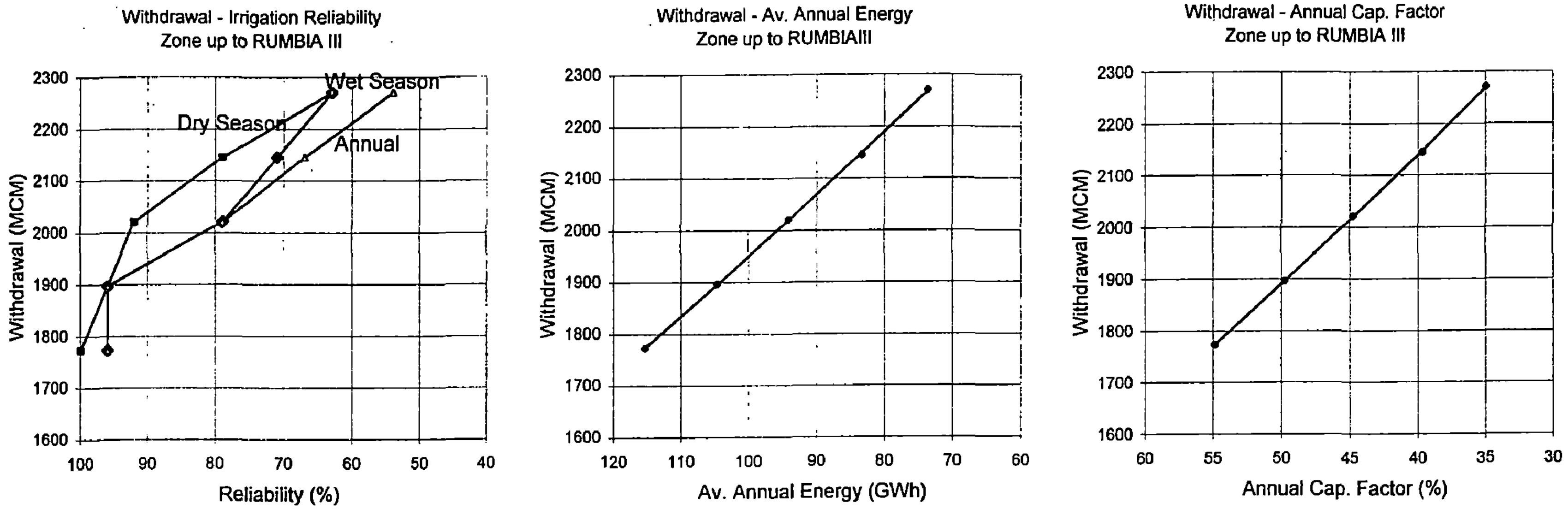


Fig. 5.7 Relationship between Withdrawal and Irrigation Reliability and Power Generation for Zone up to RUMBIA III (5 conditions withdrawal)

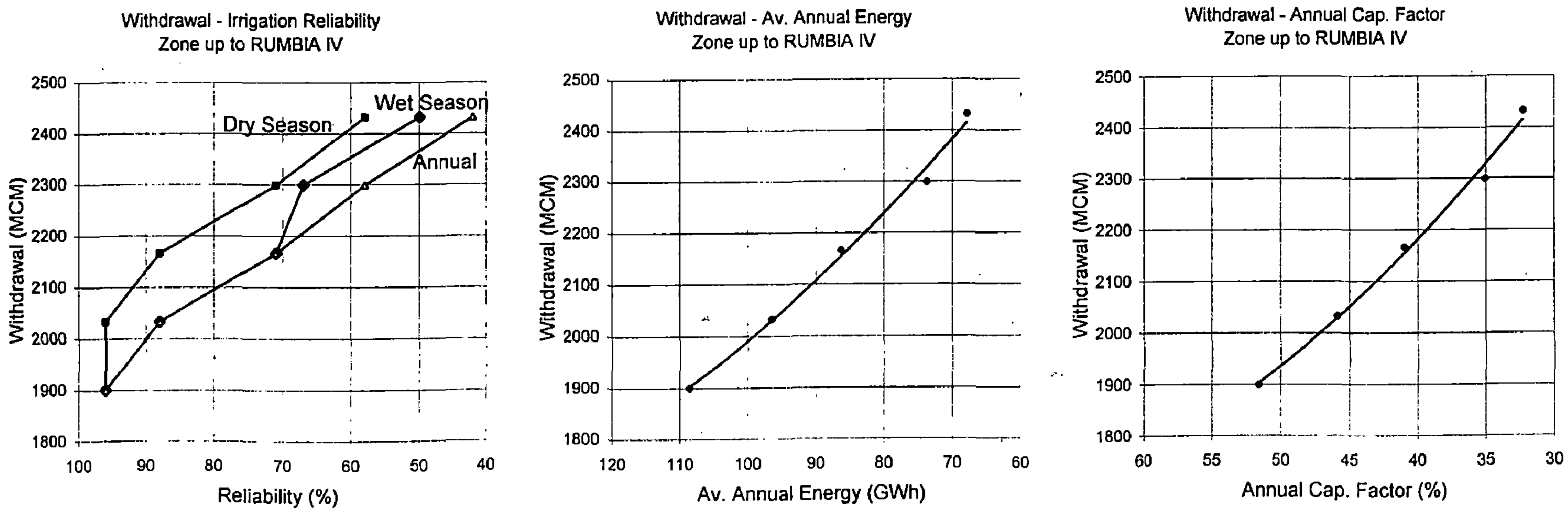


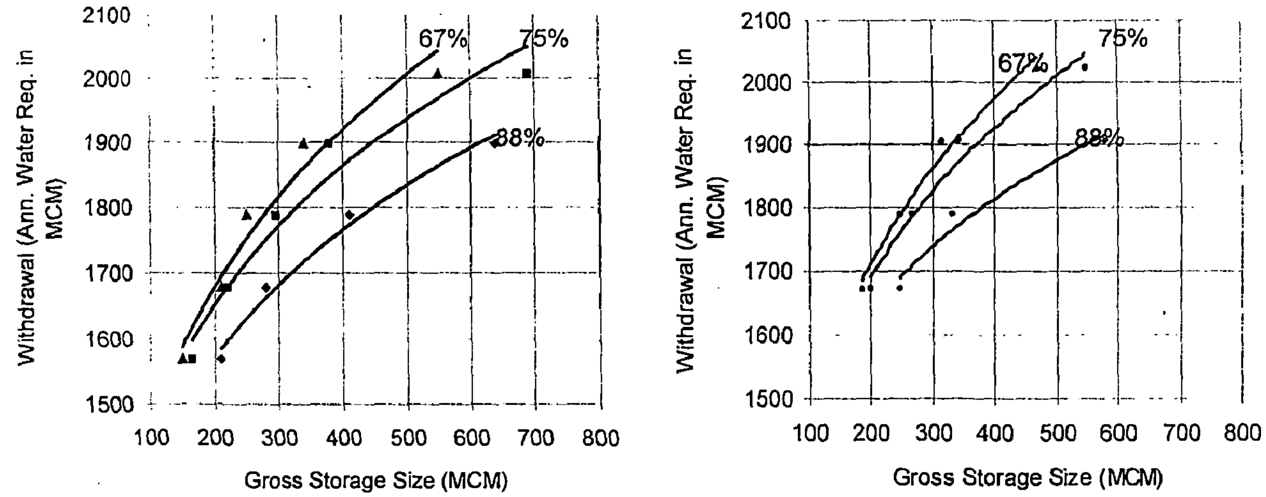
Fig. 5.5 Relationship between Withdrawal and Irrigation Reliability and Power Generation for Zone up to RUMBIA IV (5 conditions withdrawal)

5.6.2 Storage Size and Withdrawal Relationship

Relationship between storage size and withdrawal (annual water requirement) with different levels of reliability in final design gives a important information in deciding storage size and withdrawal, for desired level of reliability.

a). Storage Size-Withdrawal-Annual Reliability Zone up to WEST RUMBIA

b). Storage Size-Withdraw al-Annual Reliability Zone up to RUMBIA II



c). Storage Size-Withdraw al-Annual Reliability Zone up to RUMBIA III

d). Storage Size-Withdrawal-Annual Reliability Zone up to RUMBIA IV

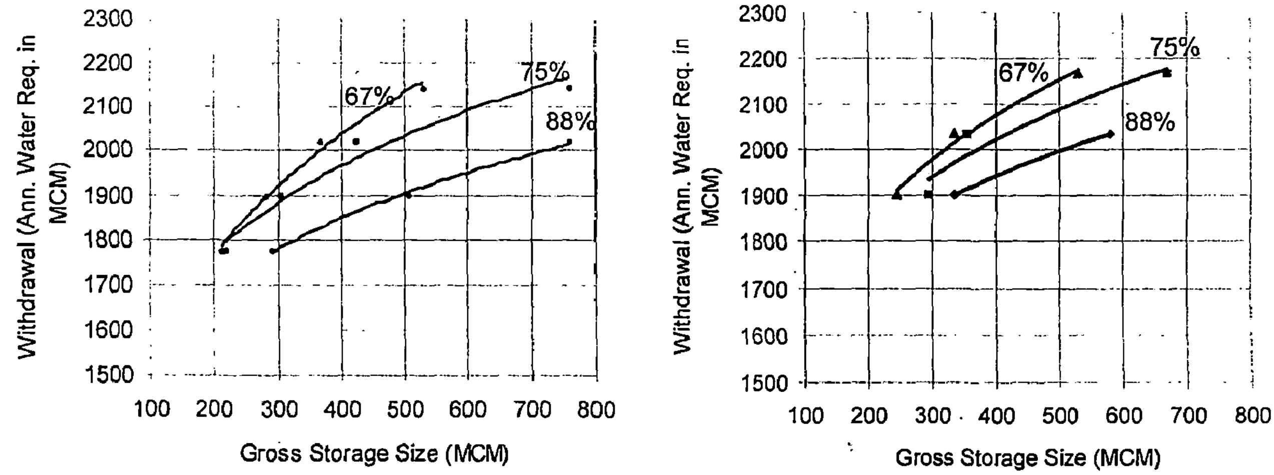


Fig. 5.8 : Relationship between Storage Size, Withdrawal and Annual Reliability for each condition/scenario

In case of Batutegi reservoir, where water release for hydropower follows the releases of irrigation, and increasing storage size does not give significant improvement in power generation, this relationship becomes the first consideration in deciding the storage size or withdrawal. The relationship is made for each irrigation area scenarios as shown in Figure 5.8.

CHAPTER 6

SUMMARY AND CONCLUSIONS

There is wide divergence in concepts, basis and approach followed in planning for irrigation water supply and hydroelectric generation. Following are the comments :

1. Electricity cannot be stored whereas irrigation water can be stored. However, electricity generation potential in terms of flow and head, which cause power generation, can be stored.
2. Production at a particular hydroelectric project need not match with consumer demand instant by instant when electricity distribution is through grid. In case of irrigation, a few days mismatch between demand and supply is tolerable depending upon crop type but there is generally no alternate source of water supply in the project command area.
3. Hydropower planning is based on 90% dependability of power generation whereas 75% dependability of water supply is the criteria for irrigation planning. It is more useful to work out relationships between storage, withdrawal, and reliability for irrigation and hydropower. The prevalent dependability criteria do not appear to have sound analytical depth.
4. In conventional simulation study, the elevation–area–capacity curve as anticipated after half of project life is first derived using Area Reduction Method (or any other appropriate method) and assumed to apply uniformly from first year up to end of project life in the simulation study. In the present study, elevation–area–capacity relationship has been revised at regular interval of 10 years and incorporated in the algorithm.
5. Conventional procedures were evolved considering limitations of data, computational facility and methods of analysis. With availability of computer technology and analytical tools, it is possible to simulate long-term behaviour of reservoir under variety of conditions and make the analysis more realistic

as well as more useful. Even preliminary design can be made more realistic and informative (storage-yield-reliability relation) for the planner. Several improvements have been made in simulation algorithms and applied in a case study

In the preliminary design techniques, simplifying assumptions are normally made. Reservoir releases are assumed constant (i.e. demand is assumed to be uniform), and evaporation is ignored. In the present study, Gould Gamma method has been used for preliminary design. Although the method is based on annual flows and assumed to be independent, it provides reliable estimates of storage for reservoirs as small as 0.1 times mean annual flow. This method is based on some assumptions and limitations.

The purpose of long-term simulation study is to permit evaluation of the performance of alternative plans for storage capacity, power generation and irrigation water supply.

Improvements in Hydropower Simulation Algorithm

1. Progressive sediment deposition and consequent change in storage capacity as well as change in elevation-area-capacity relation have been taken into account in the long-term simulation study.
2. Information on *average elevation* and *average reservoir area* during a month is needed for finding net head and net gain/loss from reservoir. Regression analysis has been used to develop best-fit relationship between a). *Initial and average elevation* and b). *Initial area and average area* for different power targets.
3. Net gain/loss from reservoir varies not only from month to month in year but also over the years due to randomness in monthly rainfall. This has been considered in the water balance study.
4. Instead of assuming constant power plant efficiency, it has been considered as a variable. Further, power generation has been based on turbine flow for each unit of turbine (4 MW).

5. Instead of using conventional procedure of finding 90% dependable power, following relationships have been developed :
   (i.) Storage size-power generation-dependability
   (ii.) Storage size-annual energy generation-dependability
   (iii.) Monthly dependable power

   Such studies provide much more useful information compared to conventional studies particularly when a reservoir is to be planned as multipurpose project.
6. Statistical indexes of physical performance such as (i) *mean and variance of monthly power and annual energy*, (ii) *dependable capacity and energy* in each month, (iii) *monthly and annual capacity factor*, are useful in hydropower planning.

Improvements in Irrigation Simulation Algorithm

With regard to irrigation, following improvements have been made and applied in case study of Batutegi reservoir for studying reliability of irrigation water supply and hydropower generation.

1. ***Variation in Irrigation Demand:*** In the conventional simulation study for irrigation system planning, a design cropping pattern is evolved and it is assumed to be fixed i.e. variation from year to year is not considered. In the present study, different scenarios of target irrigation area and different cropping intensities are considered. Irrigation release requirements at the Batutegi reservoir have been considered to vary not only from month to month but also from year to year due to randomness of flow contribution from interim catchment between Batutegi reservoir and Argoguruh weir.
2. ***Consideration of Group System of Irrigation:*** Water distribution is an important component of irrigation system design and implementation. Each irrigation project has its own specific water distribution plan to achieve project target. The water balance simulation study of irrigation has to be done according to the water distribution plan.

In Indonesia, water distribution plan is based on group system. Concept of *Golongan* (Group) system of irrigation has been introduced and applied in determining irrigation demand in time and space framework. The peak irrigation demand is reduced due to staggering of crop calendar in *Golongans. For example in case of Batutegi project, peak demand is 5003* m^3*/month/ha (without Golongan system) to 3686* m^3*/month/ha by consideration of staggering crop calendar in six golongans.* Thus, the concept of *Golongan* is useful both in irrigation system design and in irrigation system operation. Use of *Golongan* concept in system design results in lower capacities of canal network at head and helps in equitable sharing of deficit water supplies.

The study mainly concentrates on water balance simulation study with priority to meet irrigation demand under different scenarios and also generate power to the extend possible. Optimal/target energy generation is not considered.

3. ***Consideration of Storage Capacity-Yield-Reliability on Annual and Seasonal Basis :*** In the conventional procedure storage capacity of an irrigation reservoir is planned to meet annual irrigation demand on 75% dependable basis. Instead of considering a fixed dependability criterion, it is considered to be more useful to work out storage capacity requirement for different dependability levels of irrigation water utilization. Further instead of considering dependability on annual basis only, dependability has been considered on crop seasonal basis also. Such analysis between storage capacity, water withdrawal and reliability provides more useful information for analyzing trade off between storage capacity and irrigation water supply target, with due consideration of desired reliability on seasonal basis.
4. ***Estimation of Net Gain or Loss from Reservoir :*** As storage during a period varies due to inflows and withdrawal from the reservoir, the reservoir area also varies. Therefore, average reservoir area should be considered in estimation of gain due to rainfall and loss due to evaporation from the reservoir. However, average area during a time interval is not known at the

beginning. As already explained in chapter IV, it is possible to develop a relationship between *initial reservoir area* and *average area* based on trial simulation study.

5. ***Trade off between Irrigation Water Supply and Power Generation:*** It is necessary to workout trade off between irrigation water supply and power generation at different reliability levels in case of a multipurpose reservoir. Usually priorities between irrigation and power generation are predecided and "as available" energy or "as available" irrigation supply are computed. Simulation study can be used to work out trade off between irrigation and power generation at different reliability levels from the storage-yield-reliability curves for irrigation and power. These trade offs provide flexibility to decision maker to choose a desired combination of irrigation water supply and power generation target at desired reliability levels.

Simulation algorithms :

(i.) An algorithm for a multipurpose reservoir (hydropower and irrigation) incorporating various improvements has been prepared (Figure 5.2).

(ii.) An algorithm for estimation of turbine flow and power generation with variable head loss and efficiency has been developed (Figure 4.4).

(iii.) An algorithm depicting application of reservoir operation rules for estimation of water release through power intake and through irrigation intake with irrigation priority has been developed (Figure 5.3).

CONCLUSIONS FROM CASE STUDY

The above-mentioned improvements have been applied in case study of Batutegi reservoir. Some of the conclusions with reference to Batutegi Reservoir Project are briefly described below:

The conclusions of analysis of sediment distribution pattern in Batutegi reservoir are :

(i.) Analysis shows that the standard classification of a reservoir is not constant. Based on original elevation-area-capacity curve, the standard classification of reservoir is type II. This type is not constant during 100 years. After 50 years period, the standard classification become type III, and it becomes type II after 75 years.

(ii.) Due to change in standard classification, the distribution pattern also changes. New zero elevation is revised based on change in elevation-area-capacity curve every 25 years. This study suggests the new zero elevation will be at elevation 198.25 m after 100 years. Compared with the analysis in which standard classification is kept constant during 100 years, new zero elevation after 100 years will be at elevation 201 m. In other words, it means live storage capacity is expected to be more than proposed in project design over the project life.

(iii.) Since elevation-area-capacity is not constant, progressive change in elevation-area-capacity relationship after every 10 years has been considered in long-term simulation study of Batutegi reservoir.

Table 3.3 and 3.4 and Figure 3.4 show the result of preliminary design in term of storage size-withdrawal (as % of mean annual flow) and probability of failure for Batutegi reservoir. For 75% annual reliability (25% probability of failure) in annual withdrawal of 66% of mean annual flow (considering only irrigation demand), the required storage capacity is 65 MCM. For 95% of mean annual flow, the required storage capacity is 295 MCM (live storage) at 75% annual reliability.

With improvements made in algorithm for simulation study of hydropower, the conclusions are:

i.) With installed capacity 12 MW (3 x 4 MW), the power generation at different reliability levels (65%, 75%, 80%, 90%) is constant at 12 MW (Figure 4.5.a), and means power generation is 12 MW even when gross storage size increases from 460 MCM to 660 MCM.

ii.) The 90% dependable power generation does not improve with increase in live storage as shown Figure 4.5.a and 4.6.a.

iii.) Storage size–power generation relationship for 12 MW and 16 MW installed capacities are shown in Fig. 4.5.a and 4.6.a. Installed capacity greater than 16 MW is not necessary if only hydropower generation is considered. Power simulation study in Table 4.3 and Figure 4.10.b show that for gross storage size 580 MCM and installed capacity of 16 MW, after 4 years period of simulation, the storage is gradually going down, and at end of 5th year the water level achieves the bottom level at MDDL. The draw down period occurs almost along the remaining 19 years period of study. The reservoir behaves like a *run of river scheme*. Similarly for higher installed capacities, the reservoir is found to behave like a run of river scheme.

iv.) Even though Batutegi reservoir serves the purposes of irrigation and hydropower, only hydropower generation has been considered in chapter IV for the purpose of illustrating the simulation procedure. Results on power generation-reliability in relation to variation in storage size and installed capacity show that the installed capacity of 24 MW as given in Project report is on higher side. Only 12 MW capacity is found to be sufficient.

v.) Increasing gross storage from 580 MCM to 660 MCM does not give significantly different power generation.

vi.) For storage size variation from 580 MCM to 660 MCM and Installed Capacity variation from 16 MW to 24 MW, the monthly power generation changes linearly with the monthly inflow in reservoir.

In simulation study with joint consideration of irrigation and power where the releases of power generation follow the irrigation supply, improvements in long-term simulation study have been made. Conclusions from analysis of Batutegi reservoir are given below:

(i.) Elevation-area-capacity curve as revised after 100 years has been applied in project design. But in this study, available storage is revised after every 10 years, based on change in elevation-area-capacity curve.

(ii.) Table 5.4 shows that with same gross storage size as in project design report (in project design is 578 MCM; this study 580 MCM), Installed Capacity 24 MW and with irrigation condition VIII, annual reliability is 88%, which is higher than acceptable reliability of 75%. The average annual energy available and mean power generation are higher in present study compared to project design (99.8 GWh in this study; and 97.8 GWh in project design). A storage of 460 MCM is adequate to meet irrigation reliability criteria but with reduced energy generation.

(iii.) Trade offs between annual irrigation water supply and average annual energy generation at different levels of seasonal and annual irrigation reliabilities can be selected from results given in Table 5.5. For example condition XVII pertains to total irrigation area of 94123 ha with 160% crop intensity (100% in wet season and 60% in dry season). This area can be served with 88% reliability in wet season, 96% reliability in dry season and 88% annual reliability. In addition 96.5 GWh average annual energy (11 MW average power) will also be available.

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ANNEXURE

GOULD GAMMA METHOD PROCEDURE

Consider a sequence of annual flows, which are assumed independent, with a mean $\bar{x}$ and standard deviation s,

n – yearly mean $\bar{x}_n = n\bar{x}$ (E.1)

n – yearly standard deviation $s_n = \left(\sum^{n} s^2\right)^2 = n^{1/2}s$ (E.2)

As a consequence of the central limit theorem, the distribution of n consecutive annual flows approaches normality as n increases. Therefore, the lower p –percentile flow is given by :

$q_{n,p} = n\bar{x} - z_p n^{1/2} s$ (E.3)

Where $q_{n,p}$ = n-year flow with a probability of occurrence of p %, that is, for p % of time n-year flow $\leq q_{n,p}$, and

z_p = standardized normal variety at p %

During a critical period,

storage required = outflow – inflow

$C_{n,p} = D_n - q_{n,p}$ (E.4)

Where $C_{n,p}$ = depletion of an initially full storage at end of an n-year period during which time the n-year flow ($q_{n,p}$) has a probability of occurrence of p %, and

D_n = constant draft from the reservoir over n years = $Dn\bar{x}$ (E.5)

Where D = constant draft as ratio of mean annual flow

Substituting Eq. E.3 in Eq. E.4,

$C_{n,p} = Dn\bar{x} - n\bar{x} + z_p n^{1/2} s$

$= n\bar{x}(D-1) + z_p n^{1/2} s$ (E.6)

To obtain the length of the critical period and the maximum required storage differentiate Eq. E.6 with respect to n and equate to zero giving :

$$CP = \frac{z_p^2}{4(1-D)^2} C_v^2 \qquad \text{(E.7)}$$

and hence $$\tau = \frac{C}{\bar{x}} = \frac{z_p^2}{4(1-D)} C_v^2 \qquad \text{(E.8)}$$

and $$C = \frac{z_p^2}{4(1-D)} C_v^2 \bar{x} \qquad \text{(E.9)}$$

Where CP = length of critical drawdown period in years,

C_v = annual coefficient of variation,

C = maximum required storage in volume units, and

τ = maximum required storage expressed as a ratio of mean annual flow

The mean and variance of a one parameter Gamma distribution, G(c), are equal and equivalent to the shape parameter, say c. It is possible to convert the mean, $\bar{x}$, and standard deviation, *s*, of a Normal distribution to Gamma units by dividing them both by $s^2/\bar{x}$. The resultant Normal distribution will have the same mean and variance, that is Gamma units.

Substituting for $\bar{x}$ and C_v^2 with Gamma units gives :

$$C\gamma = \frac{z_p^2}{4(1-D)} \qquad \text{(E.10)}$$

Where $C\gamma$ = storage volume in Gamma units.

Gould argued that the difference d between the lower p percentile flow of a Gamma c distribution and that of a Normal distribution with mean and variance both equal to c is approximately constant for a given value of p over a large range of shape parameter c. Values of d are given in Table 3.1. Because of the constancy of d for a given p, according to Gould the critical period for a Gamma distributed inflow is the same as that for normally distributed inflow with the same mean and coefficient of variation, and that the storage required for an inflow that has a Gamma distribution is d Gamma units less than that required for a Normal distribution. In order words, as shown diagrammatically in Fig. 1, inflows for a Gamma distribution will be greater than for the Normal case and the storage should be decreased by d Gamma units.

Hence,

$$C\gamma = \frac{z_p^{\,2}}{4(1-D)} - d \qquad \text{(E.11)}$$

$$\tau\gamma = \frac{z_p^{\,2}}{4c(1-D)} - \frac{d}{c} \qquad \text{(E.12)}$$

Where $\tau\gamma$ = required storage divided by mean annual flow in Gamma unit that is, storage / c

Table 1 Values of z_p and d.

p percentile risk of failure in any year	z_p	D
0.5	3.30	d not constant
1.0	2.33	1.5
2.0	2.05	1.1
3.0	1.88	0.9
4.0	1.75	0.8
5.0	1.64	0.6
7.5	1.44	0.4 } Method is not recommended for use in this range
10	1.28	0.3

The required storage can be converted from Gamma units to units of volume as a ratio of mean flow by multiplying the right-hand side of Eq. E.11 by $\left(\frac{s^2}{\bar{x}}\right)\frac{1}{\bar{x}}$.

$$\tau = \frac{z_p^{\,2}}{4(1-D)} C_v^{\,2} - dC_v^{\,2}$$

$$\tau = \left(\frac{z_p^{\,2}}{4(1-D)} - d\right) C_v^{\,2} \qquad \text{(E.13)}$$

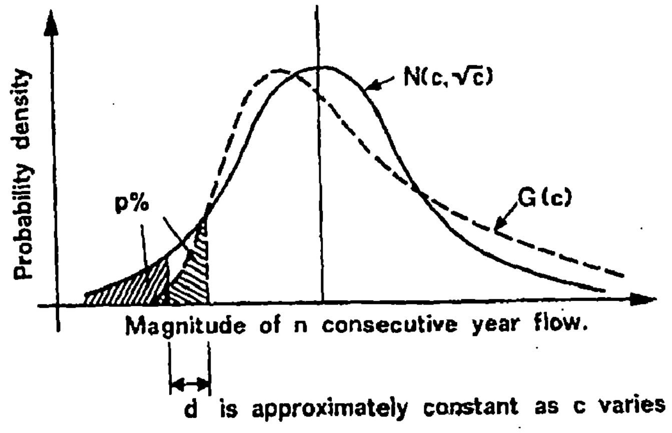


Fig. 1 : Diagrammatic illustration of the difference between inflows for the Normal and Gamma distribution

Although the method is based on annual flows, it provides reliable estimates of storage for reservoirs as small as 0.1 times mean annual flow.

This method is based on the following assumptions and limitations :

1. The critical drawdown period is sufficiently long for the sum of n-year inflow to be normally distributed. Only one failure occurs during the critical drawdown period.
2. For non normally distributed flows, a small correction allows gamma distributed flows to be modeled.
3. Method is based on annual flows and these are assumed independent.
4. The draft rate or withdrawal is uniform from year to year.

Notwithstanding the above limitations, as a preliminary procedure the Gould Gamma Method provides very good estimates of carryover storage over the whole range of practical interest.

The complementary use of Eq. E.13 is to make a preliminary estimate of reservoir yield. Eq. E.13 can be recast so that it is expressed in terms of withdrawal or reservoir yield :

$$D = 1 - \frac{z_p^{\,2} C_v^{\,2}}{4(\tau + dC_v^{\,2})} \qquad \text{(E.14)}$$

To be practical use, net effective lake evaporation needs to be subtracted from the gross yield to provide an effective yield estimate. An appropriate adjustment procedure is discussed.

Adjustment for Evaporation

If the draft rate has not been modified to reflect the effects of net lake evaporation, then an adjustment to storage size is required. Prior to dam construction, the long term rainfall-runoff relation for the are which will be flooded by the proposed reservoir can be expressed as follows :

$$R_B = P_B - ET_B \qquad \text{(E.15)}$$

Where R_B = mean annual runoff before reservoir inundation

P_B = mean annual rainfall, and

ET_B = mean annual evapotranspiration.

After the reservoir is filled, the relation can be expressed as :

$$R_A = P_A - EO_A \qquad \text{(E.16)}$$

Where R_A = mean annual runoff after reservoir is filled

P_A = mean annual rainfall

EO_A = mean annual evaporation from the water surface

Assuming that the mean annual rainfall before and after construction remains approximately equal, that is, $P_B = P_A$, then

$$\Delta E = R_B - R_A \qquad \text{(E.17)}$$

$$= EO_A - ET_B \qquad \text{(E.18)}$$

nothing that $\Delta E \geq 0$, where ΔE = mean annual net evaporation loss.

Lake or open surface water evaporation can be estimated by one of the recognized theoretical or empirical procedures or by applying an annual pan coefficient (p) to tank evaporation data (Ep), thus :

$$EO_A = p\,Ep \qquad \text{(E.19)}$$

Pre dam evapotranspiration estimates are difficult to determine, than one approach is through Eq. E.15, thus :

$$ET_B = P_B - R_B$$

Another factor that is required is the length of critical drawdown period. It can be found from Eq. E.7.

Thus the final adjustment factor for net reservoir evaporation loss is given by combining mean annual net evaporation loss, mean surface reservoir area and drawdown period as follows :

$$\Delta SE = c\,A_F\,\Delta E\,CP \qquad \text{(E.20)}$$

Where ΔSE = amount that computed storage needs to be increased to account for the net reservoir evaporation loss,

A_F = surface area of the reservoir at full supply level,

ΔE = net evaporation loss, determine from Eq. E.18,

CP = critical drawdown.

c = constant

Based on an analysis of the storage capacity-surface area curves for six Australian dam sites, the constant c is equal as 0.7.

An alternative approach is to first determine the value of the effective area (A_F+A_E), where A_E is the area of the minimum pool to be maintained. By multiplying this effective area by the net effective evaporation (lake evaporation minus rainfall), with appropriate unit conversion, a quick estimate of evaporation volume loss can be found for preliminary design purposes.

Appendix 1

Computation of Sediment Distribution Pattern after 50, 75 and 100 years

Table 1.A Computation for Sediment Distribution Pattern after 50 Years Based On M Value of Elevation - Capacity Curve Revised after 25 Years - by Area Reduction Method

Maximum Water Level	=	280.0	
Stream Bed Level (After 25 years	=	184.5	
Est. of Sediment Vol during 25 yr	=	28.0	Mm^3

New Zero elevation	=	189.50	
Area	=	0.15	Km^2
Relative depth p	=	0.05	
Ap	=	0.52	
K = Area/Ap	=	0.30	

Sl No	Elevation (m)	Revised 1 area (Km^2)	Revised 1 capacity (Mm^3)	Depth (2)-184.5 (m)	Relative depth p (5)/95.5	Ap Type II	Sediment area Kap 0.30x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 2 area (3)-(8) (Km^2)	Revised 2 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.55	792.0	95.5	1.000	0.200	0.059	0.662	28.0	28.0	23.49	764.0
2	275.0	20.97	672.6	90.5	0.948	0.695	0.206	1.174	27.3	27.3	20.77	645.3
3	270.0	18.87	578.6	85.5	0.895	0.892	0.264	1.412	26.1	26.1	18.61	552.5
4	265.0	16.74	479.8	80.5	0.843	1.018	0.301	1.571	24.7	24.7	16.44	455.1
5	260.0	15.11	411.2	75.5	0.791	1.106	0.327	1.682	23.2	23.2	14.79	388.1
6	255.0	13.19	332.7	70.5	0.738	1.168	0.346	1.760	21.5	21.5	12.85	311.2
7	250.0	11.63	279.3	65.5	0.686	1.211	0.358	1.812	19.7	19.7	11.27	259.5
8	245.0	10.17	223.4	60.5	0.634	1.238	0.366	1.841	17.9	17.9	9.81	205.5
9	240.0	8.67	181.0	55.5	0.581	1.251	0.370	1.851	16.1	16.1	8.30	165.0
10	235.0	7.36	145.1	50.5	0.529	1.251	0.370	1.841	14.2	14.2	6.99	130.9
11	230.0	6.16	107.6	45.5	0.476	1.238	0.366	1.814	12.4	12.4	5.80	95.2
12	225.0	5.02	79.9	40.5	0.424	1.214	0.359	1.768	10.6	10.6	4.66	69.4
13	220.0	3.67	54.4	35.5	0.372	1.177	0.348	1.703	8.8	8.8	3.32	45.6
14	215.0	2.68	32.7	30.5	0.319	1.126	0.333	1.618	7.1	7.1	2.35	25.6
15	210.0	1.99	18.9	25.5	0.267	1.061	0.314	1.508	5.5	5.5	1.68	13.4
16	205.0	1.46	11.4	20.5	0.215	0.978	0.289	1.368	4.0	4.0	1.17	7.4
17	200.0	0.92	7.0	15.5	0.162	0.872	0.258	1.189	2.6	2.6	0.66	4.4
18	195.0	0.50	3.5	10.5	0.110	0.736	0.218	1.022	1.4	1.4	0.29	2.0
19	**189.5**	**0.15**	**0.2**	**5.0**	**0.052**	**0.520**	**0.154**	**0.385**	**0.4**	**0.2**	**0.00**	**0.0**
20	184.5	0.00	0.0	0.0	0.000	0.000	0.000	0.000	0.0	0.0	0.00	0.0

Appendix 1

Computation of Sediment Distribution Pattern after 50, 75 and 100 years

Table 1.B Computation for Sediment Distribution Pattern after 75 Years Based On M Value of Elevation - Capacity Curve Revised after 50 Years - by Area Reduction Method

Maximum Water Level = 280.0
Stream Bed Level (after 50 year = 189.5
Est. of Sediment Vol during 25 yr = 28.0 Mm^3

New Zero elevation = 193.75
Area = 0.15 Km^2
Relative depth p = 0.05
Ap = 0.492
K = Area/Ap = 0.31

Sl No	Elevation (m)	Revised 2 area (Km^2)	Revised 2 capacity (Mm^3)	Depth (2)-189.5 (m)	Relative depth p (5)/90.5	Ap Type III	Sediment area Kap 0.31x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 3 area (3)-(8) (Km^2)	Revised 3 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.49	764.0	90.5	1.000	0.000	0.000	0.015	28.0	28.0	23.5	736.0
2	275.0	20.77	645.3	85.5	0.945	0.019	0.006	0.083	28.0	28.0	20.8	617.3
3	270.0	18.61	552.5	80.5	0.890	0.088	0.027	0.230	27.9	27.9	18.6	524.6
4	265.0	16.44	455.1	75.5	0.834	0.208	0.065	0.452	27.7	27.7	16.4	427.5
5	260.0	14.79	388.1	70.5	0.779	0.375	0.116	0.738	27.2	27.2	14.7	360.9
6	255.0	12.85	311.2	65.5	0.724	0.577	0.179	1.071	26.5	26.5	12.7	284.8
7	250.0	11.27	259.5	60.5	0.669	0.805	0.250	1.433	25.4	25.4	11.0	234.1
8	245.0	9.81	205.5	55.5	0.613	1.043	0.324	1.800	24.0	24.0	9.5	181.5
9	240.0	8.30	165.0	50.5	0.558	1.278	0.396	2.150	22.2	22.2	7.9	142.8
10	235.0	6.99	130.9	45.5	0.503	1.495	0.463	2.457	20.0	20.0	6.5	110.8
11	230.0	5.80	95.2	40.5	0.448	1.675	0.520	2.698	17.6	17.6	5.3	77.7
12	225.0	4.66	69.4	35.5	0.392	1.805	0.560	2.845	14.9	14.9	4.1	54.5
13	220.0	3.32	45.6	30.5	0.337	1.865	0.578	2.874	12.0	12.0	2.7	33.6
14	215.0	2.35	25.6	25.5	0.282	1.842	0.571	2.759	9.1	9.1	1.8	16.4
15	210.0	1.68	13.4	20.5	0.227	1.718	0.533	2.479	6.4	6.4	1.1	7.0
16	205.0	1.17	7.4	15.5	0.171	1.480	0.459	2.015	3.9	3.9	0.7	3.5
17	200.0	0.66	4.4	10.5	0.116	1.119	0.347	1.561	1.9	1.9	0.3	2.5
18	**193.8**	**0.15**	**1.0**	**4.3**	**0.047**	**0.492**	**0.153**	**0.324**	**0.3**	**1.0**	**0.0**	**0.0**
19	189.5	0.00	0.0	0.0	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0

Appendix 1

Computation of Sediment Distribution Pattern after 50, 75 and 100 years

Table 1.C Computation for Sediment Distribution Pattern after 100 Years Based On M Value of Elevation - Capacity Curve Revised after 75 Years - by Area Reduction Method

Maximum Water Level = 280.0
Stream Bed Level (after 50 year = 193.8
Est. of Sediment Vol during 25 yr = 28.0 Mm^3

New Zero elevation = 198.25
Area = 0.17 Km^2
Relative depth p = 0.052
Ap = 0.52
K = Area/Ap = 0.33

Sl No	Elevation (m)	Revised 3 area (Km^2)	Revised 3 capacity (Mm^3)	Depth (2)-193.75 (m)	Relative depth p (5)/86.25	Ap Type II	Sediment area Kap 0.33x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 4 area (3)-(8) (Km^2)	Revised 4 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.49	736.0	86.3	1.000	0.200	0.066	0.756	28.0	28.0	23.4	708.1
2	275.0	20.76	617.3	81.3	0.942	0.722	0.237	1.349	27.2	27.2	20.5	590.1
3	270.0	18.58	524.6	76.3	0.884	0.923	0.303	1.618	25.9	25.9	18.3	498.7
4	265.0	16.37	427.5	71.3	0.826	1.049	0.344	1.792	24.3	24.3	16.0	403.2
5	260.0	14.67	360.9	66.3	0.768	1.135	0.373	1.910	22.5	22.5	14.3	338.4
6	255.0	12.67	284.8	61.3	0.710	1.193	0.392	1.988	20.6	20.6	12.3	264.2
7	250.0	11.02	234.1	56.3	0.652	1.230	0.404	2.034	18.6	18.6	10.6	215.6
8	245.0	9.48	181.5	51.3	0.594	1.249	0.410	2.051	16.5	16.5	9.1	165.0
9	240.0	7.90	142.8	46.3	0.536	1.252	0.411	2.043	14.5	14.5	7.5	128.3
10	235.0	6.53	110.8	41.3	0.478	1.239	0.407	2.010	12.4	12.4	6.1	98.4
11	230.0	5.28	77.7	36.3	0.420	1.211	0.398	1.952	10.4	10.4	4.9	67.3
12	225.0	4.10	54.5	31.3	0.362	1.168	0.383	1.868	8.5	8.5	3.7	46.0
13	220.0	2.75	33.6	26.3	0.304	1.109	0.364	1.755	6.6	6.6	2.4	27.0
14	215.0	1.78	16.4	21.3	0.246	1.030	0.338	1.606	4.9	4.9	1.4	11.6
15	210.0	1.14	7.0	16.3	0.188	0.928	0.305	1.412	3.3	3.3	0.8	3.8
16	205.0	0.71	3.5	11.3	0.130	0.794	0.260	1.454	1.8	1.8	0.4	1.7
17	**198.3**	**0.17**	**1.1**	**4.5**	**0.052**	**0.520**	**0.171**	**0.384**	**0.4**	**1.1**	**0.0**	**0.0**
18	193.8	0.00	0.0	0.0	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0

Appendix 1

Computation of Sediment Distribution Pattern after 50, 75 and 100 years

Table 1.D Computation for Sediment Distribution Pattern After 100 Years Based On M Value of Original Elevation-apacity Curve (if No Change in every 25 years) by Area Reduction Method

Maximum Water Level = 280.0
Original Stream Bed Level = 173.5
Est. of Sediment Vol during 100 Yr = 112.0 Mm^3

New Zero elevation = **201.00**
Area = 1.221 Km^2
Relative depth p = 0.258
Ap = 1.05
K = Area/Ap = 1.17

Sl No	Elevation (m)	Original area (Km^2)	Original capacity (Mm^3)	Depth (2)-173.5 (m)	Relative depth p (5)/106.5	Ap Type II	Sediment area Kap 1.17x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 1 area (3)-(8) (Km^2)	Revised 1 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.60	820.00	106.50	1.00	0.200	0.233	2.527	112.000	112.000	23.37	708.00
2	275.0	21.15	700.00	101.50	0.95	0.667	0.778	4.445	109.473	109.473	20.37	590.53
3	270.0	19.10	605.00	96.50	0.91	0.859	1.001	5.366	105.028	105.028	18.10	499.97
4	265.0	17.00	505.00	91.50	0.86	0.983	1.146	5.989	99.662	99.662	15.85	405.34
5	260.0	15.40	442.00	86.50	0.81	1.073	1.250	6.441	93.673	93.673	14.15	348.33
6	255.0	13.50	355.00	81.50	0.77	1.139	1.327	6.772	87.232	87.232	12.17	267.77
7	250.0	11.95	300.00	76.50	0.72	1.187	1.382	7.010	80.460	80.460	10.57	219.54
8	245.0	10.50	242.50	71.50	0.67	1.220	1.421	7.169	73.450	73.450	9.08	169.05
9	240.0	9.00	198.50	66.50	0.62	1.241	1.446	7.260	66.281	66.281	7.55	132.22
10	235.0	7.70	160.87	61.50	0.58	1.251	1.458	7.288	59.022	59.022	6.24	101.85
11	230.0	6.50	121.74	56.50	0.53	1.251	1.457	7.257	51.734	51.734	5.04	70.01
12	225.0	5.35	92.39	51.50	0.48	1.241	1.445	7.169	44.477	44.477	3.90	47.91
13	220.0	4.00	65.22	46.50	0.44	1.221	1.422	7.023	37.308	37.308	2.58	27.91
14	215.0	3.00	41.85	41.50	0.39	1.191	1.387	6.818	30.284	30.284	1.61	11.56
15	210.0	2.30	26.50	36.50	0.34	1.150	1.340	6.550	23.466	23.466	0.96	3.03
16	205.0	1.75	17.50	31.50	0.30	1.099	1.280	5.001	16.916	16.916	0.47	0.58
17	**201.0**	**1.22**	**12.00**	**27.50**	**0.26**	**1.048**	**1.221**	**5.945**	**11.915**	**12.000**	**0.00**	**0.00**
18	195.0	0.76	6.80	21.50	0.20	0.954	0.761	2.989	5.970	6.800	0.00	0.00
19	190.0	0.43	2.75	16.50	0.15	0.855	0.435	1.562	2.981	2.750	0.00	0.00
20	185.0	0.19	0.25	11.50	0.11	0.730	0.190	0.825	1.419	0.250	0.00	0.00
21	180.0	0.14	0.09	6.50	0.06	0.560	0.140	0.538	0.594	0.090	0.00	0.00
22	175.0	0.08	0.01	1.50	0.01	0.274	0.075	0.056	0.056	0.010	0.00	0.00
23	173.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.00	0.00

Appendix 2

Monthly Inflows at Batutegi Dam

Monthly Inflows at Batutegi Reservoir in MCM

No	Year	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Total
1	1969-70	86.81	61.17	56.08	58.59	40.60	43.21	38.33	51.88	51.51	99.32	91.78	129.03	808.3
2	1970-71	99.31	91.19	80.13	63.73	52.54	42.42	46.66	58.68	61.19	79.55	53.42	62.38	791.2
3	1971-72	66.58	52.63	39.41	37.58	31.27	37.29	43.91	77.60	87.74	92.99	66.77	64.76	698.5
4	1972-73	68.27	78.01	51.30	31.78	30.37	22.91	18.07	21.15	34.47	55.60	52.62	80.00	544.6
5	1973-74	62.17	78.96	56.32	39.09	39.60	60.63	48.63	46.75	76.43	44.64	51.03	39.89	644.1
6	1974-75	52.25	48.25	32.59	32.13	35.23	41.23	35.58	38.85	49.80	73.92	72.26	55.58	567.7
7	1975-76	77.82	57.61	37.87	35.53	36.61	30.79	38.26	44.57	35.11	51.29	73.85	65.62	584.9
8	1976-77	60.59	39.63	25.56	34.08	30.79	18.21	38.14	36.26	47.76	66.96	88.05	69.92	555.9
9	1977-78	99.48	60.93	69.95	51.41	34.54	32.91	30.44	26.10	67.72	69.02	84.24	134.79	761.5
10	1978-79	80.77	90.97	82.49	61.15	51.77	47.94	46.31	70.88	123.58	86.59	110.39	108.37	961.2
11	1979-80	89.22	88.04	62.12	102.01	62.07	51.26	39.69	40.07	46.87	93.76	61.64	59.54	796.3
12	1980-81	63.93	55.80	43.61	37.47	50.15	61.02	47.50	95.80	117.01	82.29	71.92	109.05	835.6
13	1981-92	112.60	115.88	67.57	47.89	35.85	60.12	43.75	40.59	56.11	109.56	102.25	84.36	876.5
14	1982-83	62.83	47.76	31.75	29.13	21.19	16.63	14.22	13.93	42.83	93.86	62.74	74.14	511.0
15	1983-84	72.61	78.40	47.23	36.45	25.83	18.12	19.42	32.96	35.70	56.80	40.10	87.32	550.9
16	1984-85	68.86	52.28	35.67	40.32	33.44	48.12	60.20	70.07	69.79	96.10	171.26	87.96	834.1
17	1985-86	93.51	71.71	49.11	52.19	44.65	40.25	45.25	37.48	40.94	67.39	58.12	91.08	691.7
18	1986-87	72.50	61.16	60.00	61.20	45.59	57.66	56.10	80.64	96.02	118.48	102.20	83.91	895.5
19	1987-88	88.72	75.88	70.71	41.10	31.87	31.40	28.39	38.91	55.75	109.95	79.58	108.10	760.4
20	1988-89	57.35	52.56	38.96	36.73	35.02	22.11	23.10	53.23	46.72	93.73	100.57	82.62	642.7
21	1989-90	58.24	45.56	39.75	7.66	10.78	34.97	23.52	14.26	35.65	62.47	83.00	42.78	458.6
22	1990-91	50.05	49.10	37.69	31.26	22.78	20.62	9.54	12.79	50.86	69.17	43.19	75.89	472.9
23	1991-92	65.55	92.43	40.94	25.23	19.75	14.00	9.04	31.56	59.27	48.13	66.61	131.31	603.8
24	1992-93	98.37	63.64	34.34	44.82	32.64	29.15	32.85	50.75	73.48	100.79	78.42	93.82	733.1
TOTAL		1808.4	1609.6	1191.1	1038.5	854.9	882.9	836.9	1085.8	1462.3	1922.4	1866.0	2022.2	16581.1
MEAN ANNUAL FLOW		75.35	67.06	49.63	43.27	35.62	36.79	34.87	45.24	60.93	80.10	77.75	84.26	690.88
STD DEVIATION		17.06	19.05	15.98	17.98	11.64	14.94	14.18	21.87	24.54	21.10	27.70	25.90	142.79
COEF. OF VAR.		0.23	0.28	0.32	0.42	0.33	0.41	0.41	0.48	0.40	0.26	0.36	0.31	0.21

Appendix 3

Simple Simulation Study for Preliminary Design

SIMPLE BEHAVIOR / SIMULATION ANALYSIS FOR PRELIMINARY DESIGN OF BATUTEGI RESERVOIR

SORAGE SIZE AT START		225.0 MCM
MEAN ANNUAL FLOW		690.88 MCM
WITHDRAWAL	90%	621.79 MCM
PER MONTH		51.82 MCM

sheet 1

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
1	1969-70	April	225.0	86.8	51.8	35.0	225.0	Full Supply
2		May	225.0	61.2	51.8	9.4	225.0	Full Supply
3		June	225.0	56.1	51.8	4.3	225.0	Full Supply
4		July	225.0	58.6	51.8	6.8	225.0	Full Supply
5		August	225.0	40.6	51.8	0.0	213.8	Full Supply
6		September	213.8	43.2	51.8	0.0	205.2	Full Supply
7		October	205.2	38.3	51.8	0.0	191.7	Full Supply
8		November	191.7	51.9	51.8	0.0	191.8	Full Supply
9		December	191.8	51.5	51.8	0.0	191.4	Full Supply
10		January	191.4	99.3	51.8	13.9	225.0	Full Supply
11		February	225.0	91.8	51.8	40.0	225.0	Full Supply
12		March	225.0	129.0	51.8	77.2	225.0	Full Supply
13	1970-71	April	225.0	99.3	51.8	47.5	225.0	Full Supply
14		May	225.0	91.2	51.8	39.4	225.0	Full Supply
15		June	225.0	80.1	51.8	28.3	225.0	Full Supply
16		July	225.0	63.7	51.8	11.9	225.0	Full Supply
17		August	225.0	52.5	51.8	0.7	225.0	Full Supply
18		September	225.0	42.4	51.8	0.0	215.6	Full Supply
19		October	215.6	46.7	51.8	0.0	210.4	Full Supply
20		November	210.4	58.7	51.8	0.0	217.3	Full Supply
21		December	217.3	61.2	51.8	1.7	225.0	Full Supply
22		January	225.0	79.5	51.8	27.7	225.0	Full Supply
23		February	225.0	53.4	51.8	1.6	225.0	Full Supply
24		March	225.0	62.4	51.8	10.6	225.0	Full Supply
25	1971-72	April	225.0	66.6	51.8	14.8	225.0	Full Supply
26		May	225.0	52.6	51.8	0.8	225.0	Full Supply
27		June	225.0	39.4	51.8	0.0	212.6	Full Supply
28		July	212.6	37.6	51.8	0.0	198.4	Full Supply
29		August	198.4	31.3	51.8	0.0	177.8	Full Supply
30		September	177.8	37.3	51.8	0.0	163.3	Full Supply
31		October	163.3	43.9	51.8	0.0	155.4	Full Supply
32		November	155.4	77.6	51.8	0.0	181.2	Full Supply
33		December	181.2	87.7	51.8	0.0	217.1	Full Supply
34		January	217.1	93.0	51.8	33.3	225.0	Full Supply
35		February	225.0	66.8	51.8	15.0	225.0	Full Supply
36		March	225.0	64.8	51.8	12.9	225.0	Full Supply

sheet 2

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
37	1972-73	April	225.0	68.3	51.8	16.5	225.0	Full Supply
38		May	225.0	78.0	51.8	26.2	225.0	Full Supply
39		June	225.0	51.3	51.8	0.0	224.5	Full Supply
40		July	224.5	31.8	51.8	0.0	204.4	Full Supply
41		August	204.4	30.4	51.8	0.0	183.0	Full Supply
42		September	183.0	22.9	51.8	0.0	154.1	Full Supply
43		October	154.1	18.1	51.8	0.0	120.3	Full Supply
44		November	120.3	21.2	51.8	0.0	89.7	Full Supply
45		December	89.7	34.5	51.8	0.0	72.3	Full Supply
46		January	72.3	55.6	51.8	0.0	76.1	Full Supply
47		February	76.1	52.6	51.8	0.0	76.9	Full Supply
48		March	76.9	80.0	51.8	0.0	105.1	Full Supply
49	1973-74	April	105.1	62.2	51.8	0.0	115.5	Full Supply
50		May	115.5	79.0	51.8	0.0	142.6	Full Supply
51		June	142.6	56.3	51.8	0.0	147.1	Full Supply
52		July	147.1	39.1	51.8	0.0	134.4	Full Supply
53		August	134.4	39.6	51.8	0.0	122.2	Full Supply
54		September	122.2	60.6	51.8	0.0	131.0	Full Supply
55		October	131.0	48.6	51.8	0.0	127.8	Full Supply
56		November	127.8	46.7	51.8	0.0	122.7	Full Supply
57		December	122.7	76.4	51.8	0.0	147.3	Full Supply
58		January	147.3	44.6	51.8	0.0	140.2	Full Supply
59		February	140.2	51.0	51.8	0.0	139.4	Full Supply
60		March	139.4	39.9	51.8	0.0	127.5	Full Supply
61	1974-75	April	127.5	52.3	51.8	0.0	127.9	Full Supply
62		May	127.9	48.3	51.8	0.0	124.3	Full Supply
63		June	124.3	32.6	51.8	0.0	105.1	Full Supply
64		July	105.1	32.1	51.8	0.0	85.4	Full Supply
65		August	85.4	35.2	51.8	0.0	68.8	Full Supply
66		September	68.8	41.2	51.8	0.0	58.2	Full Supply
67		October	58.2	35.6	51.8	0.0	42.0	Full Supply
68		November	42.0	38.9	51.8	0.0	29.1	Full Supply
69		December	29.1	49.8	51.8	0.0	27.0	Full Supply
70		January	27.0	73.9	51.8	0.0	49.2	Full Supply
71		February	49.2	72.3	51.8	0.0	69.6	Full Supply
72		March	69.6	55.6	51.8	0.0	73.4	Full Supply

Appendix 3

Simple Simulation Study for Preliminary Design

sheet 3

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
73	1975-76	April	73.4	77.8	51.8	0.0	99.4	Full Supply
74		May	99.4	57.6	51.8	0.0	105.2	Full Supply
75		June	105.2	37.9	51.8	0.0	91.2	Full Supply
76		July	91.2	35.5	51.8	0.0	74.9	Full Supply
77		August	74.9	36.6	51.8	0.0	59.7	Full Supply
78		September	59.7	30.8	51.8	0.0	38.7	Full Supply
79		October	38.7	38.3	51.8	0.0	25.1	Full Supply
80		November	25.1	44.6	51.8	0.0	17.9	Full Supply
81		December	17.9	35.1	51.8	0.0	1.2	Full Supply
82		January	1.2	51.3	51.8	0.0	0.7	Full Supply
83		February	0.7	73.8	51.8	0.0	22.7	Full Supply
84		March	22.7	65.6	51.8	0.0	36.5	Full Supply
85	1976-77	April	36.5	60.6	51.8	0.0	45.3	Full Supply
86		May	45.3	39.6	51.8	0.0	33.1	Full Supply
87		June	33.1	25.6	51.8	0.0	6.8	Full Supply
88		July	6.8	34.1	40.9	0.0	0.0	Deficit
89		August	0.0	30.8	30.8	0.0	0.0	Deficit
90		September	0.0	18.2	18.2	0.0	0.0	Deficit
91		October	0.0	38.1	38.1	0.0	0.0	Deficit
92		November	0.0	36.3	36.3	0.0	0.0	Deficit
93		December	0.0	47.8	47.8	0.0	0.0	Deficit
94		January	0.0	67.0	51.8	0.0	15.1	Full Supply
95		February	15.1	88.0	51.8	0.0	51.4	Full Supply
96		March	51.4	69.9	51.8	0.0	69.5	Full Supply
97	1977-78	April	69.5	99.5	51.8	0.0	117.1	Full Supply
98		May	117.1	60.9	51.8	0.0	126.3	Full Supply
99		June	126.3	69.9	51.8	0.0	144.4	Full Supply
100		July	144.4	51.4	51.8	0.0	144.0	Full Supply
101		August	144.0	34.5	51.8	0.0	126.7	Full Supply
102		September	126.7	32.9	51.8	0.0	107.8	Full Supply
103		October	107.8	30.4	51.8	0.0	86.4	Full Supply
104		November	86.4	26.1	51.8	0.0	60.7	Full Supply
105		December	60.7	67.7	51.8	0.0	76.6	Full Supply
106		January	76.6	69.0	51.8	0.0	93.8	Full Supply
107		February	93.8	84.2	51.8	0.0	126.2	Full Supply
108		March	126.2	134.8	51.8	0.0	209.2	Full Supply

sheet 4

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
109	1978-79	April	209.2	80.8	51.8	13.2	225.0	Full Supply
110		May	225.0	91.0	51.8	39.2	225.0	Full Supply
111		June	225.0	82.5	51.8	30.7	225.0	Full Supply
112		July	225.0	61.1	51.8	9.3	225.0	Full Supply
113		August	225.0	51.8	51.8	0.0	225.0	Full Supply
114		September	225.0	47.9	51.8	0.0	221.1	Full Supply
115		October	221.1	46.3	51.8	0.0	215.6	Full Supply
116		November	215.6	70.9	51.8	9.6	225.0	Full Supply
117		December	225.0	123.6	51.8	71.8	225.0	Full Supply
118		January	225.0	86.6	51.8	34.8	225.0	Full Supply
119		February	225.0	110.4	51.8	58.6	225.0	Full Supply
120		March	225.0	88.4	51.8	36.6	225.0	Full Supply
121	1979-80	April	225.0	89.2	51.8	37.4	225.0	Full Supply
122		May	225.0	88.0	51.8	36.2	225.0	Full Supply
123		June	225.0	62.1	51.8	10.3	225.0	Full Supply
124		July	225.0	102.0	51.8	50.2	225.0	Full Supply
125		August	225.0	62.1	51.8	10.3	225.0	Full Supply
126		September	225.0	51.3	51.8	0.0	224.4	Full Supply
127		October	224.4	39.7	51.8	0.0	212.3	Full Supply
128		November	212.3	40.1	51.8	0.0	200.6	Full Supply
129		December	200.6	46.9	51.8	0.0	195.6	Full Supply
130		January	195.6	93.8	51.8	12.6	225.0	Full Supply
131		February	225.0	61.6	51.8	9.8	225.0	Full Supply
132		March	225.0	59.5	51.8	7.7	225.0	Full Supply
133	1980-81	April	225.0	63.9	51.8	12.1	225.0	Full Supply
134		May	225.0	55.8	51.8	4.0	225.0	Full Supply
135		June	225.0	43.6	51.8	0.0	216.8	Full Supply
136		July	216.8	37.5	51.8	0.0	202.4	Full Supply
137		August	202.4	50.2	51.8	0.0	200.8	Full Supply
138		September	200.8	61.0	51.8	0.0	210.0	Full Supply
139		October	210.0	47.5	51.8	0.0	205.7	Full Supply
140		November	205.7	95.8	51.8	24.7	225.0	Full Supply
141		December	225.0	117.0	51.8	65.2	225.0	Full Supply
142		January	225.0	82.3	51.8	30.5	225.0	Full Supply
143		February	225.0	71.9	51.8	20.1	225.0	Full Supply
144		March	225.0	109.1	51.8	57.2	225.0	Full Supply

Appendix 3

Simple Simulation Study for Preliminary Design

sheet 5

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
145	1981-82	April	225.0	112.6	51.8	60.8	225.0	Full Supply
146		May	225.0	115.9	51.8	64.1	225.0	Full Supply
147		June	225.0	67.6	51.8	15.8	225.0	Full Supply
148		July	225.0	47.9	51.8	0.0	221.1	Full Supply
149		August	221.1	35.9	51.8	0.0	205.1	Full Supply
150		September	205.1	60.1	51.8	0.0	213.4	Full Supply
151		October	213.4	43.8	51.8	0.0	205.3	Full Supply
152		November	205.3	40.6	51.8	0.0	194.1	Full Supply
153		December	194.1	56.1	51.8	0.0	198.4	Full Supply
154		January	198.4	109.6	51.8	31.2	225.0	Full Supply
155		February	225.0	102.2	51.8	50.4	225.0	Full Supply
156		March	225.0	84.4	51.8	32.5	225.0	Full Supply
157	1982-83	April	225.0	62.8	51.8	11.0	225.0	Full Supply
158		May	225.0	47.8	51.8	0.0	220.9	Full Supply
159		June	220.9	31.8	51.8	0.0	200.9	Full Supply
160		July	200.9	29.1	51.8	0.0	178.2	Full Supply
161		August	178.2	21.2	51.8	0.0	147.6	Full Supply
162		September	147.6	16.6	51.8	0.0	112.4	Full Supply
163		October	112.4	14.2	51.8	0.0	74.8	Full Supply
164		November	74.8	13.9	51.8	0.0	36.9	Full Supply
165		December	36.9	42.8	51.8	0.0	27.9	Full Supply
166		January	27.9	93.9	51.8	0.0	70.0	Full Supply
167		February	70.0	62.7	51.8	0.0	80.9	Full Supply
168		March	80.9	74.1	51.8	0.0	103.2	Full Supply
169	1983-84	April	103.2	72.6	51.8	0.0	124.0	Full Supply
170		May	124.0	78.4	51.8	0.0	150.6	Full Supply
171		June	150.6	47.2	51.8	0.0	146.0	Full Supply
172		July	146.0	36.5	51.8	0.0	130.6	Full Supply
173		August	130.6	25.8	51.8	0.0	104.6	Full Supply
174		September	104.6	18.1	51.8	0.0	70.9	Full Supply
175		October	70.9	19.4	51.8	0.0	38.5	Full Supply
176		November	38.5	33.0	51.8	0.0	19.7	Full Supply
177		December	19.7	35.7	51.8	0.0	3.6	Full Supply
178		January	3.6	56.8	51.8	0.0	8.6	Full Supply
179		February	8.6	40.1	48.7	0.0	0.0	Deficit
180		March	0.0	87.3	51.8	0.0	35.5	Full Supply

sheet 6

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
181	1984-85	April	35.5	68.9	51.8	0.0	52.5	Full Supply
182		May	52.5	52.3	51.8	0.0	53.0	Full Supply
183		June	53.0	35.7	51.8	0.0	36.9	Full Supply
184		July	36.9	40.3	51.8	0.0	25.4	Full Supply
185		August	25.4	33.4	51.8	0.0	7.0	Full Supply
186		September	7.0	48.1	51.8	0.0	3.3	Full Supply
187		October	3.3	60.2	51.8	0.0	11.7	Full Supply
188		November	11.7	70.1	51.8	0.0	29.9	Full Supply
189		December	29.9	69.8	51.8	0.0	47.9	Full Supply
190		January	47.9	96.1	51.8	0.0	92.2	Full Supply
191		February	92.2	171.3	51.8	0.0	211.6	Full Supply
192		March	211.6	88.0	51.8	22.8	225.0	Full Supply
193	1985-86	April	225.0	93.5	51.8	41.7	225.0	Full Supply
194		May	225.0	71.7	51.8	19.9	225.0	Full Supply
195		June	225.0	49.1	51.8	0.0	222.3	Full Supply
196		July	222.3	52.2	51.8	0.0	222.7	Full Supply
197		August	222.7	44.6	51.8	0.0	215.5	Full Supply
198		September	215.5	40.3	51.8	0.0	203.9	Full Supply
199		October	203.9	45.3	51.8	0.0	197.4	Full Supply
200		November	197.4	37.5	51.8	0.0	183.0	Full Supply
201		December	183.0	40.9	51.8	0.0	172.2	Full Supply
202		January	172.2	67.4	51.8	0.0	187.7	Full Supply
203		February	187.7	58.1	51.8	0.0	194.0	Full Supply
204		March	194.0	91.1	51.8	8.3	225.0	Full Supply
205	1986-87	April	225.0	72.5	51.8	20.7	225.0	Full Supply
206		May	225.0	61.2	51.8	9.3	225.0	Full Supply
207		June	225.0	60.0	51.8	8.2	225.0	Full Supply
208		July	225.0	61.2	51.8	9.4	225.0	Full Supply
209		August	225.0	45.6	51.8	0.0	218.8	Full Supply
210		September	218.8	57.7	51.8	0.0	224.6	Full Supply
211		October	224.6	56.1	51.8	3.9	225.0	Full Supply
212		November	225.0	80.6	51.8	28.8	225.0	Full Supply
213		December	225.0	96.0	51.8	44.2	225.0	Full Supply
214		January	225.0	118.5	51.8	66.7	225.0	Full Supply
215		February	225.0	102.2	51.8	50.4	225.0	Full Supply
216		March	225.0	83.9	51.8	32.1	225.0	Full Supply

Appendix 3

Simple Simulation Study for Preliminary Design

sheet 7

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
217	1987-88	April	225.0	88.7	51.8	36.9	225.0	Full Supply
218		May	225.0	75.9	51.8	24.1	225.0	Full Supply
219		June	225.0	70.7	51.8	18.9	225.0	Full Supply
220		July	225.0	41.1	51.8	0.0	214.3	Full Supply
221		August	214.3	31.9	51.8	0.0	194.3	Full Supply
222		September	194.3	31.4	51.8	0.0	173.9	Full Supply
223		October	173.9	28.4	51.8	0.0	150.5	Full Supply
224		November	150.5	38.9	51.8	0.0	137.6	Full Supply
225		December	137.6	55.8	51.8	0.0	141.5	Full Supply
226		January	141.5	109.9	51.8	0.0	199.7	Full Supply
227		February	199.7	79.6	51.8	2.4	225.0	Full Supply
228		March	225.0	108.1	51.8	56.3	225.0	Full Supply
229	1988-89	April	225.0	57.3	51.8	5.5	225.0	Full Supply
230		May	225.0	52.6	51.8	0.7	225.0	Full Supply
231		June	225.0	39.0	51.8	0.0	212.1	Full Supply
232		July	212.1	36.7	51.8	0.0	197.1	Full Supply
233		August	197.1	35.0	51.8	0.0	180.3	Full Supply
234		September	180.3	22.1	51.8	0.0	150.6	Full Supply
235		October	150.6	23.1	51.8	0.0	121.8	Full Supply
236		November	121.8	53.2	51.8	0.0	123.3	Full Supply
237		December	123.3	46.7	51.8	0.0	118.2	Full Supply
238		January	118.2	93.7	51.8	0.0	160.1	Full Supply
239		February	160.1	100.6	51.8	0.0	208.8	Full Supply
240		March	208.8	82.6	51.8	14.6	225.0	Full Supply
241	1989-90	April	225.0	58.2	51.8	6.4	225.0	Full Supply
242		May	225.0	45.6	51.8	0.0	218.7	Full Supply
243		June	218.7	39.7	51.8	0.0	206.7	Full Supply
244		July	206.7	7.7	51.8	0.0	162.5	Full Supply
245		August	162.5	10.8	51.8	0.0	121.5	Full Supply
246		September	121.5	35.0	51.8	0.0	104.6	Full Supply
247		October	104.6	23.5	51.8	0.0	76.3	Full Supply
248		November	76.3	14.3	51.8	0.0	38.8	Full Supply
249		December	38.8	35.6	51.8	0.0	22.6	Full Supply
250		January	22.6	62.5	51.8	0.0	33.3	Full Supply
251		February	33.3	83.0	51.8	0.0	64.5	Full Supply
252		March	64.5	62.8	51.8	0.0	75.4	Full Supply

sheet 8

No	Year	Month	Storage at start of month	Inflow	Withdrawal	Spill	Storage at end of month	Remark
253	1990-91	April	75.4	50.1	51.8	0.0	73.7	Full Supply
254		May	73.7	49.1	51.8	0.0	70.9	Full Supply
255		June	70.9	37.7	51.8	0.0	56.8	Full Supply
256		July	56.8	31.3	51.8	0.0	36.2	Full Supply
257		August	36.2	22.8	51.8	0.0	7.2	Full Supply
258		September	7.2	20.6	27.8	0.0	0.0	Deficit
259		October	0.0	9.5	9.5	0.0	0.0	Deficit
260		November	0.0	12.8	12.8	0.0	0.0	Deficit
261		December	0.0	50.9	50.9	0.0	0.0	Deficit
262		January	0.0	69.2	51.8	0.0	17.4	Full Supply
263		February	17.4	43.2	51.8	0.0	8.7	Full Supply
264		March	8.7	75.9	51.8	0.0	32.8	Full Supply
265	1991-92	April	32.8	65.6	51.8	0.0	46.5	Full Supply
266		May	46.5	92.4	51.8	0.0	87.2	Full Supply
267		June	87.2	40.9	51.8	0.0	76.3	Full Supply
268		July	76.3	25.2	51.8	0.0	49.7	Full Supply
269		August	49.7	19.8	51.8	0.0	17.6	Full Supply
270		September	17.6	14.0	31.6	0.0	0.0	Deficit
271		October	0.0	9.0	9.0	0.0	0.0	Deficit
272		November	0.0	31.6	31.6	0.0	0.0	Deficit
273		December	0.0	59.3	51.8	0.0	7.5	Full Supply
274		January	7.5	48.1	51.8	0.0	3.8	Full Supply
275		February	3.8	66.6	51.8	0.0	18.6	Full Supply
276		March	18.6	131.3	51.8	0.0	98.1	Full Supply
277	1992-93	April	98.1	98.4	51.8	0.0	144.6	Full Supply
278		May	144.6	63.6	51.8	0.0	156.4	Full Supply
279		June	156.4	34.3	51.8	0.0	139.0	Full Supply
280		July	139.0	44.8	51.8	0.0	132.0	Full Supply
281		August	132.0	32.6	51.8	0.0	112.8	Full Supply
282		September	112.8	29.1	51.8	0.0	90.1	Full Supply
283		October	90.1	32.9	51.8	0.0	71.2	Full Supply
284		November	71.2	50.8	51.8	0.0	70.1	Full Supply
285		December	70.1	73.5	51.8	0.0	91.8	Full Supply
286		January	91.8	100.8	51.8	0.0	140.7	Full Supply
287		February	140.7	78.4	51.8	0.0	167.3	Full Supply
288		March	167.3	93.8	51.8	0.0	209.3	Full Supply

RELIABILITY ANALYSIS

MONTHLY BASIS		
TOTAL NO. OF MONTH	288	MONTH
TOTAL NO. OF MONTH FAILURE	14	MONTH
PROBABILITY OF FAILURE	5	%
TIME RELIABILITY	95	%

ANNUAL BASIS		
TOTAL NO. OF YEAR	24	YEAR
TOTAL NO. OF YEAR FAILURE	4	YEAR
PROBABILITY OF FAILURE	17	%
ANNUAL RELIABILITY	83	%

TOTAL DEMAND	14,923	MCM
TOTAL DEFICIT	291	MCM
VOLUMETRIC RELIABILITY	98.0	%
RESILIENCE	6	MONTH

Appendix 4

Monthly Rainfall and Gain/Loss from Reservoir

MONTHLY RAINFALL AND GAIN/LOSS FROM RESERVOIR

No	Year	Month	Monthly Rainfall (mm)	Mean Evapo. (mm)	Gain/ Loss (mm)
1	1969-70	April	155.1	112.0	43.1
2		May	111.9	112.0	-0.1
3		June	103.3	128.0	-24.7
4		July	107.6	124.0	-16.4
5		August	77.3	124.0	-46.7
6		September	81.7	116.0	-34.3
7		October	73.4	110.0	-36.6
8		November	96.3	110.0	-13.7
9		December	95.6	121.0	-25.4
10		January	176.2	128.0	48.2
11		February	163.5	126.0	37.5
12		March	226.2	120.0	106.2
13	1970-71	April	176.1	112.0	64.1
14		May	162.5	112.0	50.5
15		June	143.8	112.0	31.8
16		July	116.2	128.0	-11.8
17		August	97.4	124.0	-26.6
18		September	80.3	124.0	-43.7
19		October	87.5	116.0	-28.5
20		November	107.7	110.0	-2.3
21		December	111.9	110.0	1.9
22		January	142.9	121.0	21.9
23		February	98.8	128.0	-29.2
24		March	113.9	126.0	-12.1
25	1971-72	April	121.0	120.0	1.0
26		May	97.5	112.0	-14.5
27		June	75.3	112.0	-36.7
28		July	72.2	112.0	-39.8
29		August	61.6	128.0	-66.4
30		September	71.7	124.0	-52.3
31		October	82.8	124.0	-41.2
32		November	139.6	116.0	23.6
33		December	156.7	110.0	46.7
34		January	165.5	110.0	55.5
35		February	121.3	121.0	0.3
36		March	118.0	128.0	-10.0
37	1972-73	April	123.9	126.0	-2.1
38		May	140.3	120.0	20.3
39		June	95.3	112.0	-16.7
40		July	62.4	112.0	-49.6
41		August	60.0	112.0	-52.0
42		September	47.5	128.0	-80.5
43		October	39.3	124.0	-84.7
44		November	44.5	124.0	-79.5
45		December	66.9	116.0	-49.1
46		January	102.5	110.0	-7.5
47		February	97.5	110.0	-12.5
48		March	143.6	121.0	22.6
49	1973-74	April	113.6	128.0	-14.4
50		May	141.9	126.0	15.9
51		June	103.7	120.0	-16.3
52		July	74.7	112.0	-37.3
53		August	75.6	112.0	-36.4
54		September	111.0	112.0	-1.0
55		October	90.8	128.0	-37.2
56		November	87.6	124.0	-36.4
57		December	137.6	124.0	13.6
58		January	84.1	116.0	-31.9
59		February	94.8	110.0	-15.2
60		March	76.1	110.0	-33.9
61	1974-75	April	96.9	121.0	-24.1
62		May	90.1	128.0	-37.9
63		June	63.8	126.0	-62.2
64		July	63.0	120.0	-57.0
65		August	68.2	112.0	-43.8
66		September	78.3	112.0	-33.7
67		October	68.8	112.0	-43.2
68		November	74.3	128.0	-53.7
69		December	92.8	124.0	-31.2
70		January	133.4	124.0	9.4
71		February	130.6	116.0	14.6
72		March	102.5	110.0	-7.5
73	1975-76	April	140.0	110.0	30.0
74		May	105.9	121.0	-15.1
75		June	72.7	128.0	-55.3
76		July	68.7	126.0	-57.3
77		August	70.5	120.0	-49.5
78		September	60.7	112.0	-51.3
79		October	73.3	112.0	-38.7
80		November	83.9	112.0	-28.1
81		December	68.0	128.0	-60.0
82		January	95.3	124.0	-28.7
83		February	133.3	124.0	9.3
84		March	119.4	116.0	3.4
85	1976-77	April	110.9	110.0	0.9
86		May	75.6	110.0	-34.4
87		June	51.9	121.0	-69.1
88		July	66.3	128.0	-61.7
89		August	60.7	126.0	-65.3
90		September	39.6	120.0	-80.4
91		October	73.1	112.0	-38.9
92		November	70.0	112.0	-42.0
93		December	89.3	112.0	-22.7
94		January	121.7	128.0	-6.3
95		February	157.2	120.0	37.2
96		March	126.6	112	14.6
97	1977-78	April	176.4	112	64.4
98		May	111.5	112	-0.5
99		June	126.7	128	-1.3
100		July	95.5	124	-28.5
101		August	67.1	124	-56.9
102		September	64.3	116	-51.7
103		October	60.2	110	-49.8
104		November	52.8	110	-57.2
105		December	122.9	121	1.9
106		January	125.1	128	-2.9
107		February	150.8	120.0	30.8
108		March	235.9	112.0	123.9
109	1978-79	April	144.9	112.0	32.9
110		May	162.1	112.0	50.1
111		June	147.8	128.0	19.8
112		July	111.9	124.0	-12.1
113		August	96.1	124.0	-27.9
114		September	89.6	116.0	-26.4
115		October	86.9	110.0	-23.1
116		November	128.3	110.0	18.3
117		December	217.0	121.0	96.0
118		January	154.7	128.0	26.7
119		February	194.8	120.0	74.8
120		March	157.7	112.0	45.7
121	1979-80	April	159.1	112.0	47.1
122		May	157.2	112.0	45.2
123		June	113.5	128.0	-14.5
124		July	180.7	124.0	56.7
125		August	113.4	124.0	-10.6
126		September	95.2	116.0	-20.8
127		October	75.7	110.0	-34.3
128		November	76.4	110.0	-33.6
129		December	87.8	121.0	-33.2
130		January	166.8	128.0	38.8
131		February	112.7	120.0	-7.3
132		March	109.2	112.0	-2.8
133	1980-81	April	116.6	112.0	4.6
134		May	102.9	112.0	-9.1
135		June	82.3	128.0	-45.7
136		July	72.0	124.0	-52.0
137		August	93.4	124.0	-30.6
138		September	111.6	116.0	-4.4
139		October	88.9	110.0	-21.1
140		November	170.2	110.0	60.2
141		December	205.9	121.0	84.9
142		January	147.5	128.0	19.5
143		February	130.0	120.0	10.0
144		March	192.5	112.0	80.5

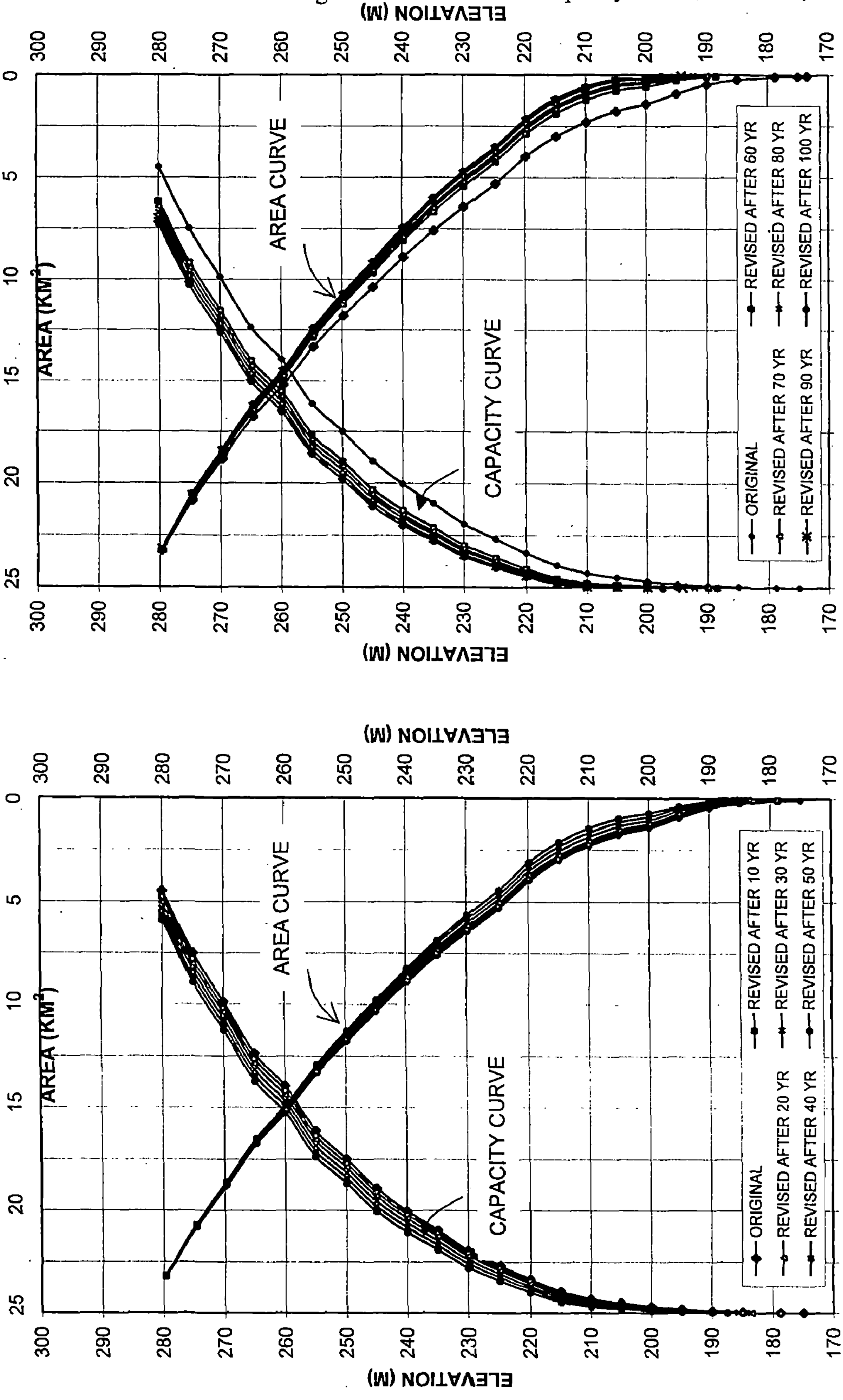
Appendix 4

Monthly Rainfall and Gain/Loss from Reservoir

No	Year	Month	Monthly Rainfall (mm)	Mean Evapo. (mm)	Gain/ Loss (mm)
145	1981-82	April	198.5	112.0	86.5
146		May	204.1	112.0	92.1
147		June	122.7	128.0	-5.3
148		July	89.5	124.0	-34.5
149		August	69.3	124.0	-54.7
150		September	110.1	116.0	-5.9
151		October	82.6	110.0	-27.4
152		November	77.2	110.0	-32.8
153		December	103.4	121.0	-17.6
154		January	193.4	128.0	65.4
155		February	181.1	120.0	61.1
156		March	151.0	112.0	39.0
157	1982-83	April	114.7	112.0	2.7
158		May	89.3	112.0	-22.7
159		June	62.4	128.0	-65.6
160		July	57.9	124.0	-66.1
161		August	44.6	124.0	-79.4
162		September	36.9	116.0	-79.1
163		October	32.8	110.0	-77.2
164		November	32.3	110.0	-77.7
165		December	81.0	121.0	-40.0
166		January	167.0	128.0	39.0
167		February	114.6	120.0	-5.4
168		March	133.7	112.0	21.7
169	1983-84	April	131.2	112.0	19.2
170		May	140.9	112.0	28.9
171		June	88.4	128.0	-39.6
172		July	70.3	124.0	-53.7
173		August	52.4	124.0	-71.6
174		September	39.4	116.0	-76.6
175		October	41.6	110.0	-68.4
176		November	64.4	110.0	-45.6
177		December	69.0	121.0	-52.0
178		January	104.5	128.0	-23.5
179		February	76.4	120.0	-43.6
180		March	155.9	112.0	43.9
181	1984-85	April	124.9	112.0	12.9
182		May	96.9	112.0	-15.1
183		June	69.0	128.0	-59.0
184		July	76.8	124.0	-47.2
185		August	65.2	124.0	-58.8
186		September	89.9	116.0	-26.1
187		October	110.3	110.0	0.3
188		November	126.9	110.0	16.9
189		December	126.4	121.0	5.4
190		January	170.7	128.0	42.7
191		February	297.3	120.0	177.3
192		March	157.0	112.0	45.0
193	1985-86	April	166.4	112.0	54.4
194		May	129.7	112.0	17.7
195		June	91.6	128.0	-36.4
196		July	96.8	124.0	-27.2
197		August	84.1	124.0	-39.9
198		September	76.7	116.0	-39.3
199		October	85.1	110.0	-24.9
200		November	72.0	110.0	-38.0
201		December	77.8	121.0	-43.2
202		January	122.4	128.0	-5.6
203		February	106.8	120.0	-13.2
204		March	162.3	112.0	50.3
205	1986-87	April	131.0	112.0	19.0
206		May	111.9	112.0	-0.1
207		June	109.9	128.0	-18.1
208		July	112.0	124.0	-12.0
209		August	85.7	124.0	-38.3
210		September	106.0	116.0	-10.0
211		October	103.4	110.0	-6.6
212		November	144.7	110.0	34.7
213		December	170.6	121.0	49.6
214		January	208.4	128.0	80.4
215		February	181.0	120.0	61.0
216		March	150.2	112.0	38.2
217	1987-88	April	158.3	112.0	46.3
218		May	136.7	112.0	24.7
219		June	128.0	128.0	0.0
220		July	78.1	124.0	-45.9
221		August	62.6	124.0	-61.4
222		September	61.8	116.0	-54.2
223		October	56.7	110.0	-53.3
224		November	74.4	110.0	-35.6
225		December	102.8	121.0	-18.2
226		January	194.1	128.0	66.1
227		February	142.9	120.0	22.9
228		March	190.9	112.0	78.9
229	1988-89	April	105.5	112.0	-6.5
230		May	97.4	112.0	-14.6
231		June	74.5	128.0	-53.5
232		July	70.8	124.0	-53.2
233		August	67.9	124.0	-56.1
234		September	46.1	116.0	-69.9
235		October	47.8	110.0	-62.2
236		November	98.5	110.0	-11.5
237		December	87.6	121.0	-33.4
238		January	166.7	128.0	38.7
239		February	178.3	120.0	58.3
240		March	148.0	112.0	36.0
241	1989-90	April	107.0	112.0	-5.0
242		May	85.6	112.0	-26.4
243		June	75.8	128.0	-52.2
244		July	21.8	124.0	-102.2
245		August	27.0	124.0	-97.0
246		September	67.8	116.0	-48.2
247		October	48.5	110.0	-61.5
248		November	32.9	110.0	-77.1
249		December	68.9	121.0	-52.1
250		January	114.1	128.0	-13.9
251		February	148.7	120.0	28.7
252		March	114.6	112.0	2.6
253	1990-91	April	93.2	112.0	-18.8
254		May	91.6	112.0	-20.4
255		June	72.4	128.0	-55.6
256		July	61.5	124.0	-62.5
257		August	47.3	124.0	-76.7
258		September	43.6	116.0	-72.4
259		October	24.9	110.0	-85.1
260		November	30.4	110.0	-79.6
261		December	94.5	121.0	-26.5
262		January	125.4	128.0	-2.6
263		February	81.6	120.0	-38.4
264		March	136.7	112.0	24.7
265	1991-92	April	119.3	112.0	7.3
266		May	164.6	112.0	52.6
267		June	77.8	128.0	-50.2
268		July	51.4	124.0	-72.6
269		August	42.2	124.0	-81.8
270		September	32.5	116.0	-83.5
271		October	24.1	110.0	-85.9
272		November	62.0	110.0	-48.0
273		December	108.7	121.0	-12.3
274		January	89.9	128.0	-38.1
275		February	121.1	120.0	1.1
276		March	230.0	112.0	118.0
277	1992-93	April	174.6	112.0	62.6
278		May	116.1	112.0	4.1
279		June	66.7	128.0	-61.3
280		July	84.4	124.0	-39.6
281		August	63.9	124.0	-60.1
282		September	58.0	116.0	-58.0
283		October	64.2	110.0	-45.8
284		November	94.4	110.0	-15.6
285		December	132.6	121.0	11.6
286		January	178.6	128.0	50.6
287		February	141.0	120.0	21.0
288		March	166.9	112.0	54.9

Appendix 5

Change in Elevation-Area-Capacity Curve after Every 10 Years



Change in Elevation - Area - Capacity Curve Revised after every 10 years during 100 years

Appendix 6

Computation of Sediment Distribution Pattern (Original, after 10, and after 20 years)

Table 6.A. Computation for Sediment Distribution Pattern during 10 Years Based On M Value of Original Elevation-Capacity Curve by Area Reduction Method

Maximum Water Level = 280.0
Original Stream Bed Level = 173.5
Est. of Sediment Vol during 10 Yr = 11.20 Mm^3

New Zero Elevation = **178.75**
Area = 0.055 Km^2
Relative depth p = 0.049
Ap = 0.52
K = Area/Ap = 0.10

Sl No	Elevation (m)	Original area (Km^2)	Original capacity (Mm^3)	Depth (2)-173.5 (m)	Relative depth p (5)/106.5	Ap Type II	Sediment area Kap 0.10x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 1 area (3)-(8) (Km^2)	Revised 1 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.60	820.00	106.5	1.000	0.395	0.041	0.271	11.20	11.20	23.56	808.80
2	275.0	21.15	700.00	101.5	0.953	0.640	0.067	0.385	10.93	10.93	21.08	689.07
3	270.0	19.10	605.00	96.5	0.906	0.830	0.087	0.476	10.55	10.55	19.01	594.45
4	265.0	17.00	505.00	91.5	0.859	0.985	0.103	0.544	10.07	10.07	16.90	494.93
5	260.0	15.40	442.00	86.5	0.812	1.090	0.114	0.585	9.53	9.53	15.29	432.47
6	255.0	13.50	355.00	81.5	0.765	1.140	0.120	0.615	8.94	8.94	13.38	346.06
7	250.0	11.95	300.00	76.5	0.718	1.205	0.126	0.641	8.33	8.33	11.82	291.67
8	245.0	10.50	242.50	71.5	0.671	1.240	0.130	0.659	7.69	7.69	10.37	234.81
9	240.0	9.00	198.50	66.5	0.624	1.275	0.134	0.669	7.03	7.03	8.87	191.47
10	235.0	7.70	160.87	61.5	0.577	1.275	0.134	0.665	6.36	6.36	7.57	154.51
11	230.0	6.50	121.74	56.5	0.531	1.260	0.132	0.655	5.69	5.69	6.37	116.04
12	225.0	5.35	92.39	51.5	0.484	1.240	0.130	0.646	5.04	5.04	5.22	87.35
13	220.0	4.00	65.22	46.5	0.437	1.225	0.128	0.636	4.39	4.39	3.87	60.82
14	215.0	3.00	41.85	41.5	0.390	1.200	0.126	0.619	3.76	3.76	2.87	38.09
15	210.0	2.30	27.00	36.5	0.343	1.160	0.122	0.606	3.14	3.14	2.18	23.86
16	205.0	1.75	19.00	31.5	0.296	1.150	0.121	0.577	2.53	2.53	1.63	16.47
17	200.0	1.40	11.50	26.5	0.249	1.050	0.110	0.527	1.96	1.96	1.29	9.54
18	195.0	0.90	6.50	21.5	0.202	0.960	0.101	0.472	1.43	1.43	0.80	5.07
19	190.0	0.43	2.90	16.5	0.155	0.840	0.088	0.402	0.96	0.96	0.35	1.94
20	185.0	0.20	0.75	11.5	0.108	0.694	0.073	0.399	0.55	0.55	0.13	0.20
21	**178.8**	**0.05**	**0.09**	**5.3**	**0.049**	**0.524**	**0.055**	**0.141**	**0.16**	**0.09**	**0.00**	**0.00**
22	175.0	0.02	0.01	1.5	0.014	0.200	0.020	0.015	0.02	0.01	0.00	0.00
23	173.5	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00

Appendix 6

Computation of Sediment Distribution Pattern (Original, after 10, and after 20 years)

Table 6.B. Computation for Sediment Distribution Pattern during 20 Years Based On M Value of Elevation-Capacity Curve Revised After 10 Years by Area Reduction Method

Maximum Water Level = 280.0
Original Stream Bed Level = 178.8
Est. of Sediment Vol during 10 Yr = 11.20 Mm^3

New Zero Elevation = **183.50**
Area = 0.057 Km^2
Relative depth p = 0.047
Ap = 0.51
K = Area/Ap = 0.11

Sl No	Elevation (m)	Revised 1 area (Km^2)	Revised 1 capacity (Mm^3)	Depth (2)-178.75 (m)	Relative depth p (5)/101.25	Ap Type II	Sediment area Kap 0.11x(7) (Km^2)	Sediment volume (Mm^3)	Accumulated sediment volume (Mm^3)	Modified accumulated volume (Mm^3)	Revised 2 area (3)-(8) (Km^2)	Revised 2 capacity (4)-(11) (Mm^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.56	808.80	101.3	1.000	0.395	0.044	0.287	11.20	11.20	23.51	797.60
2	275.0	21.08	689.07	96.3	0.951	0.640	0.071	0.407	10.91	10.91	21.01	678.15
3	270.0	19.01	594.45	91.3	0.901	0.828	0.092	0.502	10.51	10.51	18.92	583.95
4	265.0	16.90	494.93	86.3	0.852	0.983	0.109	0.573	10.01	10.01	16.79	484.92
5	260.0	15.29	432.47	81.3	0.802	1.085	0.120	0.614	9.43	9.43	15.17	423.04
6	255.0	13.38	346.06	76.3	0.753	1.130	0.125	0.647	8.82	8.82	13.26	337.24
7	250.0	11.82	291.67	71.3	0.704	1.205	0.134	0.678	8.17	8.17	11.69	283.50
8	245.0	10.37	234.81	66.3	0.654	1.240	0.137	0.697	7.49	7.49	10.23	227.32
9	240.0	8.87	191.47	61.3	0.605	1.275	0.141	0.707	6.80	6.80	8.72	184.68
10	235.0	7.57	154.51	56.3	0.556	1.275	0.141	0.703	6.09	6.09	7.42	148.42
11	230.0	6.37	116.04	51.3	0.506	1.260	0.140	0.693	5.39	5.39	6.23	110.66
12	225.0	5.22	87.35	46.3	0.457	1.240	0.137	0.682	4.69	4.69	5.08	82.66
13	220.0	3.87	60.82	41.3	0.407	1.220	0.135	0.665	4.01	4.01	3.74	56.81
14	215.0	2.87	38.09	36.3	0.358	1.180	0.131	0.639	3.35	3.35	2.74	34.75
15	210.0	2.18	23.86	31.3	0.309	1.125	0.125	0.610	2.71	2.71	2.05	21.15
16	205.0	1.63	16.47	26.3	0.259	1.075	0.119	0.570	2.10	2.10	1.51	14.37
17	200.0	1.29	9.54	21.3	0.210	0.980	0.109	0.514	1.53	1.53	1.18	8.02
18	195.0	0.80	5.07	16.3	0.160	0.875	0.097	0.439	1.01	1.01	0.70	4.06
19	190.0	0.35	1.94	11.3	0.111	0.710	0.079	0.440	0.57	0.57	0.27	1.37
20	**183.5**	**0.06**	**0.17**	**4.8**	**0.047**	**0.510**	**0.057**	**0.134**	**0.13**	**0.17**	**0.00**	**0.00**
21	178.8	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
22	175.0	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
23	173.5	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00

Appendix 6

Computation of Sediment Distribution Pattern (Original, after 10, and after 20 years)

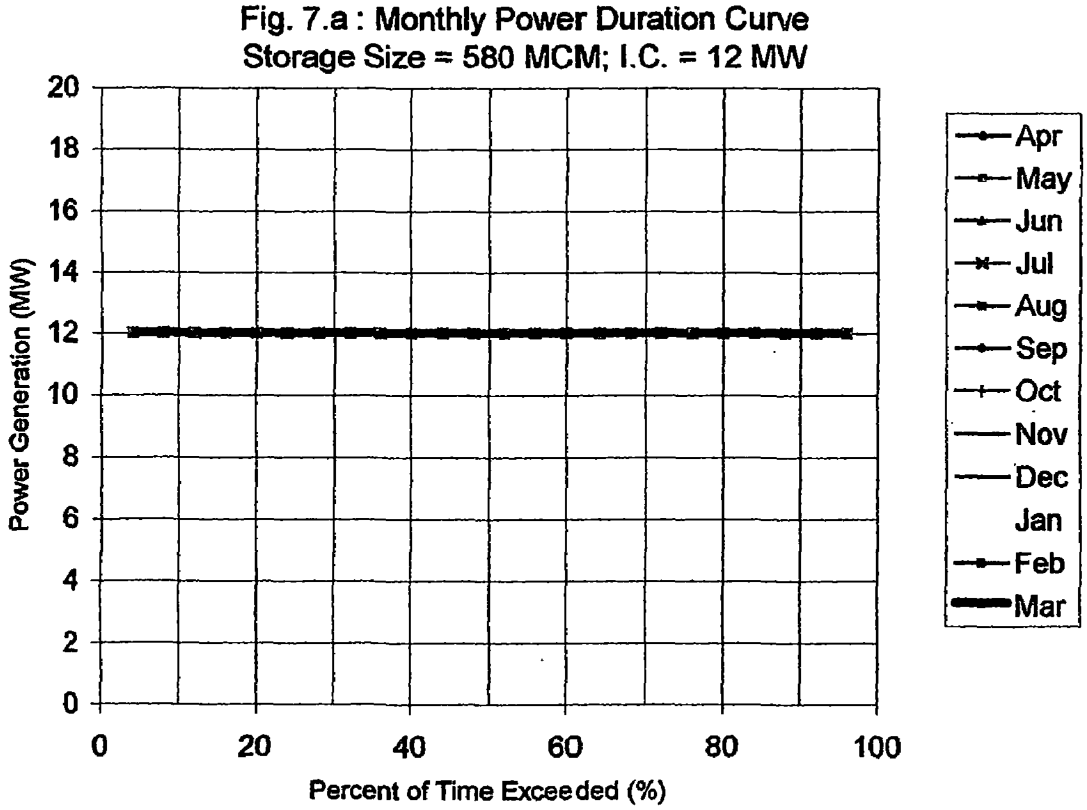
Table 6.C. Computation for Sediment Distribution Pattern during 30 Years Based On M Value of Elevation-Capacity Curve Revised After 20 Years by Empirical Reduction Method

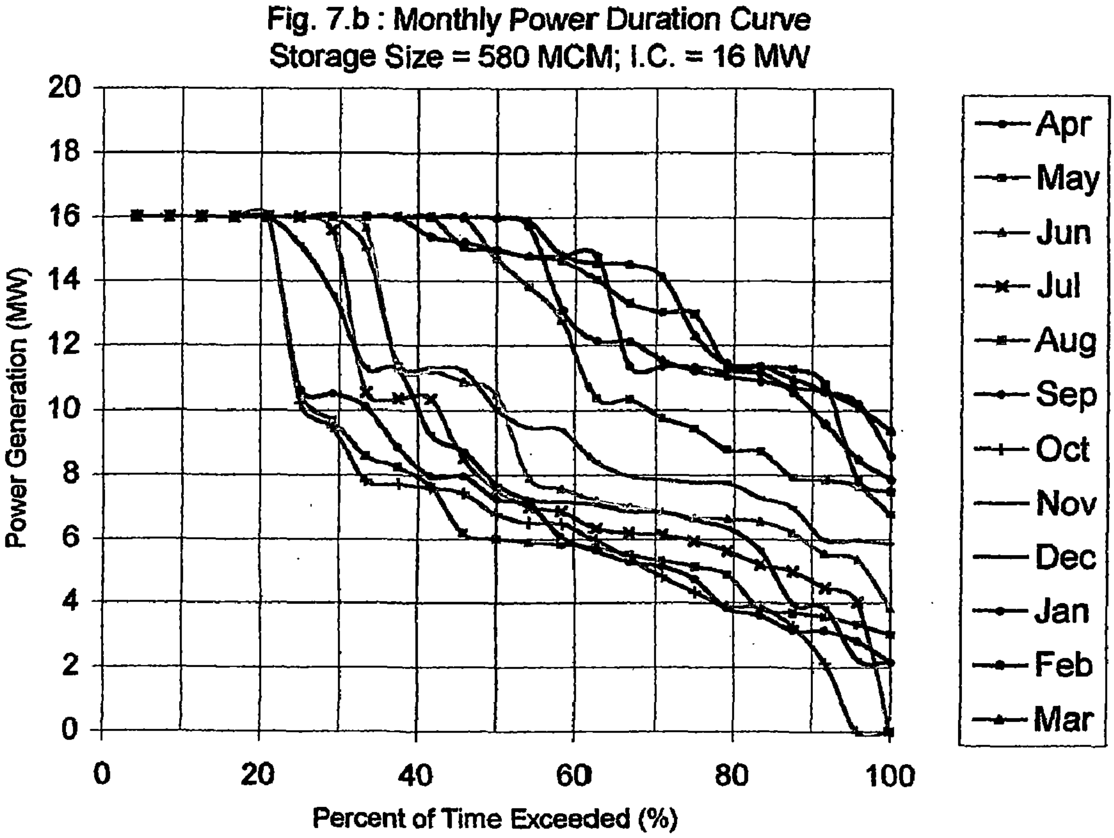
Maximum Water Level = 280.0
Original Stream Bed Level = 183.5
Est. of Sediment Vol during 10 Yr = . 11.20 Mm³

New Zero Elevation = **184.40**
Area = 0.011 Km²
Relative depth p = 0.009
Ap = 0.09
K = Area/Ap = 0.12

Sl No	Elevation (m)	Revised 2 area (Km²)	Revised 2 capacity (Mm³)	Depth (2)-183.5 (m)	Relative depth p (5)/96.5	Ap Type III	Sediment area Kap 0.12x(7) (Km²)	Sediment volume (Mm³)	Accumulated sediment volume (Mm³)	Modified accumulated volume (Mm³)	Revised 3 area (3)-(8) (Km²)	Revised 3 capacity (4)-(11) (Mm³)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	280.0	23.51	797.60	96.5	1.000	0.000	0.000	0.005	11.20	11.20	23.51	786.39
2	275.0	21.01	678.15	91.5	0.948	0.017	0.002	0.027	11.20	11.20	21.01	666.96
3	270.0	18.92	583.95	86.5	0.896	0.077	0.009	0.075	11.17	11.17	18.91	572.78
4	265.0	16.79	484.92	81.5	0.845	0.182	0.021	0.149	11.10	11.10	16.77	473.83
5	260.0	15.17	423.04	76.5	0.793	0.330	0.038	0.245	10.95	10.95	15.13	412.09
6	255.0	13:26	337.24	71.5	0.741	0.511	0.059	0.358	10.70	10.70	13.20	326.54
7	250.0	11.69	283.50	66.5	0.689	0.718	0.084	0.482	10.34	10.34	11.61	273.16
8	245.0	10.23	227.32	61.5	0.637	0.939	0.109	0.611	9.86	9.86	10.12	217.46
9	240.0	8.72	184.68	56.5	0.585	1.163	0.135	0.739	9.25	9.25	8.59	175.43
10	235.0	7.42	148.42	51.5	0.534	1.377	0.160	0.857	8.51	8.51	7.26	139.91
11	230.0	6.23	110.66	46.5	0.482	1.568	0.182	0.957	7.66	7.66	6.05	103.00
12	225.0	5.08	82.66	41.5	0.430	1.723	0.200	1.033	6.70	6.70	4.88	75.96
13	220.0	3.74	56.81	36.5	0.378	1.827	0.213	1.075	5.67	5.67	3.52	51.15
14	215.0	2.74	34.75	31.5	0.326	1.868	0.217	1.076	4.59	4.59	2.53	30.15
15	210.0	2.05	21.15	26.5	0.275	1.832	0.213	1.029	3.51	3.51	1.84	17.64
16	205.0	1.51	14.37	21.5	0.223	1.705	0.198	0.926	2.48	2.48	1.31	11.89
17	200.0	1.18	8.02	16.5	0.171	1.479	0.172	0.763	1.56	1.56	1.01	6.46
18	195.0	0.70	4.06	11.5	0.119	1.143	0.133	0.535	0.80	0.80	0.57	3.26
19	190.0	0.27	1.37	6.5	0.067	0.696	0.081	0.256	0.26	0.26	0.19	1.11
20	**184.4**	**0.01**	**0.10**	**0.9**	**0.009**	**0.011**	**0.011**	**0.005**	**0.00**	**0.10**	**0.00**	**0.00**
21	183.5	0.00	0.00	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00

Monthly Power Duration Curves for Installed Capacity 12 MW & 16 MW





Appendix 8

Simulation Study for Irrigation and Hydropower

Simulation Study for Irrigation and Hydropower Using Monthly Data in Unit of Volume

TOTAL IRRIGATION AREA	81355	HA
CROP INTENSITY	180.0	%
TAIL WATER LEVEL	170.0	M
FRL	268.5	M

GOLONGAN I	19,561	HA
GOLONGAN II	19,561	HA
GOLONGAN III	19,561	HA
GOLONGAN IV	7,336	HA
GOLONGAN V	7,336	HA
TOTAL AREA	73,355	HA

	0-10yr	10-20yr	20-25yr
Irrigation Intake	208.0	208.0	208.0
Storage below Irrigation Intake	25.9	23.0	20.5
MDDL	226.0	226.0	226.0
STORAGE BELOW MDDL (MCM)	99.0	94.0	89.0
GROSS STORAGE SIZE	580.0	569.6	559.3
LIVE STORAGE (MCM)	481.0	475.6	470.3

INSTALLED CAPACITY	24.00	MW

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Using Original Elevation - Area - Capacity Curve (from 1969 to 1979)																					
1	1969-70	April	268.5	18.54	580.0	86.8	0.78	667.6	270.4	496.8	5.2	82.4	82.4	0.0	82.4	5.2	580.0	268.5	18.54	24.0	17262	0
2		May	268.5	18.54	580.0	61.2	0.00	641.2	237.9	335.1	5.4	85.2	61.2	0.0	61.2	0.0	580.0	268.5	18.54	17.2	12814	0
3		June	268.5	18.54	580.0	56.1	-0.45	635.6	228.2	291.2	5.2	82.5	55.6	0.0	55.6	0.0	580.0	268.5	18.54	16.2	11654	0
4		July	268.5	18.54	580.0	58.6	-0.30	638.3	84.9	362.5	5.4	85.2	58.3	0.0	58.3	0.0	580.0	268.5	18.54	16.4	12211	0
5		August	268.5	18.54	580.0	40.6	-0.85	619.8	0.0	70.8	5.4	85.2	39.8	0.0	39.8	0.0	580.0	268.5	18.54	11.2	8329	0
6		September	268.5	18.54	580.0	43.2	-0.62	622.6	0.0	292.4	5.2	82.5	42.6	0.0	42.6	0.0	580.0	268.5	18.54	12.4	8921	0
7		October	268.5	18.54	580.0	38.3	-0.66	617.7	30.6	75.3	5.4	85.2	37.7	0.0	37.7	0.0	580.0	268.5	18.54	10.6	7690	0
8		November	268.5	18.54	580.0	51.9	-0.25	631.6	202.6	48.5	162.2	82.5	82.5	79.7	162.2	0.0	469.4	261.9	16.06	24.0	17280	0
9		December	261.9	16.06	469.4	51.5	-0.40	520.5	256.8	75.4	191.0	91.8	91.8	99.2	191.0	0.0	329.5	252.7	12.82	24.0	17856	0
10		January	252.7	12.82	329.5	99.3	0.60	429.4	255.8	425.7	5.4	103.0	0.0	5.4	5.4	0.0	424.1	259.1	15.05	0.0	0	0
11		February	259.1	15.05	424.1	91.8	0.55	516.4	177.9	687.6	4.8	85.7	0.0	4.8	4.8	0.0	511.6	264.4	17.01	0.0	0	0
12		March	264.4	17.01	511.6	129.0	1.76	642.4	161.2	1010.7	5.4	89.2	62.4	0.0	62.4	0.0	580.0	268.5	18.54	16.8	12487	0
13	1970-71	April	268.5	18.54	580.0	99.3	1.16	680.5	270.4	547.5	5.2	82.5	82.5	0.0	82.5	18.0	580.0	268.5	18.54	24.0	17280	0
14		May	268.5	18.54	580.0	91.2	0.91	672.1	237.9	568.6	5.4	85.2	85.2	0.0	85.2	6.9	580.0	268.5	18.54	24.0	17856	0
15		June	268.5	18.54	580.0	80.1	0.58	660.7	228.2	294.1	5.2	82.5	80.7	0.0	80.7	0.0	580.0	268.5	18.54	23.5	16907	0
16		July	268.5	18.54	580.0	63.7	-0.21	643.5	84.9	262.3	5.4	85.2	63.5	0.0	63.5	0.0	580.0	268.5	18.54	17.9	13306	0
17		August	268.5	18.54	580.0	52.5	-0.48	632.1	0.0	259.4	5.4	85.2	52.1	0.0	52.1	0.0	580.0	268.5	18.54	14.7	10904	0
18		September	268.5	18.54	580.0	42.4	-0.79	621.6	0.0	110.9	5.2	82.5	41.6	0.0	41.6	0.0	580.0	268.5	18.54	12.1	8720	0
19		October	268.5	18.54	580.0	46.7	-0.52	626.1	30.6	216.3	5.4	85.2	46.1	0.0	46.1	0.0	580.0	268.5	18.54	13.0	9668	0
20		November	268.5	18.54	580.0	58.7	-0.04	638.6	202.6	141.9	63.8	82.5	63.8	0.0	63.8	0.0	574.8	268.2	18.42	18.6	13369	0
21		December	268.2	18.42	574.8	61.2	0.03	636.0	256.8	221.8	36.9	85.5	56.1	0.0	56.1	0.0	580.0	268.5	18.54	15.7	11708	0
22		January	268.5	18.54	580.0	79.5	0.40	659.9	255.8	538.8	5.4	85.2	79.9	0.0	79.9	0.0	580.0	268.5	18.54	22.5	16739	0
23		February	268.5	18.54	580.0	53.4	-0.53	632.9	177.9	249.2	4.8	77.0	52.9	0.0	52.9	0.0	580.0	268.5	18.54	16.5	11079	0
24		March	268.5	18.54	580.0	62.4	-0.22	642.2	161.2	236.7	5.4	85.2	62.2	0.0	62.2	0.0	580.0	268.5	18.54	17.5	13022	0
25	1971-72	April	268.5	18.54	580.0	66.6	0.02	646.6	270.4	349.2	5.2	82.5	66.6	0.0	66.6	0.0	580.0	268.5	18.54	19.4	13950	0
26		May	268.5	18.54	580.0	52.6	-0.26	632.4	237.9	253.3	5.4	85.2	52.4	0.0	52.4	0.0	580.0	268.5	18.54	14.7	10970	0
27		June	268.5	18.54	580.0	39.4	-0.66	618.7	228.2	159.2	72.6	82.5	72.6	0.0	72.6	0.0	546.2	266.5	17.78	21.1	15200	0
28		July	266.5	17.78	546.2	37.6	-0.69	583.1	84.9	149.3	5.4	87.1	0.0	5.4	5.4	0.0	577.7	268.4	18.49	0.0	0	0
29		August	268.4	18.49	577.7	31.3	-1.20	607.8	0.0	66.9	5.4	85.4	27.8	0.0	27.8	0.0	580.0	268.5	18.54	7.8	5812	0
30		September	268.5	18.54	580.0	37.3	-0.95	616.3	0.0	128.1	5.2	82.5	36.3	0.0	36.3	0.0	580.0	268.5	18.54	10.6	7612	0
31		October	268.5	18.54	580.0	43.9	-0.74	623.2	30.6	96.0	5.4	85.2	43.2	0.0	43.2	0.0	580.0	268.5	18.54	12.2	9043	0
32		November	268.5	18.54	580.0	77.6	0.43	658.0	202.6	581.0	5.2	82.5	78.0	0.0	78.0	0.0	580.0	268.5	18.54	22.7	16346	0
33		December	268.5	18.54	580.0	87.7	0.84	668.6	256.8	734.0	5.4	85.2	85.2	0.0	85.2	3.3	580.0	268.5	18.54	24.0	17856	0
34		January	268.5	18.54	580.0	93.0	1.00	674.0	255.8	436.0	5.4	85.2	85.2	0.0	85.2	8.8	580.0	268.5	18.54	24.0	17856	0
35		February	268.5	18.54	580.0	66.8	0.01	646.8	177.9	280.8	4.8	77.0	66.8	0.0	66.8	0.0	580.0	268.5	18.54	20.8	13988	0
36		March	268.5	18.54	580.0	64.8	-0.18	644.6	161.2	249.0	5.4	85.2	64.6	0.0	64.6	0.0	580.0	268.5	18.54	18.2	13529	0

Appendix 8

Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
37	1972-73	April	268.5	18.54	580.0	68.3	-0.04	648.2	270.4	225.1	47.6	82.5	68.2	0.0	68.2	0.0	580.0	268.5	18.54	19.9	14294	0
38		May	268.5	18.54	580.0	78.0	0.37	658.4	237.9	271.3	5.4	85.2	78.4	0.0	78.4	0.0	580.0	268.5	18.54	22.1	16418	0
39		June	268.5	18.54	580.0	51.3	-0.30	631.0	228.2	168.9	62.4	82.5	62.4	0.0	62.4	0.0	568.6	267.8	18.28	18.2	13068	0
40		July	267.8	18.28	568.6	31.8	-0.89	599.5	84.9	88.8	5.4	85.9	19.5	0.0	19.5	0.0	580.0	268.5	18.54	5.5	4055	0
41		August	268.5	18.54	580.0	30.4	-0.94	609.4	0.0	76.1	5.4	85.2	29.4	0.0	29.4	0.0	580.0	268.5	18.54	8.3	6166	0
42		September	268.5	18.54	580.0	22.9	-1.46	601.5	0.0	29.9	5.2	82.5	21.5	0.0	21.5	0.0	580.0	268.5	18.54	6.2	4495	0
43		October	268.5	18.54	580.0	18.1	-1.53	596.5	30.6	6.1	25.9	85.2	25.9	0.0	25.9	0.0	570.7	267.9	18.33	7.3	5421	0
44		November	267.9	18.33	570.7	21.2	-1.42	590.4	202.6	34.3	177.1	83.0	83.0	94.1	177.1	0.0	413.3	258.5	14.81	24.0	17280	0
45		December	258.5	14.81	413.3	34.5	-0.71	447.0	256.8	81.4	184.7	95.7	95.7	89.0	184.7	0.0	262.4	246.8	11.03	24.0	17856	0
46		January	246.8	11.03	262.4	55.6	-0.08	317.9	255.8	257.6	5.4	112.2	0.0	5.4	5.4	0.0	312.5	251.2	12.37	0.0	0	0
47		February	251.2	12.37	312.5	52.6	-0.15	365.0	177.9	298.1	4.8	95.0	0.0	4.8	4.8	0.0	360.2	255.3	13.62	0.0	0	0
48		March	255.3	13.62	360.2	80.0	0.30	440.5	161.2	733.6	5.4	99.6	0.0	5.4	5.4	0.0	435.1	259.8	15.29	0.0	0	0
49	1973-74	April	259.8	15.29	435.1	62.2	-0.22	497.1	270.4	244.4	27.4	91.1	27.4	0.0	27.4	0.0	469.7	261.9	16.07	7.2	5188	0
50		May	261.9	16.07	469.7	79.0	0.25	548.9	237.9	368.3	5.4	91.8	0.0	5.4	5.4	0.0	543.6	266.3	17.72	0.0	0	0
51		June	266.3	17.72	543.6	56.3	-0.28	599.6	228.2	222.1	6.3	84.5	19.6	0.0	19.6	0.0	580.0	268.5	18.54	5.6	4009	0
52		July	268.5	18.54	580.0	39.1	-0.67	618.4	84.9	78.5	6.7	85.2	38.4	0.0	38.4	0.0	580.0	268.5	18.54	10.8	8047	0
53		August	268.5	18.54	580.0	39.6	-0.66	618.9	0.0	121.8	5.4	85.2	38.9	0.0	38.9	0.0	580.0	268.5	18.54	11.0	8157	0
54		September	268.5	18.54	580.0	60.6	-0.02	640.6	0.0	272.2	5.2	82.5	60.6	0.0	60.6	0.0	580.0	268.5	18.54	17.6	12696	0
55		October	268.5	18.54	580.0	48.6	-0.67	628.0	30.6	187.9	5.4	85.2	48.0	0.0	48.0	0.0	580.0	268.5	18.54	13.5	10045	0
56		November	268.5	18.54	580.0	46.7	-0.66	626.1	202.6	119.6	87.3	82.5	82.5	4.8	87.3	0.0	538.7	266.0	17.62	24.0	17280	0
57		December	266.0	17.62	538.7	76.4	0.23	615.4	256.8	376.9	5.4	87.6	35.4	0.0	35.4	0.0	580.0	268.5	18.54	9.7	7219	0
58		January	268.5	18.54	580.0	44.6	-0.58	624.1	255.8	159.3	101.5	85.2	85.2	16.3	101.5	0.0	522.5	265.1	17.25	24.0	17856	0
59		February	265.1	17.25	522.5	51.0	-0.26	573.3	177.9	275.8	4.8	80.0	0.0	4.8	4.8	0.0	568.4	267.8	18.28	0.0	0	0
60		March	267.8	18.28	568.4	39.9	-0.61	607.7	161.2	198.9	5.4	85.9	27.7	0.0	27.7	0.0	580.0	268.5	18.54	7.8	5767	0
61	1974-75	April	268.5	18.54	580.0	52.3	-0.44	631.8	270.4	216.3	56.9	82.5	56.9	0.0	56.9	0.0	574.9	268.2	18.43	16.6	11925	0
62		May	268.2	18.43	574.9	48.3	-0.68	622.5	237.9	222.5	16.1	85.5	42.5	0.0	42.5	0.0	580.0	268.5	18.54	11.9	8865	0
63		June	268.5	18.54	580.0	32.6	-1.13	611.5	228.2	94.6	140.6	82.5	82.5	58.1	140.6	0.0	470.8	262.0	16.09	24.0	17280	0
64		July	262.0	16.09	470.8	32.1	-0.90	502.1	84.9	67.2	18.6	91.8	18.6	0.0	18.6	0.0	483.5	262.7	16.38	4.9	3620	0
65		August	262.7	16.38	483.5	35.2	-0.70	518.0	0.0	119.8	5.4	90.9	0.0	5.4	5.4	0.0	512.7	264.5	17.03	0.0	0	0
66		September	264.5	17.03	512.7	41.2	-0.56	553.3	0.0	151.8	5.2	86.3	0.0	5.2	5.2	0.0	548.1	266.6	17.83	0.0	0	0
67		October	266.6	17.83	548.1	35.6	-0.75	583.0	30.6	44.6	5.4	87.0	0.0	5.4	5.4	0.0	577.6	268.4	18.49	0.0	0	0
68		November	268.4	18.49	577.6	38.9	-0.97	615.5	202.6	44.5	166.4	82.6	82.6	83.7	166.4	0.0	449.1	260.6	15.61	24.0	17280	0
69		December	260.6	15.61	449.1	49.8	-0.48	498.5	256.8	100.5	164.5	93.2	93.2	71.3	164.5	0.0	334.0	253.1	12.94	24.0	17856	0
70		January	253.1	12.94	334.0	73.9	0.12	408.0	255.8	150.6	110.8	102.5	102.5	8.3	110.8	0.0	297.2	249.9	11.96	24.0	17856	0
71		February	249.9	11.96	297.2	72.3	0.17	369.6	177.9	286.3	4.8	96.8	0.0	4.8	4.8	0.0	364.8	255.6	13.72	0.0	0	0
72		March	255.6	13.72	364.8	55.6	-0.10	420.3	161.2	133.9	28.8	99.2	28.8	0.0	28.8	0.0	391.5	257.2	14.32	7.0	5177	0

Appendix 8

Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
73	1975-76	April	257.2	14.32	391.5	77.8	0.42	469.7	270.4	199.6	74.5	94.1	74.5	0.0	74.5	0.0	395.3	257.4	14.40	19.0	13675	0
74		May	257.4	14.40	395.3	57.6	-0.21	452.7	237.9	104.4	140.5	96.9	96.9	43.6	140.5	0.0	312.2	251.2	12.36	24.0	17856	0
75		June	251.2	12.36	312.2	37.9	-0.67	349.3	228.2	49.9	187.6	101.8	101.8	85.8	187.6	0.0	161.7	235.1	7.73	24.0	17280	0
76		July	235.1	7.73	161.7	35.5	-0.44	196.8	84.9	35.6	51.9	131.3	0.0	51.9	51.9	0.0	145.0	232.7	7.15	0.0	0	0
77		August	232.7	7.15	145.0	36.6	-0.35	181.2	0.0	37.8	5.4	134.2	0.0	5.4	5.4	0.0	175.9	236.8	8.21	0.0	0	0
78		September	236.8	8.21	175.9	30.8	-0.41	206.2	0.0	55.1	5.2	128.1	0.0	5.2	5.2	0.0	201.1	239.9	9.08	0.0	0	0
79		October	239.9	9.08	201.1	38.3	-0.35	239.0	30.6	55.4	5.4	125.2	0.0	5.4	5.4	0.0	233.6	243.9	10.20	0.0	0	0
80		November	243.9	10.20	233.6	44.6	-0.28	277.9	202.6	41.2	169.9	113.4	113.4	56.4	169.9	0.0	108.0	227.3	5.89	24.0	17280	0
81		December	227.3	5.89	108.0	35.1	-0.35	142.8	256.8	128.3	135.2	142.5	0.0	116.9	116.9	0.0	25.9	208.0	2.13	0.0	0	-18
82		January	208.0	2.13	25.9	51.3	-0.06	77.1	255.8	206.9	51.5	209.6	0.0	51.2	51.2	0.0	25.9	208.0	2.13	0.0	0	0
83		February	208.0	2.13	25.9	73.8	0.02	99.8	177.9	160.3	18.6	188.5	0.0	18.6	18.6	0.0	81.2	222.8	4.83	0.0	0	0
84		March	222.8	4.83	81.2	65.6	0.02	146.8	161.2	349.2	5.4	154.7	0.0	5.4	5.4	0.0	141.5	232.2	7.03	0.0	0	0
85	1976-77	April	232.2	7.03	141.5	60.6	0.01	202.1	270.4	176.4	98.9	134.7	0.0	98.9	98.9	0.0	103.1	226.6	5.72	0.0	0	0
86		May	226.6	5.72	103.1	39.6	-0.19	142.6	237.9	89.0	156.7	144.2	43.6	73.1	116.7	0.0	25.9	208.0	2.13	7.2	5393	-40
87		June	208.0	2.13	25.9	25.6	-0.15	51.3	228.2	28.0	210.7	206.6	0.0	25.4	25.4	0.0	25.9	208.0	2.13	0.0	0	-185
88		July	208.0	2.13	25.9	34.1	-0.14	59.8	84.9	14.9	73.7	211.7	0.0	33.9	33.9	0.0	25.9	208.0	2.13	0.0	0	-40
89		August	208.0	2.13	25.9	30.8	-0.14	56.5	0.0	26.8	5.4	212.2	0.0	5.4	5.4	0.0	51.2	216.8	3.43	0.0	0	0
90		September	216.8	3.43	51.2	18.2	-0.28	69.1	0.0	9.7	5.2	166.6	0.0	5.2	5.2	0.0	63.9	219.4	4.03	0.0	0	0
91		October	219.4	4.03	63.9	38.1	-0.16	101.9	30.6	33.0	5.4	162.5	0.0	5.4	5.4	0.0	96.6	225.6	5.49	0.0	0	0
92		November	225.6	5.49	96.6	36.3	-0.23	132.6	202.6	43.2	167.7	141.3	0.0	106.7	106.7	0.0	25.9	208.0	2.13	0.0	0	-61
93		December	208.0	2.13	25.9	47.8	-0.05	73.6	256.8	82.9	183.1	209.9	0.0	47.7	47.7	0.0	25.9	208.0	2.13	0.0	0	-135
94		January	208.0	2.13	25.9	67.0	-0.01	92.8	255.8	364.7	5.4	208.7	0.0	5.4	5.4	0.0	87.5	224.0	5.12	0.0	0	0
95		February	224.0	5.12	87.5	88.0	0.19	175.7	177.9	608.6	4.8	141.3	0.0	4.8	4.8	0.0	170.9	236.2	8.04	0.0	0	0
96		March	236.2	8.04	170.9	69.9	0.12	240.9	161.2	459.1	5.4	133.9	0.0	5.4	5.4	0.0	235.6	244.2	10.26	0.0	0	0
97	1977-78	April	244.2	10.26	235.6	99.5	0.65	335.7	270.4	340.3	5.2	113.0	0.0	5.2	5.2	0.0	330.5	252.8	12.85	0.0	0	0
98		May	252.8	12.85	330.5	60.9	-0.01	391.4	237.9	172.9	68.4	102.9	68.4	0.0	68.4	0.0	323.0	252.2	12.65	16.0	11871	0
99		June	252.2	12.65	323.0	69.9	-0.02	393.0	228.2	248.1	5.2	100.5	0.0	5.2	5.2	0.0	387.8	257.0	14.23	0.0	0	0
100		July	257.0	14.23	387.8	51.4	-0.40	438.8	84.9	68.7	17.0	97.5	17.0	0.0	17.0	0.0	421.7	259.0	15.00	4.2	3121	0
101		August	259.0	15.00	421.7	34.5	-0.83	455.4	0.0	24.2	5.4	95.1	0.0	5.4	5.4	0.0	450.1	260.7	15.63	0.0	0	0
102		September	260.7	15.63	450.1	32.9	-0.79	482.2	0.0	34.9	5.2	90.1	0.0	5.2	5.2	0.0	477.0	262.3	16.23	0.0	0	0
103		October	262.3	16.23	477.0	30.4	-0.79	506.7	30.6	12.5	19.1	91.4	19.1	0.0	19.1	0.0	487.6	263.0	16.47	5.0	3735	0
104		November	263.0	16.47	487.6	26.1	-0.92	512.7	202.6	40.0	171.1	87.8	87.8	83.3	171.1	0.0	341.7	253.8	13.14	24.0	17280	0
105		December	253.8	13.14	341.7	67.7	0.03	409.4	256.8	165.2	96.5	101.6	96.5	0.0	96.5	0.0	313.0	251.3	12.38	22.8	16960	0
106		January	251.3	12.38	313.0	69.0	-0.03	381.9	255.8	277.6	5.4	105.1	0.0	5.4	5.4	0.0	376.6	256.3	13.98	0.0	0	0
107		February	256.3	13.98	376.6	84.2	0.42	461.2	177.9	383.8	4.8	88.8	0.0	4.8	4.8	0.0	456.4	261.1	15.77	0.0	0	0
108		March	261.1	15.77	456.4	134.8	1.91	593.1	161.2	759.1	5.4	92.7	13.1	0.0	13.1	0.0	580.0	268.5	16.54	3.4	2525	0

Appendix 8

Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
109	1978-79	April	268.5	18.54	580.0	80.8	0.60	661.4	270.4	306.9	5.2	82.5	81.4	0.0	81.4	0.0	580.0	268.5	18.54	23.7	17044	0
110		May	268.5	18.54	580.0	91.0	0.91	671.9	237.9	408.6	5.4	85.2	85.2	0.0	85.2	6.6	580.0	268.5	18.54	24.0	17856	0
111		June	268.5	18.54	580.0	82.5	0.36	662.8	228.2	384.2	5.2	82.5	82.5	0.0	82.5	0.4	580.0	268.5	18.54	24.0	17280	0
112		July	268.5	18.54	580.0	61.1	-0.22	640.9	84.9	196.4	5.4	85.2	60.9	0.0	60.9	0.0	580.0	268.5	18.54	17.2	12763	0
113		August	268.5	18.54	580.0	51.8	-0.51	631.3	0.0	146.1	5.4	85.2	51.3	0.0	51.3	0.0	580.0	268.5	18.54	14.4	10740	0
114		September	268.5	18.54	580.0	47.9	-0.48	627.5	0.0	135.6	5.2	82.5	47.5	0.0	47.5	0.0	580.0	268.5	18.54	13.8	9942	0
115		October	268.5	18.54	580.0	46.3	-0.42	625.9	30.6	229.9	5.4	85.2	45.9	0.0	45.9	0.0	580.0	268.5	18.54	12.9	9613	0
116		November	268.5	18.54	580.0	70.9	0.33	651.2	202.6	302.9	5.2	82.5	71.2	0.0	71.2	0.0	580.0	268.5	18.54	20.7	14917	0
117		December	268.5	18.54	580.0	123.6	1.74	705.3	256.8	545.2	5.4	85.2	85.2	0.0	85.2	40.1	580.0	268.5	18.54	24.0	17856	0
118		January	268.5	18.54	580.0	86.6	0.48	667.1	255.8	523.3	5.4	85.2	85.2	0.0	85.2	1.8	580.0	268.5	18.54	24.0	17856	0
119		February	268.5	18.54	580.0	110.4	1.35	691.7	177.9	604.2	4.8	77.0	77.0	0.0	77.0	34.8	580.0	268.5	18.54	24.0	16128	0
120		March	268.5	18.54	580.0	88.4	0.83	669.2	161.2	297.3	5.4	85.2	85.2	0.0	85.2	4.0	580.0	268.5	18.54	24.0	17856	0
	Using Elevation - Area - Capacity Curve Revised after 10 Years																					
121	1979-80	April	268.5	18.54	569.6	89.2	0.85	659.7	270.4	382.5	5.2	82.5	82.5	0.0	82.5	7.6	569.6	268.5	18.45	24.0	17280	0
122		May	268.5	18.45	569.6	88.0	0.81	658.5	237.9	278.3	5.4	85.2	85.2	0.0	85.2	3.6	569.6	268.5	18.45	24.0	17856	0
123		June	268.5	18.45	569.6	62.1	-0.26	631.5	228.2	141.8	90.9	82.5	82.5	8.4	90.9	0.0	540.6	266.7	17.79	24.0	17280	0
124		July	266.7	17.79	540.6	102.0	0.98	643.6	84.9	155.3	5.4	86.9	73.9	0.0	73.9	0.0	569.6	268.5	18.45	20.4	15195	0
125		August	268.5	18.45	569.6	62.1	-0.19	631.5	0.0	23.9	5.4	85.2	61.9	0.0	61.9	0.0	569.6	268.5	18.45	17.4	12963	0
126		September	268.5	18.45	569.6	51.3	-0.37	620.5	0.0	33.8	5.2	82.5	50.9	0.0	50.9	0.0	569.6	268.5	18.45	14.8	10659	0
127		October	268.5	18.45	569.6	39.7	-0.62	608.7	30.6	79.6	5.4	85.2	39.1	0.0	39.1	0.0	569.6	268.5	18.45	11.0	8186	0
128		November	268.5	18.45	569.6	40.1	-0.61	609.1	202.6	64.1	145.7	82.5	82.5	63.2	145.7	0.0	463.4	262.1	16.04	24.0	17280	0
129		December	262.1	16.04	463.4	46.9	-0.52	509.7	256.8	189.6	70.8	91.6	70.8	0.0	70.8	0.0	439.0	260.6	15.49	18.5	13791	0
130		January	260.6	15.49	439.0	93.8	0.59	533.3	255.8	839.0	5.4	93.2	0.0	5.4	5.4	0.0	528.0	266.0	17.51	0.0	0	0
131		February	266.0	17.51	528.0	61.6	-0.12	589.5	177.9	502.6	4.8	79.1	19.9	0.0	19.9	0.0	569.6	268.5	18.45	6.0	4048	0
132		March	268.5	18.45	569.6	59.5	-0.05	629.1	161.2	303.4	5.4	85.2	59.5	0.0	59.5	0.0	569.6	268.5	18.45	16.7	12462	0
133	1980-81	April	268.5	18.45	569.6	63.9	0.08	633.6	270.4	311.0	5.2	82.5	64.0	0.0	64.0	0.0	569.6	268.5	18.45	18.6	13410	0
134		May	268.5	18.45	569.6	55.8	-0.16	625.3	237.9	221.1	17.6	85.2	55.6	0.0	55.6	0.0	569.6	268.5	18.45	15.7	11655	0
135		June	268.5	18.45	569.6	43.6	-0.82	612.4	228.2	89.2	146.3	82.5	82.5	63.8	146.3	0.0	466.1	262.2	16.10	24.0	17280	0
136		July	262.2	16.10	466.1	37.5	-0.82	502.8	84.9	80.5	5.4	91.4	0.0	5.4	5.4	0.0	497.4	264.1	16.81	0.0	0	0
137		August	264.1	16.81	497.4	50.2	-0.50	547.1	0.0	153.4	5.4	89.5	0.0	5.4	5.4	0.0	541.7	266.8	17.82	0.0	0	0
138		September	266.8	17.82	541.7	61.0	-0.08	602.6	0.0	235.2	5.2	84.0	33.0	0.0	33.0	0.0	569.6	268.5	18.45	9.4	6791	0
139		October	268.5	18.45	569.6	47.5	-0.38	616.7	30.6	268.9	5.4	85.2	47.1	0.0	47.1	0.0	569.6	268.5	18.45	13.3	9871	0
140		November	268.5	18.45	569.6	95.8	1.08	666.5	202.6	455.8	5.2	82.5	82.5	0.0	82.5	14.4	569.6	268.5	18.45	24.0	17280	0
141		December	268.5	18.45	569.6	117.0	1.53	688.1	256.8	526.4	5.4	85.2	85.2	0.0	85.2	33.3	569.6	268.5	18.45	24.0	17856	0
142		January	268.5	18.45	569.6	82.3	0.35	652.3	255.8	651.8	5.4	85.2	82.6	0.0	82.6	0.0	569.6	268.5	18.45	23.3	17312	0
143		February	268.5	18.45	569.6	71.9	0.18	641.7	177.9	520.9	4.8	77.0	72.1	0.0	72.1	0.0	569.6	268.5	18.45	22.5	15104	0
144		March	268.5	18.45	569.6	109.1	1.45	680.1	161.2	763.0	5.4	85.2	85.2	0.0	85.2	25.3	569.6	268.5	18.45	24.0	17856	0

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Irrigation Water Demand			Maximum Power Flow (MCM)	Water Realese Throught			Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)	Energy Generation (MWh)	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)				Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)		Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)		Storage (MCM)	Elevation (m)	Area (km2)			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
145	1981-82	April	268.5	18.45	569.6	112.6	1.56	683.8	270.4	659.8	5.2	82.5	82.5	0.0	82.5	31.7	569.6	268.5	18.45	24.0	17280	0
146		May	268.5	18.45	569.6	115.9	1.66	687.2	237.9	621.7	5.4	85.2	85.2	0.0	85.2	32.3	569.6	268.5	18.45	24.0	17856	0
147		June	268.5	18.45	569.6	67.6	-0.10	637.1	228.2	169.1	62.2	82.5	67.5	0.0	67.5	0.0	569.6	268.5	18.45	19.6	14135	0
148		July	268.5	18.45	569.6	47.9	-0.62	616.9	84.9	70.2	15.5	85.2	47.3	0.0	47.3	0.0	569.6	268.5	18.45	13.3	9902	0
149		August	268.5	18.45	569.6	35.9	-0.99	604.5	0.0	87.6	5.4	85.2	34.9	0.0	34.9	0.0	569.6	268.5	18.45	9.8	7303	0
150		September	268.5	18.45	569.6	60.1	-0.11	629.6	0.0	297.5	5.2	82.5	60.0	0.0	60.0	0.0	569.6	268.5	18.45	17.5	12572	0
151		October	268.5	18.45	569.6	43.8	-0.49	612.9	30.6	227.7	5.4	85.2	43.3	0.0	43.3	0.0	569.6	268.5	18.45	12.2	9062	0
152		November	268.5	18.45	569.6	40.6	-0.59	609.6	202.6	139.7	66.2	82.5	66.2	0.0	66.2	0.0	543.5	266.9	17.86	19.2	13858	0
153		December	266.9	17.86	543.5	56.1	-0.31	599.3	256.8	273.3	5.4	86.7	29.7	0.0	29.7	0.0	569.6	268.5	18.45	8.2	6106	0
154		January	268.5	18.45	569.6	109.6	1.18	680.4	255.8	835.1	5.4	85.2	85.2	0.0	85.2	25.5	569.6	268.5	18.45	24.0	17856	0
155		February	268.5	18.45	569.6	102.2	1.10	673.0	177.9	761.0	4.8	77.0	77.0	0.0	77.0	26.4	569.6	268.5	18.45	24.0	16128	0
156		March	268.5	18.45	569.6	84.4	0.70	654.7	161.2	465.2	5.4	85.2	85.1	0.0	85.1	0.0	569.6	268.5	18.45	23.9	17818	0
157	1982-83	April	268.5	18.45	569.6	62.8	0.05	632.5	270.4	233.0	39.3	82.5	62.9	0.0	62.9	0.0	569.6	268.5	18.45	18.3	13172	0
158		May	268.5	18.45	569.6	47.8	-0.41	617.0	237.9	96.8	148.5	85.2	85.2	63.3	148.5	0.0	468.5	262.4	16.16	24.0	17856	0
159		June	262.4	16.16	468.5	31.8	-1.04	499.2	228.2	86.4	149.2	88.3	88.3	60.9	149.2	0.0	349.9	255.2	13.47	24.0	17280	0
160		July	255.2	13.47	349.9	29.1	-0.87	378.2	84.9	41.5	45.6	99.7	45.6	0.0	45.6	0.0	332.5	253.8	13.01	11.0	8176	0
161		August	253.8	13.01	332.5	21.2	-1.01	352.7	0.0	16.9	5.4	101.6	0.0	5.4	5.4	0.0	347.4	255.1	13.41	0.0	0	0
162		September	255.1	13.41	347.4	16.6	-1.04	363.0	0.0	40.1	5.2	96.7	0.0	5.2	5.2	0.0	357.8	255.7	13.65	0.0	0	0
163		October	255.7	13.65	357.8	14.2	-1.03	371.0	30.6	54.8	5.4	99.1	0.0	5.4	5.4	0.0	365.6	256.2	13.82	0.0	0	0
164		November	256.2	13.82	365.6	13.9	-1.05	378.5	202.6	16.1	196.3	95.3	95.3	101.0	196.3	0.0	182.2	238.4	8.53	24.0	17280	0
165		December	238.4	8.53	182.2	42.8	-0.34	224.7	256.8	73.5	192.9	128.5	128.5	64.4	192.9	0.0	31.8	212.1	2.51	24.0	17856	0
166		January	212.1	2.51	31.8	93.9	0.10	125.7	255.8	795.4	5.4	190.6	0.0	5.4	5.4	0.0	120.4	229.9	6.37	0.0	0	0
167		February	229.9	6.37	120.4	62.7	-0.03	183.1	177.9	348.8	4.8	128.4	0.0	4.8	4.8	0.0	178.2	238.0	8.39	0.0	0	0
168		March	238.0	8.39	178.2	74.1	0.18	252.6	161.2	279.9	5.4	129.7	0.0	5.4	5.4	0.0	247.2	246.1	10.71	0.0	0	0
169	1983-84	April	246.1	10.71	247.2	72.6	0.20	320.0	270.4	351.8	5.2	109.6	0.0	5.2	5.2	0.0	314.8	252.2	12.54	0.0	0	0
170		May	252.2	12.54	314.8	78.4	0.36	393.6	237.9	188.1	52.3	103.8	52.3	0.0	52.3	0.0	341.2	254.6	13.25	12.1	9003	0
171		June	254.6	13.25	341.2	47.2	-0.51	388.0	228.2	48.9	188.7	97.3	97.3	91.4	188.7	0.0	199.3	240.6	9.13	24.0	17280	0
172		July	240.6	9.13	199.3	36.5	-0.48	235.3	84.9	39.3	47.9	123.8	47.9	0.0	47.9	0.0	187.3	239.1	8.71	9.3	6914	0
173		August	239.1	8.71	187.3	25.8	-0.61	212.5	0.0	16.6	5.4	127.1	0.0	5.4	5.4	0.0	207.2	241.6	9.41	0.0	0	0
174		September	241.6	9.41	207.2	18.1	-0.71	224.6	0.0	30.2	5.2	117.9	0.0	5.2	5.2	0.0	219.4	243.1	9.83	0.0	0	0
175		October	243.1	9.83	219.4	19.4	-0.66	238.2	30.6	56.2	5.4	118.8	0.0	5.4	5.4	0.0	232.8	244.8	10.30	0.0	0	0
176		November	244.8	10.30	232.8	33.0	-0.46	265.3	202.6	46.6	164.1	111.9	111.9	52.2	164.1	0.0	101.2	227.1	5.70	24.0	17280	0
177		December	227.1	5.70	101.2	35.7	-0.29	136.6	256.8	82.9	183.1	142.6	42.6	71.0	113.6	0.0	23.0	208.0	2.01	7.2	5332	-69
178		January	208.0	2.01	23.0	56.8	-0.05	79.7	255.8	265.3	5.4	209.4	0.0	5.4	5.4	0.0	74.4	222.4	4.60	0.0	0	0
179		February	222.4	4.60	74.4	40.1	-0.20	114.3	177.9	227.0	4.8	138.9	0.0	4.8	4.8	0.0	109.4	228.3	5.99	0.0	0	0
180		March	228.3	5.99	109.4	87.3	0.26	197.0	161.2	600.5	5.4	147.1	0.0	5.4	5.4	0.0	191.7	239.6	8.86	0.0	0	0

Appendix 8
Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
181	1984-85	April	239.6	8.86	191.7	68.9	0.11	260.6	270.4	248.6	22.9	121.8	22.9	0.0	22.9	0.0	237.7	245.3	10.45	4.5	3247	0
182		May	245.3	10.45	237.7	52.3	-0.15	289.9	237.9	189.2	51.2	114.8	51.2	0.0	51.2	0.0	238.7	245.3	10.47	10.7	7966	0
183		June	245.3	10.47	238.7	35.7	-0.61	273.7	228.2	186.8	43.5	110.9	43.5	0.0	43.5	0.0	230.2	244.4	10.21	9.4	6778	0
184		July	244.4	10.21	230.2	40.3	-0.47	270.1	84.9	79.5	5.7	116.3	0.0	5.7	5.7	0.0	264.4	247.7	11.17	0.0	0	0
185		August	247.7	11.17	264.4	33.4	-0.64	297.2	0.0	78.9	5.4	110.7	0.0	5.4	5.4	0.0	291.8	250.1	11.91	0.0	0	0
186		September	250.1	11.91	291.8	48.1	-0.30	339.7	0.0	316.0	5.2	103.4	0.0	5.2	5.2	0.0	334.5	254.0	13.07	0.0	0	0
187		October	254.0	13.07	334.5	60.2	0.00	394.7	30.6	359.6	5.4	101.4	0.0	5.4	5.4	0.0	389.3	257.6	14.36	0.0	0	0
188		November	257.6	14.36	389.3	70.1	0.24	459.6	202.6	300.2	5.2	93.6	0.0	5.2	5.2	0.0	454.4	261.5	15.84	0.0	0	0
189		December	261.5	15.84	454.4	69.8	0.08	524.3	256.8	444.3	5.4	92.2	0.0	5.4	5.4	0.0	519.0	265.4	17.30	0.0	0	0
190		January	265.4	17.30	519.0	96.1	0.72	615.8	255.8	489.8	5.4	88.2	46.2	0.0	46.2	0.0	569.6	268.5	18.45	12.6	9351	0
191		February	268.5	18.45	569.6	171.3	3.19	744.1	177.9	314.3	4.8	77.0	77.0	0.0	77.0	97.5	569.6	268.5	18.45	24.0	16128	0
192		March	268.5	18.45	569.6	88.0	0.81	658.4	161.2	247.8	5.4	85.2	85.2	0.0	85.2	3.5	569.6	268.5	18.45	24.0	17856	0
193	1985-86	April	268.5	18.45	569.6	93.5	0.98	664.1	270.4	376.8	5.2	82.5	82.5	0.0	82.5	12.0	569.6	268.5	18.45	24.0	17280	0
194		May	268.5	18.45	569.6	71.7	0.32	641.6	237.9	251.0	5.4	85.2	72.0	0.0	72.0	0.0	569.6	268.5	18.45	20.3	15089	0
195		June	268.5	18.45	569.6	49.1	-0.66	618.1	228.2	135.1	98.0	82.5	82.5	15.5	98.0	0.0	520.1	265.5	17.33	24.0	17280	0
196		July	265.5	17.33	520.1	52.2	-0.46	571.8	84.9	262.8	5.4	88.1	0.0	5.4	5.4	0.0	566.5	268.3	18.38	0.0	0	0
197		August	268.3	18.38	566.5	44.6	-0.72	610.4	0.0	306.2	5.4	85.4	40.8	0.0	40.8	0.0	569.6	268.5	18.45	11.5	8525	0
198		September	268.5	18.45	569.6	40.3	-0.71	609.2	0.0	459.1	5.2	82.5	39.5	0.0	39.5	0.0	569.6	268.5	18.45	11.5	8284	0
199		October	268.5	18.45	569.6	45.3	-0.45	614.4	30.6	557.4	5.4	85.2	44.8	0.0	44.8	0.0	569.6	268.5	18.45	12.6	9385	0
200		November	268.5	18.45	569.6	37.5	-0.68	606.4	202.6	93.0	115.3	82.5	82.5	32.8	115.3	0.0	491.1	263.8	16.67	24.0	17280	0
201		December	263.8	16.67	491.1	40.9	-0.70	531.3	256.8	51.7	215.9	89.9	89.9	126.1	215.9	0.0	315.4	252.2	12.55	24.0	17856	0
202		January	252.2	12.55	315.4	67.4	-0.07	382.7	255.8	343.3	5.4	103.7	0.0	5.4	5.4	0.0	377.4	256.9	14.09	0.0	0	0
203		February	256.9	14.09	377.4	58.1	-0.18	435.3	177.9	549.6	4.8	88.1	0.0	4.8	4.8	0.0	430.5	260.1	15.29	0.0	0	0
204		March	260.1	15.29	430.5	91.1	0.75	522.3	161.2	662.8	5.4	93.8	0.0	5.4	5.4	0.0	517.0	265.3	17.26	0.0	0	0
205	1986-87	April	265.3	17.26	517.0	72.5	0.32	589.8	270.4	464.6	5.2	85.4	20.2	0.0	20.2	0.0	569.6	268.5	18.45	5.7	4077	0
206		May	268.5	18.45	569.6	61.2	0.00	630.8	237.9	174.8	66.4	85.2	66.4	0.0	66.4	0.0	564.3	268.2	18.33	18.7	13916	0
207		June	268.2	18.33	564.3	60.0	-0.32	624.0	228.2	107.8	126.7	82.8	82.8	43.9	126.7	0.0	497.3	264.1	16.81	24.0	17280	0
208		July	264.1	16.81	497.3	61.2	-0.20	558.3	84.9	139.1	5.4	89.5	0.0	5.4	5.4	0.0	553.0	267.5	18.07	0.0	0	0
209		August	267.5	18.07	553.0	45.6	-0.68	597.9	0.0	314.8	5.4	86.2	28.2	0.0	28.2	0.0	569.6	268.5	18.45	7.9	5853	0
210		September	268.5	18.45	569.6	57.7	-0.18	627.1	0.0	401.9	5.2	82.5	57.5	0.0	57.5	0.0	569.6	268.5	18.45	16.7	12041	0
211		October	268.5	18.45	569.6	56.1	-0.12	625.6	30.6	297.3	5.4	85.2	56.0	0.0	56.0	0.0	569.6	268.5	18.45	15.8	11727	0
212		November	268.5	18.45	569.6	80.6	0.62	650.9	202.6	336.8	5.2	82.5	81.3	0.0	81.3	0.0	569.6	268.5	18.45	23.6	17023	0
213		December	268.5	18.45	569.6	96.0	0.89	666.5	256.8	197.6	62.4	85.2	85.2	0.0	85.2	11.7	569.6	268.5	18.45	24.0	17856	0
214		January	268.5	18.45	569.6	118.5	1.45	689.5	255.8	684.6	5.4	85.2	85.2	0.0	85.2	34.7	569.6	268.5	18.45	24.0	17856	0
215		February	268.5	18.45	569.6	102.2	1.10	672.9	177.9	585.5	4.8	77.0	77.0	0.0	77.0	26.3	569.6	268.5	18.45	24.0	16128	0
216		March	268.5	18.45	569.6	83.9	0.69	654.2	161.2	363.8	5.4	85.2	84.6	0.0	84.6	0.0	569.6	268.5	18.45	23.8	17722	0

Appendix 8

Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow (MCM)	Reservoir Gain/ Loss (MCM)	Gross Water Available (MCM)	Irrigation Water Demand			Maximum Power Flow. (MCM)	Water Realese Throught			Spill Out (MCM)	Reservoir at end of month			Power Generation (MW)	Energy Generation (MWh)	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)				Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)		Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)		Storage (MCM)	Elevation (m)	Area (km2)			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
217	1987-88	April	268.5	18.45	569.6	88.7	0.83	659.2	270.4	310.1	5.2	82.5	82.5	0.0	82.5	7.1	569.6	268.5	18.45	24.0	17280	0
218		May	268.5	18.45	569.6	75.9	0.44	645.9	237.9	146.6	96.1	85.2	85.2	10.8	96.1	0.0	549.8	267.3	18.00	24.0	17856	0
219		June	267.3	18.00	549.8	70.7	0.00	620.6	228.2	94.1	141.2	83.6	83.6	57.6	141.2	0.0	479.4	263.1	16.40	24.0	17280	0
220		July	263.1	16.40	479.4	41.1	-0.74	519.8	84.9	30.8	56.9	90.6	56.9	0.0	56.9	0.0	462.8	262.1	16.03	15.1	11217	0
221		August	262.1	16.03	462.8	31.9	-0.96	493.8	0.0	10.2	5.4	91.6	0.0	5.4	5.4	0.0	488.4	263.6	16.61	0.0	0	0
222		September	263.6	16.61	488.4	31.4	-0.88	518.9	0.0	0.3	5.2	87.1	0.0	5.2	5.2	0.0	513.7	265.1	17.18	0.0	0	0
223		October	265.1	17.18	513.7	28.4	-0.89	541.2	30.6	45.1	5.4	88.5	0.0	5.4	5.4	0.0	535.9	266.5	17.68	0.0	0	0
224		November	266.5	17.68	535.9	38.9	-0.61	574.2	202.6	49.0	161.6	84.3	84.3	77.3	161.6	0.0	412.6	259.0	14.89	24.0	17280	0
225		December	259.0	14.89	412.6	55.8	-0.27	468.0	256.8	74.3	192.1	95.0	95.0	97.1	192.1	0.0	275.9	248.7	11.48	24.0	17856	0
226		January	248.7	11.48	275.9	109.9	0.74	386.6	255.8	710.6	5.4	109.0	0.0	5.4	5.4	0.0	381.2	257.1	14.18	0.0	0	0
227		February	257.1	14.18	381.2	79.6	0.32	461.1	177.9	450.1	4.8	87.9	0.0	4.8	4.8	0.0	456.3	261.7	15.88	0.0	0	0
228		March	261.7	15.88	456.3	108.1	1.23	565.6	161.2	298.9	5.4	92.1	0.0	5.4	5.4	0.0	560.3	267.9	18.24	0.0	0	0
229	1988-89	April	267.9	18.24	560.3	57.3	-0.12	617.5	270.4	143.5	133.5	83.0	83.0	50.5	133.5	0.0	484.0	263.3	16.51	24.0	17280	0
230		May	263.3	16.51	484.0	52.6	-0.24	536.3	237.9	176.3	64.9	90.3	64.9	0.0	64.9	0.0	471.5	262.6	16.22	17.2	12824	0
231		June	262.6	16.22	471.5	39.0	-0.85	509.6	228.2	49.6	187.9	88.2	88.2	99.8	187.9	0.0	321.6	252.8	12.72	24.0	17280	0
232		July	252.8	12.72	321.6	36.7	-0.66	357.7	84.9	46.6	40.2	102.9	40.2	0.0	40.2	0.0	317.4	252.4	12.61	9.4	6981	0
233		August	252.4	12.61	317.4	35.0	-0.69	351.8	0.0	54.1	5.4	103.5	0.0	5.4	5.4	0.0	346.4	255.0	13.39	0.0	0	0
234		September	255.0	13.39	346.4	22.1	-0.92	367.6	0.0	75.0	5.2	96.7	0.0	5.2	5.2	0.0	362.4	256.0	13.75	0.0	0	0
235		October	256.0	13.75	362.4	23.1	-0.84	384.7	30.6	131.1	5.4	98.7	0.0	5.4	5.4	0.0	379.3	257.0	14.13	0.0	0	0
236		November	257.0	14.13	379.3	53.2	-0.16	432.4	202.6	322.9	5.2	94.3	0.0	5.2	5.2	0.0	427.2	259.9	15.22	0.0	0	0
237		December	259.9	15.22	427.2	46.7	-0.50	473.4	256.8	265.4	5.4	94.0	0.0	5.4	5.4	0.0	468.1	262.4	16.15	0.0	0	0
238		January	262.4	16.15	468.1	93.7	0.61	562.4	255.8	538.1	5.4	91.3	0.0	5.4	5.4	0.0	557.1	267.7	18.17	0.0	0	0
239		February	267.7	18.17	557.1	100.6	1.03	658.7	177.9	628.1	4.8	77.6	89.1	0.0	89.1	0.0	569.6	268.5	18.45	27.5	18503	0
240		March	268.5	18.45	569.6	82.6	0.65	652.9	161.2	723.7	5.4	85.2	83.3	0.0	83.3	0.0	569.6	268.5	18.45	23.4	17442	0
	Using Elevation - Area - Capacity Curve Revised after 20 Years																					
241	1989-90	April	268.5	18.45	559.3	58.2	-0.09	617.4	270.4	199.1	75.0	82.5	75.0	0.0	75.0	0.0	542.4	267.5	17.97	21.8	15717	0
242		May	267.5	17.97	542.4	45.6	-0.46	587.5	237.9	56.4	191.0	86.2	86.2	104.8	191.0	0.0	396.5	258.6	14.62	24.0	17856	0
243		June	258.6	14.62	396.5	39.7	-0.75	435.5	228.2	99.0	135.9	92.4	92.4	43.5	135.9	0.0	299.6	251.6	12.22	24.0	17280	0
244		July	251.6	12.22	299.6	7.7	-1.22	306.0	84.9	53.1	33.5	104.7	33.5	0.0	33.5	0.0	272.6	249.1	11.48	7.7	5708	0
245		August	249.1	11.48	272.6	10.8	-1.09	282.2	0.0	37.4	5.4	108.4	0.0	5.4	5.4	0.0	276.9	249.5	11.60	0.0	0	0
246		September	249.5	11.60	276.9	35.0	-0.55	311.3	0.0	272.2	5.2	104.3	0.0	5.2	5.2	0.0	306.1	252.2	12.40	0.0	0	0
247		October	252.2	12.40	306.1	23.5	-0.75	328.9	30.6	54.1	5.4	103.8	0.0	5.4	5.4	0.0	323.5	253.8	12.88	0.0	0	0
248		November	253.8	12.88	323.5	14.3	-0.97	336.8	202.6	88.6	119.9	98.4	98.4	21.6	119.9	0.0	216.9	243.7	9.86	24.0	17280	0
249		December	243.7	9.86	216.9	35.6	-0.50	252.0	256.8	352.9	5.4	117.6	0.0	5.4	5.4	0.0	246.7	246.8	10.76	0.0	0	0
250		January	246.8	10.76	246.7	62.5	-0.15	309.0	255.8	261.4	5.4	112.2	0.0	5.4	5.4	0.0	303.6	251.9	12.33	0.0	0	0
251		February	251.9	12.33	303.6	83.0	0.35	387.0	177.9	722.6	4.8	94.1	0.0	4.8	4.8	0.0	382.1	257.7	14.29	0.0	0	0
252		March	257.7	14.29	382.1	62.8	0.04	445.0	161.2	416.0	5.4	96.6	0.0	5.4	5.4	0.0	439.6	261.2	15.61	0.0	0	0

Appendix 8

Simulation Study for Irrigation and Hydropower

No	Year	Month	Reservoir at beginning of month			Inflow	Reservoir Gain/ Loss	Gross Water Available	Irrigation Water Demand			Maximum Power Flow	Water Realese Throught			Spill Out	Reservoir at end of month			Power Generation	Energy Generation	Deficit Irrigation Demand
			Elevation (m)	Area (km2)	Storage (MCM)	(MCM)	(MCM)	(MCM)	Req. in Argoguruh (MCM)	Runoff Argoguruh (MCM)	Demand in Dam (MCM)	(MCM)	Power Intake (MCM)	Irrigation Intake (MCM)	Total Release (MCM)	(MCM)	Storage (MCM)	Elevation (m)	Area (km2)	(MW)	(MWh)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
253	1990-91	April	261.2	15.61	439.6	50.1	-0.29	489.4	270.4	91.1	188.7	89.6	89.6	99.1	188.7	0.0	300.7	251.7	12.25	24.0	17280	0
254		May	251.7	12.25	300.7	49.1	-0.25	349.5	237.9	159.3	82.7	104.5	82.7	0.0	82.7	0.0	266.8	248.6	11.32	19.0	14131	0
255		June	248.6	11.32	266.8	37.7	-0.62	303.9	228.2	59.1	177.9	105.7	105.7	72.3	177.9	0.0	125.9	231.6	6.62	24.0	17280	0
256		July	231.6	6.62	125.9	31.3	-0.41	156.8	84.9	60.6	25.5	134 9	0.0	25.5	25.5	0.0	131.2	232.4	6.81	0.0	0	0
257		August	232.4	6.81	131.2	22.8	-0.52	153.5	0.0	74.9	5.4	132.8	0.0	5.4	5.4	0.0	148.1	235.0	7.41	0.0	0	0
258		September	235.0	7.41	148.1	20.6	-0.53	168.2	0.0	77.7	5.2	125.2	0.0	5.2	5.2	0.0	163.0	236.9	7.95	0.0	0	0
259		October	236.9	7.95	163.0	9.5	-0.67	171.9	30.6	36.2	5.4	125.8	0.0	5.4	5.4	0.0	166.6	237.3	8.07	0.0	0	0
260		November	237.3	8.07	166.6	12.8	-0.63	178.7	202.6	72.9	136.5	122.1	89.7	46.7	136.5	0.0	42.3	216.6	3.11	17.6	12693	0
261		December	216.6	3.11	42.3	50.9	-0.08	93.0	256.8	358.8	5.4	171.9	0.0	5.4	5.4	0.0	87.7	225.8	5.26	0.0	0	0
262		January	225.8	5.26	87.7	69.2	-0.01	156.8	255.8	963.7	5.4	148.9	0.0	5.4	5.4	0.0	151.5	235.4	7.53	0.0	0	0
263		February	235.4	7.53	151.5	43.2	-0.29	194.4	177.9	527.3	4.8	122.9	0.0	4.8	4.8	0.0	189.6	240.2	8.89	0.0	0	0
264		March	240.2	8.89	189.6	75.9	0.22	265.7	161.2	832.9	5.4	124.6	0.0	5.4	5.4	0.0	260.3	248.0	11.14	0.0	0	0
265	1991-92	April	248.0	11.14	260.3	65.6	0.08	325.9	270.4	581.3	5.2	106.6	0.0	5.2	5.2	0.0	320.8	253.5	12.80	0.0	0	0
266		May	253.5	12.80	320.8	92.4	0.66	413.8	237.9	224.5	14.1	102.0	14.1	0.0	14.1	0.0	399.8	258.8	14.69	3.3	2462	0
267		June	258.8	14.69	399.8	40.9	-0.72	440.0	228.2	32.1	206.4	92.2	92.2	114.2	206.4	0.0	233.6	245.6	10.40	24.0	17280	0
268		July	245.6	10.40	233.6	25.2	-0.74	258.1	84.9	16.6	71.9	114.2	71.9	0.0	71.9	0.0	186.2	239.8	8.77	15.1	11237	0
269		August	239.8	8.77	186.2	19.8	-0.71	205.2	0.0	13.4	5.4	125.5	0.0	5.4	5.4	0.0	199.9	241.5	9.26	0.0	0	0
270		September	241.5	9.26	199.9	14.0	-0.76	213.1	0.0	13.2	5.2	117.9	0.0	5.2	5.2	0.0	207.9	242.5	9.54	0.0	0	0
271		October	242.5	9.54	207.9	9.0	-0.81	216.2	30.6	12.8	18.8	119.8	18.8	0.0	18.8	0.0	197.4	241.2	9.17	3.8	2802	0
272		November	241.2	9.17	197.4	31.6	-0.43	228.5	202.6	87.9	120.7	118.6	118.6	2.1	120.7	0.0	107.8	228.8	5.98	24.0	17280	0
273		December	228.8	5.98	107.8	59.3	-0.07	167.0	256.8	291.7	5.4	142.5	0.0	5.4	5.4	0.0	161.7	236.7	7.90	0.0	0	0
274		January	236.7	7.90	161.7	48.1	-0.30	209.5	255.8	391.9	5.4	132.7	0.0	5.4	5.4	0.0	204.2	242.1	9.41	0.0	0	0
275		February	242.1	9.41	204.2	66.6	0.01	270.8	177.9	440.0	4.8	109.1	0.0	4.8	4.8	0.0	266.0	248.5	11.29	0.0	0	0
276		March	248.5	11.29	266.0	131.3	1.31	398.6	161.2	572.0	5.4	109.3	0.0	5.4	5.4	0.0	393.2	258.4	14.54	0.0	0	0
277	1992-93	April	258.4	14.54	393.2	98.4	0.89	492.5	270.4	397.9	5.2	92.7	0.0	5.2	5.2	0.0	487.3	264.1	16.70	0.0	0	0
278		May	264.1	16.70	487.3	63.6	0.07	551.0	237.9	304.4	5.4	89.5	0.0	5.4	5.4	0.0	545.6	267.7	18.04	0.0	0	0
279		June	267.7	18.04	545.6	34.3	-1.08	578.9	228.2	45.3	192.5	83.2	83.2	109.3	192.5	0.0	386.4	258.0	14.38	24.0	17280	0
280		July	258.0	14.38	386.4	44.8	-0.56	430.7	84.9	46.3	40.6	96.3	40.6	0.0	40.6	0.0	390.1	258.2	14.47	10.1	7531	0
281		August	258.2	14.47	390.1	32.6	-0.85	421.8	0.0	76.9	5.4	96.0	0.0	5.4	5.4	0.0	416.5	259.8	15.08	0.0	0	0
282		September	259.8	15.08	416.5	29.1	-0.86	444.8	0.0	173.9	5.2	91.1	0.0	5.2	5.2	0.0	439.6	261.2	15.61	0.0	0	0
283		October	261.2	15.61	439.6	32.9	-0.70	471.8	30.6	54.7	5.4	92.5	0.0	5.4	5.4	0.0	466.4	262.9	16.22	0.0	0	0
284		November	262.9	16.22	466.4	50.8	-0.25	516.9	202.6	43.5	167.4	87.9	87.9	79.5	167.4	0.0	349.5	255.7	13.54	24.0	17280	0
285		December	255.7	13.54	349.5	73.5	0.15	423.1	256.8	326.1	5.4	99.0	0.0	5.4	5.4	0.0	417.8	259.9	15.10	0.0	0	0
286		January	259.9	15.10	417.8	100.8	0.75	519.3	255.8	633.6	5.4	94.0	0.0	5.4	5.4	0.0	513.9	265.7	17.31	0.0	0	0
287		February	265.7	17.31	513.9	78.4	0.35	592.7	177.9	484.6	4.8	79.4	33.4	0.0	33.4	0.0	559.3	268.5	18.35	10.1	6798	0
288		March	268.5	18.35	559.3	93.8	0.98	654.1	161.2	415.2	5.4	85.2	85.2	0.0	85.2	9.6	559.3	268.5	18.35	24.0	17856	0

NO OF MONTH FAILURE	7	MONTH
TOTAL MONTH	288	MONTH
TIME RELIABILITY	98	%

NO OF YEAR FAILURE	3	YEAR
TOTAL YEAR	24	YEAR
ANNUAL RELIABILITY	88	%

NO OF WET SEASON FAILURE	3	YEAR
TOTAL YEAR	24	YEAR
WET SEASON RELIABILITY	88	%

NO OF DRY SEASON FAILURE	1	YEAR
TOTAL YEAR	24	YEAR
DRY SEASON RELIABILITY	96	%

MEAN POWER GENERATION	11.4	MW
VARIANCE POWER GENERATION	102.3	

AVERAGE ANNUAL ENERGY GENERATION	99.8	GWh
ANNUAL CAPACITY FACTOR	47.5	%