SIMULATION OF A RESERVOIR SYSTEM WITH MULTIPLE OBJECTIVES

By

LEENA DIVAKAR

THESIS

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Faculty of Agricultural Engineering and Technology
Kerala Agricultural University

Department of Irrigation and Drainage Engineering
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA

2001

DECLARATION

I hereby declare that this thesis entitled "**Simulation of a reservoir system with multiple objectives**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

13/11/01

LEENA DIVAKAR.

Tavanur,
Date: 13.11.01

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Certified that this thesis entitled "**Simulation of a reservoir system with multiple objectives**" is a record of research work done independently by Ms. Leena Divakar under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Tavanur,
Date: 13-11-2001

Mary Regina. F
(Chairperson, Advisory Committee)
Assistant Professor
Department of IDE
KCAET, Tavanur.

CERTIFICATE

We the undersigned members of the Advisory Committee of Ms. Leena Divakar, a candidate for the degree of Master of Technology in Agricultural Engineering majoring in Soil and Water Engineering, agree that the thesis entitled "**Simulation of a reservoir system with multiple objectives**" may be submitted by Ms. Leena Divakar in partial fulfillment of the requirement for the degree.

Mary Regina. F
(Chairperson, Advisory Committee)
Assistant Professor
Department of IDE
KCAET, Tavanur.

Dr. K. John Thomas
Dean
K.C.A.E.T, Tavanur
(Member)

Dr. Jobi V. Paul
Associate Prof. & Head
Dept. of Ag. Engg.
College of Horticulture, Vellanikara
(Member)

Smt. Josephina Paul
Assistant Professor
Computer Science
Directorate of Research
Vellanikara
(Member)

External Examiner
Dr. D Chandrasekhar
Professor College of Agrl Engg
TNAU Coimbatore

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Dedicated

To

My Virtuous Parents

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SYMBOLS AND ABBREVATIONS

Agrl.	:	Agricultural
Apr.	:	April
A.S.C.E	:	American Society of Civil Engineers
Aug.	:	August
Bull.	:	Bulletin
Calif.	:	California
Cent.	:	Centre
cft.	:	cubic feet
cm	:	centimetre (s)
Contd.	:	Continued
cum.	:	cubic metre (s)
Dec.	:	December
dia.	:	diameter
DIV.	:	Division
DRINK	:	Drinking water
Engg.	:	Engineering
et al.	:	and others
etc.	:	(etceteras) and the rest
EVP	:	Evaporation
Feb.	:	February
Fig.	:	Figure
ft.	:	feet
Ha.	:	hectare
Hydraul.	:	Hydraulics
Hydrol.	:	Hydrology
I.A.H.S	:	International Association of Hydrological sciences
I.C.I.D	:	International Commission on Irrigation and Drainage
i.e.	:	that is

in.	:	inches
INFL	:	Inflow
INIST	:	Initial storage
Inst.	:	Institute
IRRIG	:	Irrigation
I.S.A.E	:	Indian Society of Agricultural Engineers
Jan.	:	January
J.	:	Journal
Jul.	:	July
Jun.	:	June
km.	:	Kilometre (s)
m.	:	Metre (s)
Mar.	:	March
Mcft.	:	Million cubic feet
Mcum./ Mm^3	:	Million cubic metre (s)
Mha.	:	Million hectare (s)
MSL	:	Mean Sea Level
No.	:	Number (s)
Nov.	:	November
Oct.	:	October
PISCI	:	Pisciculture
Proc.	:	Proceedings
pp.	:	Pages
REC	:	Recreation
REMST	:	Remaining storage
Res.	:	Research
Sep.	:	September
sec.	:	Second (s)
SPILL	:	Spillway discharge
Sq.	:	Square

Tech.	:	Technology
Univ.	:	University
viz.	:	Namely
&	:	And
°C	:	Degree Centigrade (s)
'	:	Minute (s)
%	:	Percent
/	:	Per

Introduction

INTRODUCTION

Water, the elixir of life sustains all forms of life on earth. It is the most important constituent of the geosystem and is also the most abundant substance on earth. Of the three components of geosystem viz., land, water and air, water links the other two by means of an endless recirculatory transport phenomenon called the hydrological cycle. Water is essential for socio- economic development as a natural key resource for agriculture and industry and provides entertaining sights most refreshing to the eye. Without water, life whether wild, domesticated or human would be as inconceivable as it could be for fish.

In order to meet the various demands and requirements of water, it is essential to obtain sufficient quantity of water in a form, which can be easily and inexpensively made available for the various uses. With the modernisation, industralisation and mechanisation of the present age, the importance of water resources is increasing by leaps and bounds. It is realised that our future depends on the efficient and economic utilization of water. Therefore all over the world efforts have begun to formulate water policies for conservation and implementation of water management programmes on a priority basis.

Nowadays a country which has water in abundance is considered as very rich. Though India has an average runoff of 1683 x 10^9 cubic metre carried by it's rivers covering an area of 369 million hectares, hardly 16% to 18% of this water is being utilised. Thus it is very important to harness the large quantities of water running in our rivers to benefit the human beings. The running water can be stored by constructing storage reservoirs across the rivers. The aim of all investigations for storage schemes is to locate, design and construct the most economical structures which may impound the much-needed water. Storage reservoirs are normally constructed for the purposes of flood control and conservation of water. It also serves the purposes of irrigation, power generation, water supply for domestic and industrial use, navigation, recreation, wildlife, sanitation etc. With the creation of more reservoirs in a single river basin, the operation of these reservoirs become more complex and when these reservoirs are multipurpose in nature with conflicting objectives, it becomes still more complex.

Basically India is an agricultural country and all it's wealth depends on the agricultural output. It is essential that water be supplied in optimum quantity at the proper time to the crops. The total rainfall in a particular area may be insufficient or ill distributed or ill timed. Therefore the objective of an irrigation engineer is to make the water available to the farmers with respect to location, time and quantity as per the crop requirements. This is possible only through a systematic system of irrigation i.e. by collecting water during the periods of excess rainfalls, by constructing dams and reservoirs and releasing it to the fields as and when needed. The performance of irrigation systems has been generally deteriorating due to various reasons. One reason is that reservoir operation has been so far largely an art handled by experience and intuition and little attempt has been made to approach it in a more scientific way.

Every reservoir has well defined rules of operation, which are at present based on past experiences. When we find that the performance of the system is poor we need to implement some drastic changes in the operational policy. But it cannot be tested straight away in systems. A modelling approach is highly useful to resolve such a problem. At some risk of over simplification, the job of the water resources engineer may be reduced to a number of basic questions. Since the water resources project is for the control of use of water, the first question naturally deals with quantity of water. This is probably the most difficult of all the design problems to answer accurately because it involves social and economic aspects as well as engineering knowledge. On the basis of an economic analysis, a decision must also be made concerning the span of years for which the proposed works should be adequate .

A new approach known as systems approach for defining a concept, methodology and techniques are being increasingly adopted for technological planning and decision making. It involves a planner to develop the numerous alternatives, identify the implications of different factors and obtain the preferred, emphasized or optimum system configuration, component capacities and management policies. The techniques consist of a host of qualified decision making sciences, the important ones being mathematical modelling and simulation. Optimisation procedures can be conveniently arranged into four groups based on the mathematical characteristics of the models viz. Linear programming, Integer programming, Nonlinear programming and Dynamic programming

Simulation is a problem solving technique in which an understanding of the behaviour and response of a system is obtained by development of a model of the system, operation of the model and observation of the resulting outputs. In recent years computer simulation has emerged as the most powerful technique among the many system analysis tools available to the designers of complex processes or systems. Simulation also allows testing of the sensitivity of outcomes to varying input assumptions and system parameters. It provides an accounting device that helps ensure internal consistency among the projections and plans. Qualitative relations among the various factors affecting supply and demand can be depicted. It is therefore considered the most generally useful technique used by the operations manager.

In deciding whether to go in or not for a simulation model, the system analyst must weigh the advantages of this technique. Simulation allows the analyst to model complex and dynamic phenomena that otherwise could not be dealt with in a scientific way. It permits experimentation that might be impossible or otherwise infeasible. It is also useful in solving problems where all values of the variables are not known or only partly known in advance. By simulating the system, the management gains valuable insight into the system and into the relative importance of the different variables. The effect of using a simulation model can be observed without actually using it in the real time. To predict this behaviour of a system over the period of a year takes only a few seconds or minutes using computer simulations. To comprehend the basic concept of simulation does not require a sophisticated mathematical background and consequently, non-technical decision-makers can comprehend simulation better than other methods.

A simulation model is usually characterized as the representation of a physical system and is used to predict the response of the system under a given set of conditions. The management and operation simulation technique is used for experimentation in order to analyse the performance of the reservoir under changing conditions. The simulation model is not able to generate an optimal solution to a reservoir problem directly. While making numerous runs of a model with alternative decision policies it can detect an optimal or near optimal solution. A reservoir system simulation model reproduces the hydrologic and in some cases, economic performance of a reservoir system for given inflows and operating rules. Various strategies can be adopted for applying simulation models. Series of runs can be made to compare system performance for alternative reservoir configuration, storage allocations, operating rules, demand levels and / or hydrologic inflow sequences.

Optimization of reservoir operation both as an individual and as a part of the system can be done by other methods. But it has been conclusively proved that the simulation techniques outweigh any of the other optimization procedures, because it offers great freedom of work and flexibility in modelling the most complex constraints governing the operation. A detailed observation of the system being simulated leads to better understanding of the system and to suggestions for improving it, which otherwise would be unobtainable. In spite of the large optimization techniques available, simulation models still remain the primary tool for reservoir planning and management studies in practice. The reason is that simulation models allow a more detailed and faithful representation of the system studied than optimization techniques do and moreover they can be easily combined with synthetically generated streamflow sequences.

The development and management of the water resources of a region has to evolve together with that of land and biomass, giving due weightage to the specific socio-economic and environmental features. As far as Kerala State is concerned, the aquatic environment of this humid tropic has given shape to its economic, social and environmental features. From this point of view of water resources, Kerala is having both abundance and scarcity. Though it has forty four rivers, most of these are monsoon – fed and short rivers which will dry up during summer months. Kerala has a total of ten completed water resources projects and about more than a dozen partially commissioned projects.

A reservoir operation simulation study on Peechi reservoir which is situated across Manali river, a major tributary of Karuvannur river in Thrissur district of Kerala was undertaken. Peechi scheme comprises of a masonry dam having an estimated storage capacity of 113.27 Mm^3 of water and a network of canal system. The canal system consists of two main canals starting from the right bank and left bank of the dam with a view to irrigate an approximate area of 18,600 ha.

Under this context, the specific objectives of the present study were framed as : -

1. to develop a simulation model for monthly operation of a reservoir with multiple objectives using historic inflow data.
2. to evolve a reservoir management policy for the Peechi reservoir system with a view to optimize the water supply to Thrissur town, kole lands and to serve the facilities of fisheries and recreation.

Review of Literature

REVIEW OF LITERATURE

This chapter primarily reviews the work done on the application of simulation techniques as applied to water resource problems relevant to the present study. The efficient allocation of water resources and subsequent distribution of benefits play an important role in water resources planning and management.

With the growing population and economic development, water requirements are rapidly growing in most parts of the world. The total fresh water supply seems to be able to cover the requirements for a long time to come, but the distribution thereof in time and space is frequently unfavourable. Storage reservoirs are the most effective tools for eliminating the discrepancies in the time variations of the requirements and resources. Man has an experience with reservoirs for the last ten thousand years and he has developed economical methods of reservoir construction for a wide variety of sites. Still, to this day, the methods of estimating the proper sizes of dams and reservoirs for the target pattern of demand have been mainly based on engineering judgement.

A reservoir is created with the impounding of part of the runoff from the catchment upstream by the construction of a dam across a river or stream. Storage is done during the period when the flow is in excess of demand and releases during the lean period so as to maintain constant water supply for drinking, irrigation and other uses including power generation. The hydrological aspects of reservoir planning mainly dealt with are (i) water availability in the river on which the dam is proposed to be constructed; (ii) determination of storage capacity to serve the target pattern of demand; and (iii) operation of the reservoir with the given target pattern.

Reservoirs can be classified on the basis of the purpose served by them.
Storage reservoirs: Storage or conservation reservoir stores surplus water during excess flow so as to maintain continuous supply for domestic needs, irrigation,

power generation, industrial purposes etc. during the period of lean supply in the river but when demand is keen.

Flood control reservoirs: These reservoirs hold back the excess of the safe carrying capacity of the river channel downstream temporarily during floods and releases later when flood recedes. They are of the following two types.

Retarding reservoirs: Retarding reservoirs are those at which gates are provided in the outlets to regulate the releases but the discharge capacity of the outlets and spillways is so fixed that it is not in excess of the flood carrying capacity of the reservoir channel downstream.

Detention reservoirs: Detention reservoirs are those, which have gated outlets, so as to provide greater flexibility in the operation of the reservoirs.

Distribution reservoirs: Distribution reservoirs are usually of limited storage capacity used primarily to cater for fluctuations in demand which may occur over short periods of several hours to several days. They also serve as local storage to take care of emergency in the event of break in main supply line or failure of the pumping plant etc.

Multipurpose reservoir: These are also termed as multiuse reservoir. In this reservoir the storage and release water are for a combination of two or more purposes such as public water supply, irrigation, hydel power generation, flood control, navigation, recreation, fisheries etc.

Balancing reservoirs: It is a reservoir, usually of limited capacity, located downstream of a main reservoir to store excess water let down from the upstream reservoir. It provides flexibility of operation, distribution, and permits regular supply to cater for the fluctuations in the requirement of water supply.

2.1 Simulation:

Simulation approach is essentially a search approach to determine optimal operating policies. First a reasonable initial operation rule is postulated and then changes in the direction of the desired objectives are tried. It is repeated several times with various inputs and parameter data to calculate values of the objective function for the different runs, to choose the best decision set.

2.1.1 Advantages of simulation:

In deciding whether to go in or not for a simulation model, the system analyst must weigh the advantages of the technique.

1. It allows the analyst to model complex and dynamic phenomena that otherwise could not be dealt with in a scientific way.
2. It permits experimentation that might be impossible or infeasible otherwise.
3. It is useful in solving problems where all values of the variables are not known or only partly known in advance.
4. By simulating the system, management gains valuable insight into the system and into the relative importance of the different variables.
5. The model of a system once constructed may be employed as often as desired to analyse different situations.
6. Simulation methods are handy for analysing proposed system in which information is sketchy at best.
7. The effect of using simulation model can be observed without actually using it in the real situation. Simulation allows for the compression of real time. To predict the behaviour of a system over the period of a year may take only a few seconds or minutes using computer simulation.
8. Usually data for further analysis can be easily generated from a simulation model.
9. To comprehend the basic concept of simulation one does not require a sophisticated mathematical background and consequently non-technical decision makers can comprehend simulation better than other methods.

2.1.2Disadvantages of simulation:

Naturally, there are some significant disadvantages in using simulation to solve operations problems

1. Different system configurations are tested to find a good, but not guaranteed best solution.
2. Due to the nature of simulation, sampling errors exists in all outputs from simulation models.
3. A real disadvantage is that simulation may often be misused if the programmers do not possess the necessary statistical background.
4. Possibly the most serious shortcoming of simulation is that it is a tool of solution evaluation and thus does not generate problem solutions.

The application of simulation to the solution of operational problems is on a steep growth trend. Simulation is being applied to a rapidly increasing variety of problems, mainly because of its ability to model complex and dynamic systems that could not be modelled otherwise. Another reason for recent explosion in simulation application is that the major disadvantages of simulation, cost and unavailability of necessary data are being mitigated by the rapid advances that have been made in computer hardware and software technology.

Hufschmidt and Fiering (1966) says that hydrologic simulation is an effective technique in comprehensive watershed planning and equally important in subsequent implementation and refinement. They reported that the simulation approach is essentially a search method. First a reasonable initial operation rule was postulated, then changes in decision rule that tend to move the operation in the direction of the desired objectives were tried. This approach resembles the trial and error approach used in traditional operational studies

Donald and Joe (1970) developed a set of simulation and optimization tools capable of analysing the development and operation of a complex multi-basin, interconnected water resource system. These models provide valuable information regarding the construction and operation of a proposed set of water projects. The simulation procedure developed by them employed a direct solution of a set of linear equations.

A mathematical modeling technique to allow simulation of the lower Delware Basin of United States and the proposed engineering structures was developed by Hulman and Erickson (1972) The technique and its application to the Delware Basin were analysed by them. An algorithm was devised which would try system requirements for successive recycling of the simulation period and to determine that system requirement which would fully utilise the storage.

The use of preemptive goal programming for the simulation of a five reservoir system in Indiana is discussed in the work by Toebes and Chang (1972), wherein a prioritization of operation objectives was developed to mimic the inplace operation scheme.

Walesh (1972) has studied the practical considerations involved in the use of simulation in the preparation of three comprehensive watershed plans and has also used the results of that simulation study in implementing these plans. With the help of seven examples he illustrated the potential role and value of simulation in watershed planning process. He concluded that hydrologic- hydraulic simulation, accomplished with digital computer programs, provides an effective means to achieve the necessary understanding of the surface water system, under both existing and hypothetical water shed conditions.

Loucks and Dorfman (1975) used some linear decision rules in chance constrained models for estimating efficient reservoir capacities and operating policies. Optimization and simulation techniques were used to evaluate the performance of each decision rule.

Sigvaldason *et al.* (1975) developed ACRES model and used as a day-to-day operating tool for defining reservoir releases in the Trent River system in Ontario. A simulation model for a multipurpose reservoir at the Leach River was developed by Harboe (1976 b). The simulation model was developed on a monthly basis and consists of the elements like mass balance for the reservoir, operation policies and energy subroutine.

A simulation model was developed by Sigvaldason (1976) and applied to the Trent river system in Ontario. He proposed a conceptual approach for simulating the response of a multipurpose multiresevoir system under different operating policies. The concept included the subdivision of each reservoir into five time based storage zones and utilized rule curves, i.e., ideal time based operating levels. Violation of individual reservoir rule curves in the various zones were based on the priority concept (i.e., maintaining some functional relationship in the relative violation of different reservoirs). The model was proved to be very effective in assessing the impact of alternative policies of operation. The model has also been used to a limited extent, as an operational tool and showed considerable promise in this area.

Eichert (1979) pointed out that from the practitioner's point of view, mathematical programming techniques have thus far not proven to be widely useful because of the complexities of water resources system and non- commensurable objectives in water management. In this regard he showed simulation as an effective tool for studying the operation of the complex water resource system incorporating the experience and judgement of the plans into the model.

Finite differential equations, integral equations and simulation were employed to ascertain mean first passage times of a non seasonal reservoir fed by various input distributions. The results were accurate to within three significant figures or better. It was found that for large capacity, skewness, correlation and mean net input great difficulty was experienced in obtaining accurate results. The concept of the standard reservoir facilitates comparisons between remarkably disparate marginal distribution of input (Pegram 1980).

Chaturvedi and Srivastava (1981) studied a complex water resources system with screening and simulation models. A simulation program was developed which continues screening on the basis of information obtained from the linear programming model. The models are developed in the context of analysis of the Narmada River, a large river basin in India for which in the first instance alternative combinations and capacities of six major dams are to be decided.

Harboe and schultz (1981) briefly introduces the theory of simulation as used in water resources projects and then describes four applications in different problem areas. The application refers to water supply, environment, water power and irrigation in different parts of the world. Conclusions were drawn in regard to the usefulness of this technique and the variety of its approaches in solving many practical problems.

Mc Bean (1981) studied the mathematical simulation model used in the planning of reservoir capacities, irrigation areas, diversions and hydroelectric installations. He discussed the issues that must be solved in the construction of a large simulation model. Other concerns in the model design included careful attention to both the computational and data efficiency of the model, the output characteristics of the model, and the maintenance of a general structure to enhance the ease of use on other basin planning problems.

A condensed disaggregation model for incorporating parameter uncertainty into monthly reservoir simulations was developed by Stedinger *et al.* (1985). The condensed model has fewer parameters and is convenient for generating flow sequences which incorporate the intrinsic variability of streamflows and the uncertainty in the parameters of the annual and monthly streamflows. For high reliability systems the results show that streamflow generation procedures which ignore model parameters uncertainty can grossly underestimate reservoir system failure rates and the severity of likely shortages, even if based on a 50 year record.

Barnes Jr. *et al.* (1986) developed a simulation model which provides necessary flexibility to analyse a wide range of assumptions for various planning alternatives of the water resource system. The size, complexity and conveyance facility of the combined CVP(Central Valley Project) and SWP (State Water Project) systems of reservoir in California, is such that proposed changes in water use or development of future water project facilities may involve analysing or changing numerous system or operational constraints. Many model features are incorporated so that the model can be used to analyse the effect of various alternatives of future surface reservoirs, changes in cross Delta transfer proposals, proposed ground water reservoirs and many other proposed system changes.

Takeuchi (1986) developed a reservoir operation rule which was named DDC curves and demonstrated satisfactory operation through a simulation study of the Fukuoka drought care during 1978-79. It deals with a simple reservoir operation model readily acceptable by practitioners responsible for operation of a single purpose water supply reservoir, given a specific water demand pattern. The selected objective was to minimize the ratio of supply deficit to the demand.

The main objectives of the Chi - Basin (Northeast Thailand) Water Use Study was to prepare a long term integrated water resource and agriculture development plan. Piper *et al.* (1989) developed a simulation model for planning water resource and agricultural developments in Chi- River Basin. A basin simulation was written to help evaluate alternative development scenarios of combinations of reservoirs and irrigation schemes.

Raman and Paul (1990) developed a computer simulation model for a multipurpose multireservoir system and tested for Chaliar River Basin of Kerala in South India. The model was designed for monthly operation with historic or generated streamflows. The monthly water requirements for different purposes are taken as the target to be achieved by the model. The simulation model has been constructed in such a way that it can accommodate different reservoir operating policies. The priorities of different water demands can be altered at any stage of the operation according to the changing needs of the region.

Reservoir system simulation models are widely used to determine a system's firm water yield, average yield or hydropower capacity. Most such models use heuristic guidelines to define the systems operating policy. Johnson *et al.*(1991) used optimization within the simulation to identify a reasonable operating strategy. They provided a theoretical justification for several heuristic-operating guidelines including the widely used space rule. The guidelines were expressed as a mathematical objective function and combined with constraints on system operation to yield one period optimization sub models that can be used to determine releases within a simulation. Use of these one period optimization models improved the simulated operation of the Central Valley Project in California over the initial period of record and provided reasonable policies for other hydrologic scenarios.

Andrews *et al.* (1992) developed a network flow programming based model, KCOM (Kern conveyance operations model) to simulate water allocation and distribution of both surface and subsurface water. Network flow programming based simulation was chosen for KCOM because of its generality, flexibility, speed and superior ability to reflect complex water allocation policies. The water allocation capabilities of network flow programming based simulation were enhanced in KCOM by the development of a sequential flow allocation technique, in which sources were allocated in different layers to meet only demands with authorized access to those sources. A validation simulation demonstrates the model's capabilities, and sensitivity analysis underscores the need for the data used to describe the system.

Wurbs (1993) presented a paper to contribute to ongoing efforts through out the water management community in sorting through the numerous reservoir system analysis models. It also helps in better understanding of methods which might be most useful in various types of decision support situations. Models were inventoried and compared from a general overview perspective, with an emphasis on practical applications. Considerations in formulating a modeling approach were outlined.

Kumar *et al.*(1996) developed a system dependent simulation model, incorporating the concept of reservoir zoning to facilitate releases and transfers. The simulation model was found to generate a large no of solutions which was screened by the optimization model. The Box complex non-linear programming algorithm was used for optimization. The performance of the system was evaluated through simulation with the optimal reservoir zones with respect to four indices, reliability, resiliency, vulnerability and deficit ratio. The results indicate that by operating the system of 15 reservoirs taken as a single unit the existing utilization of water may be increased significantly.

An optimization simulation model was defined as a tool for planning, designing and managing surface reservoirs in Negev desert, Israel. The model allowed a relatively simple and objective economical study for the production of water in terms of optimal reservoir location and reservoir design to be undertaken. The simulation was carried out over actual flow records taking into account the stochastic nature of runoff. A sensitivity analysis was added for parameters such as sedimentation, infiltration , investment costs, interest and sequence of flows within the flow record. (Pushmann and Lohr , 1996)

Hughes *et al.* (1997) devised a technique that uses a reference time series of daily flow data to represent the prevailing climate and trigger the releases. The technique has been incorporated into a preliminary version of a reservoir simulation model and is designed for planning purposes to illustrate the effect on day to day pattern of releases, as well as to control releases.

Nalbantis and Koutsoyiannis (1997) formulated and tested a parametric rule for multireservoir system operation. The rule was embedded in a simulation model so that optimization requires repeated simulations of the system operation with specific values of the parameters each time. The rule was tested in the case of the multireservoir water supply system of the city of Athens, which was driven by the operating goals (avoidance of spills, leakage losses and conveyance problems) Two problems at the system design level were tackled. First, the total release from the system is maximised for a selected level of failure probability. A detailed simulation model was used in the case study. Sensitivity analysis of the rule's parameters revealed a subset of insensitive parameters that allowed for rule simplification. Finally the rule was validated through comparison with a number of heuristic rules also applied to the test case.

2.2 Operating policy:

Water resource planning is concerned with the establishment of appropriate operating policies besides the structural and hydrological issues. Operating policy refer to achievement of the said transformation, for instance how much and when the releases should be made from the reservoirs, what should be the quality management under different circumstances etc. The capacities and operating policy specify normative design on planning specifications under stochastic conditions of input, state and output demand. In many instances development of operating rules that are best in some sense is a prime objective of the simulation experiments.

Harboe (1970) developed DP models under the basis to find optimal operation rules in short and long term periods. In short time, the objective is to find the hourly withdrawals from the reservoir. In the long term, the objective has been to determine the monthly release from the reservoir over a large period of time, usually coincident with a critical period of runoff or over the economical life of the project.

Roefs and Bodin (1970) grouped the approaches to the solution of the reservoir operation problem into three classes; a simulation approach, an explicit stochastic approach and an implicit stochastic approach. In the simulation approach the effects of an operating rule were simulated on the basis of sequence of streamflows. By trial and error or possibly some search procedure an operating rule was found that achieved the desired objectives the best. When the length of the historical flow sequence is sufficient for a reliable estimation of the effects of the rules investigated, it is commonly extended or replaced by a synthetic sequence.

A mathematical model that can be useful in determining the optimum design and operation of a single multipurpose reservoir was formulated by Mobasheri, and Harboe (1970). The development purposes included firm water supply, firm on-peak and dump hydropower production, flood control, and low augmentation. The model is based upon a two stage optimization technique. It takes into account the fact that economic returns from a project are a function of both design and operational rules of the project. A dynamic programming algorithm, which has a physical recursive equation, computes the optimum operation policy of a feasible design.

Most of the simulation models assume that some particular historical streamflow is representative of the entire hydrologic time series (Askew *et al.* 1971). He successfully used critical period hydrology for design purpose in a reservoir simulation study.

Simulation models are symbolic or numerical abstractions of a system under study (Van Horn, 1971).A sequence of mathematical statements describe the design and operating characteristics of the components of the system being modelled. Such a sequence of statements , adjusted to coincide with the characteristics of a basin and combined with a series of historical or generated streamflow at various gauging stations, provide a means of simulating the operations of that system in order to protect and analyze it's performance.

Becker and Yeh (1974) developed a methodology for real time optimization of water release and hydropower. They utilized dynamic programming for the selection of an optimal reservoir release policy path through a specified number of policy periods, with iterative linear programming used for period by period optimization.

Reservoir operation objectives were considered by maximising an objective function while maintaining various minimum values of a second objective in an optimization constraint in a study by Croley II and Rao (1979). An operation rule was formulated from the optimum decision set associated with the selected trade off level, by using Implicit Stochastic Optimization methods already available. These techniques were applied to the practical problem of the Coralville reservoir ,Iowa for flood control and recreation operating purposes and resulting operation rules were compared to the existing operation rule.

Studies show that incorporating the parameter uncertainty in annual streamflow statistics generating into monthly streamflow algorithms can have a major impact on estimates of reservoir system reliability and distributions describing possible future system performance (Stedinger, 1979).

Bhaskar and Whitlatch (1980) analysed a single multipurpose reservoir using a backward looking dynamic program algorithm to obtain optimal releases. Monthly policies were derived by regressing the optimal set of releases on the input and state variables. Linear and non linear release policies were developed, verified and compared through simulation.

Yeh and Becker (1982) developed practical procedures for the analysis of a multiple purpose, multiple facility reservoir to guide real time decisions concerning the optimal operation of the system . Application is made to the California Central Valley Project. The five purposes (benefit) treated as objective in the multiobjective optimization include hydropower production, fish production, water quality maintenance , water supply and recreation.

Houck (1982) presented the results of some numerical experiments, which indicate that the true operation objective function written in real-time model may not be the best one to use for real time operation. He found another objective function which, when used in the same real time model, produced operation results which were better than that measured by the true objective function.

The development of general reservoir system operating rules by deterministic optimization was investigated by Karamouz and Houck (1982). They developed an algorithm that cycles through a deterministic dynamic program, regression analysis and a simulation model and was tested for 48 cases. Annual operating rules were determined for 12 cases and monthly operating rules were determined for 36 cases. The results using the algorithm for the 48 cases demonstrated the significant value of the algorithm in selecting reservoir operating rules.

A study was made of the optimal operation of an existing multipurpose, multi-reservoir system by using forecasts An optimization model was constructed for a system of four flood control reservoirs in the Green River Basin, Kentucky having recreation and low-flow augmentation as secondary objectives. The resulting model, called the Green River Basin Operation Optimization Model (GRBOOM), was designed for use in real time operation as well as in long run operation studies. The model is easily modifiable and very flexible and allows sensitivity analysis and experimentation with new operating policies. (Yazicigil *et al.* 1983)

Datta and Burger (1984) used a series of synthetic short term forecasted values to examine a single reservoir. The objective function of the operation model is assumed to be the best possible tradeoff between probable deviations from two operation targets, release and storage volume. Actual losses, deviations between actual and forecasted losses, the variance of shortage and release volume and operational performance measures including reliability, resiliency and vulnerability were found to be sensitive to the relative importance given to deviations from release or storage targets and the quality of forecasts.

Most applications of stochastic dynamic programming have derived stationary policies which use the previous periods inflow as a hydrologic state variable. Stedinger *et al.* (1984) developed a stochastic dynamic programming model, which employs the best forecast of the current period's inflow to define a reservoir release policy and to calculate the expected benefits from future operations. The study showed that the use of the best inflow forecast as a hydrologic state variable, instead of the preceding period's inflow, resulted in substantial improvements in simulated reservoir operations with derived stationary reservoir operating policies. The results illustrate the potential stochastic dynamic programming algorithm. It identifies the optimal policy within the class of policies examined.

Tai and Goulter (1987) presented a technique based upon stochastic dynamic programming for a three reservoir hydroelectric system. It involved use of historical inflow data for the down stream reservoir. At each iteration the optimal policies for the downstream reservoir were used to provide relative weightings or targets for operation of upstream reservoirs. New input inflows to the downstream reservoirs were obtained by running the historical streamflow record through the optimal policies for the upstream reservoirs. This flow was then used to develop a new operating policy for the downstream reservoir and hence new targets for the upstream reservoirs. Results obtained from the procedure were compared with the results obtained by the historical operation of the system. The estimated benefits generated from the technique were shown to be similar to the benefits generated by the historical operation of the system with the difference being within the bounds expected from the choice of the number of storage states.

Kuezera and Diment (1988) developed WASP (Water Assignment Simulation Package) to facilitate analysis of the performance of the headworks and transfer components of a water supply system under different operating policies and changes to system configuration. WASP is based on a network LP to take advantage of computer codes upto 100 times faster than standard LP codes.

A methodology was developed by Simonovic and Burn (1989) which aims to determine the optimal operating horizon of a single multipurpose reservoir. The optimal value of the operating horizon was selected horizon based on the trade off between most reliable inflow forecast for shorter horizons and better reservoir operation associated with the use of longer operating horizons. The benefits of the methodology were illustrated through an application of the technique in simulating the operation of Green Reservoir in Kentucky.

Kuo *et al.* (1990) reported the development and application of a modelling package for the real time operation of Feitsui and Shihmen Reservoirs in the Tanshui River Basin, China. The modelling package consists of a 10 day streamflow forecast model, a rule curve based simulation model and an optimization model. Tested with actual operational records and a hypothetical condition, the models were seen to be capable of producing improved 10 day operating rules for the present reservoir system. Given a forecasted streamflow sequence for the entire year, the simulation model is first used to determine whether a severe shortage of water is expected. The simulation results were used as an initial feasible operating policy and an appropriate objective function. A dynamic programming based optimization model is then used to determine an improved operating policy.

Mohan and Keskar (1991) studied the goal programming approach for multipurpose reservoir operation and applied it to the Bhadra reservoir system. Irrigation and Hydropower were taken as the dual purposes. The objective of the model was to satisfy sequentially a series of operating criteria. Two goal programming models, one with the objective function as minimizing the deviations from storage targets and other with the objective function as minimizing the deviations from release targets were formulated and applied to the reservoir system under study. The results proved that the model with release target is prefered over the model with storage targets for determining operational policies for multi-purpose reservoir system.

A simulation of irrigation policy and reservoir operation was carried out to confirm that extending the irrigated area of the Periyar Vaigai irrigation System from 61,000 Ha to 78,500 Ha would not reduce it's existing productivity. (Venugopal *et al.* 1991). The extra supply for the new data would come from modernising the existing scheme and saving water from more efficient operation procedures.

Hajilal *et al.* (1995) studied dynamic programming model to fourteen seasons for optimal reservoir operations for irrigation management and applied this to Paithan reservoir of Jaikawadi irrigation Project (Maharashtra). The problem of real-time reservoir operation for optimizing the crop yield in the command area is considered to occur at two distinct stages, i.e. the planning stage and the real-time management stage. It was concluded that for irrigation management, the prediction of inflows close to actual ones in water shortage years is of utmost importance as real-time release policies can only then be framed accurately for optimal use of the limited water. In high flow seasons there is not much control over the inflows as most of the inflows will be lost in the form of spills.

2.3 Type of data:

To investigate properties of hydrologic variables relating to distribution of water quantity and water quality data in time and space are available. The first type is the historic or chronological data or observation of process in time. Short historical records are extended with the techniques of hydrologic synthesis and operational hydrology. The new synthetic sequences either preserve the statistical characters of historical records or follow a prescribed probability distribution or both.

Young (1966) applied implicit stochastic approach for the determination of an optimal annual operation rule for one reservoir. The elements of the approach were streamflow synthesis, deterministic optimization and regression analysis. Streamflow synthesis was used to provide several equally probable sequences of streamflows, which would occur in future. Deterministic optimization was used to map these data on possible future streamflows into data on future storage levels and release schedules.

Mejia *et al.* (1974) analysed a system that serves recreation and flow augmentation purposes. Values of recreational utility were computed at each lake for all summer months of the period of simulation and summed over all years. The monthly disutilities of not meeting a specified target flow were determined on the basis of a loss function and were again added up over the period of simulation. The operation rules ranged from so called conventional policy that uses flow forecasting and mathematical programming for optimization. Historical data were used to simulate the operation of the system under different rules and an assessment of policies was made on the basis of multiobjective criteria.

Yeh (1985) reviewed the state of the art of mathematical models developed for reservoir operations including simulation models. A general overview was presented and historical development of each key model was critically reviewed.

Vedula *et al.* (1986) studied the operation of Bhadra reservoir system using optimization (over a year and within a year storage model) and simulation (with both historic and generated monthly streamflows) based on a 52 year record of monthly inflow data for irrigation and hydropower generation. The simulation runs were carried out for a special irrigation channel with historic data. A comparison of the performance with the identified policies with actual performance made over a period of 11 years showed that a significant increase in hydropower production has been possible thus far without sacrificing the irrigation component.

A primary role of systems analysis is to provide an improved basis for decision making. Simonovic (1992) concluded that a gap exits between research studies and the application of systems approach in practice. He presented two examples to bridge the gap. A simple simulation optimization model for reservoir sizing has been presented as an example of how the systems approach may respond to the practical needs of water resource engineers. Such an approach easily incorporates storage dependent losses, as it too relies on the continuity equation. It also includes a reliability and accepts historical or synthetic streamflows.

Materials & Methods

MATERIALS AND METHODS

Kerala, is a tropical humid region which lies between 18^0 18' and 12^0 48' north latitude and 74^0 52' and 77^0 22' east longitude along the coast of southwestern part of the Indian subcontinent. Its georaphical area is 38863 sq km and physiographically it is divided into low land, mid land and high land. Even though blessed with 3m of rainfall, 44 rivers, chains of backwater bodies, plenty of reservoirs, tanks, ponds etc., during summer, water level goes down to the silted bottoms in many areas. Deforestation and increasing population along with undulating topography contribute to dry riverbeds and increasing dry wells in the state. Compared to the national average, unit land of Kerala receives 2.5 times more rainfall but the same unit of land has to support 3.6 times more population. Hence for self sufficiency unit land of Kerala has to produce 3.6 times more food and biomass, also the same unit of land has to produce more drinking water and has to meet associated water requirements compared to the national average.

The clue to solve the water crisis in the midst of plentiful rainfall is to arrest and conserve as much rainwater as possible. For this the state should have both short and long term specific water management strategies. The process of planning and management of water resources has become exceedingly complex, particularly since several competing and sometimes conflicting demands of various uses are to be met.

Out of the thirty reservoirs in the state only four reservoirs have drinking water component whereas the others are used for irrigation and hydel power generation. Perhaps, the cheapest, best and the only long term solution to meet most of the domestic and industrial water needs in future is to draw water from all existing and future reservoirs. According to the National Water Policy, next to drinking water the priority is for irrigation. Of the total geographical area only 57% is under cultivation, out of which only 0.3Mha has been brought under irrigation. Therefore there is a great need to evolve integrated basin plans for the rivers of the state considering physiographic, agroclimatic and hydrologic features. A river basin or a watershed is a natural integrator of all hydrologic processes within its boundaries.

The Karuvannur watershed lies between 10^0 15' to 10^0 40' north latitudes and 76^0 00' to 76^0 35'east longitudes. It is located in Thrissur and western boundary of Palakkad districts of Kerala. The Karuvannur river which has a length of 48 km originates from the Western Ghats and is fed by its two main tributaries namely the Manali and Kurumali. The Manali river originates from Vanyampara Hills, in the outskirts of Thrissur and Palakkad districts at an elevation of +928m. The river basin has an area of 1054 sq km.

Peechi irrigation project which is built across Manali river has been in operation for nearly forty years and is selected for the present study. Peechi dam was conceived and conceptualised in the forties and the early fifties. It came into existence in the year 1957. The dam was intended to irrigate 4586 ha of new conversion lands, 1619 ha of single crop land converted to double crop land, 4048 ha of existing double crop lands and 8095 ha of kole lands. In addition to these irrigation needs, the dam materialised as the sole source of drinking water to almost the entire Thrissur Corporation.

Looking back we see that a lot of water has flown under bridge and the needs have increased many folds. Therefore it becomes imperative to preserve every drop of water and the system demands scientific planning and distribution of water. The planning of a large project presents a complex management task calling for a high degree of co-ordination and control. Simulation is an experimental problem solving technique by making observations of the performance over time of a dynamic model of the system. The objective of simulation studies are (i) system simulation in order to study the performance under hydrologic and other inputs and (ii) to study and abstract the performance using relevant performance indices.

In this chapter the methods adopted for the development of simulation model are dealt with. The model described has been formulated on the historic streamflow data of Peechi reservoir taken as twelve monthly periods from June to May, as it is considered as the water year. A detailed description of the study region is presented in the following few sections.

3.1 Location

The dam site chosen at Peechi is about 20 km east of Thrissur town and 8km away from the National Highway 47 at Pattikkad. The reservoir has a water spread area of 12.95 sq. km. and water distribution system of two main canals, one on the right bank and other on the left bank. The location map of the study area, the Karuvannur river basin, is shown in Fig.1. The vicinity map of Peechi dam located across the Manali river, one of the major tributaries of Karuvannur river is shown in Fig.2. It is situated at 10^0 26' North latitude and 76^0 24' East longitude.

3.2 Climate

3.2.1 Rainfall

The catchment area of the reservoir is fed by the two monsoons which is prominent in the state i.e. the southwest monsoon from June to August and the north east monsoon from September to December. The mean monthly distribution of rainfall of the region is shown in Fig.3. The average rainfall of the region is 2921 mm.

3.2.2 Temperature

The maximum temperature of the region is 27 ^{0}C and the minimum is 23.8^{0}C. The monthly distribution of temperature is given in Fig.4.

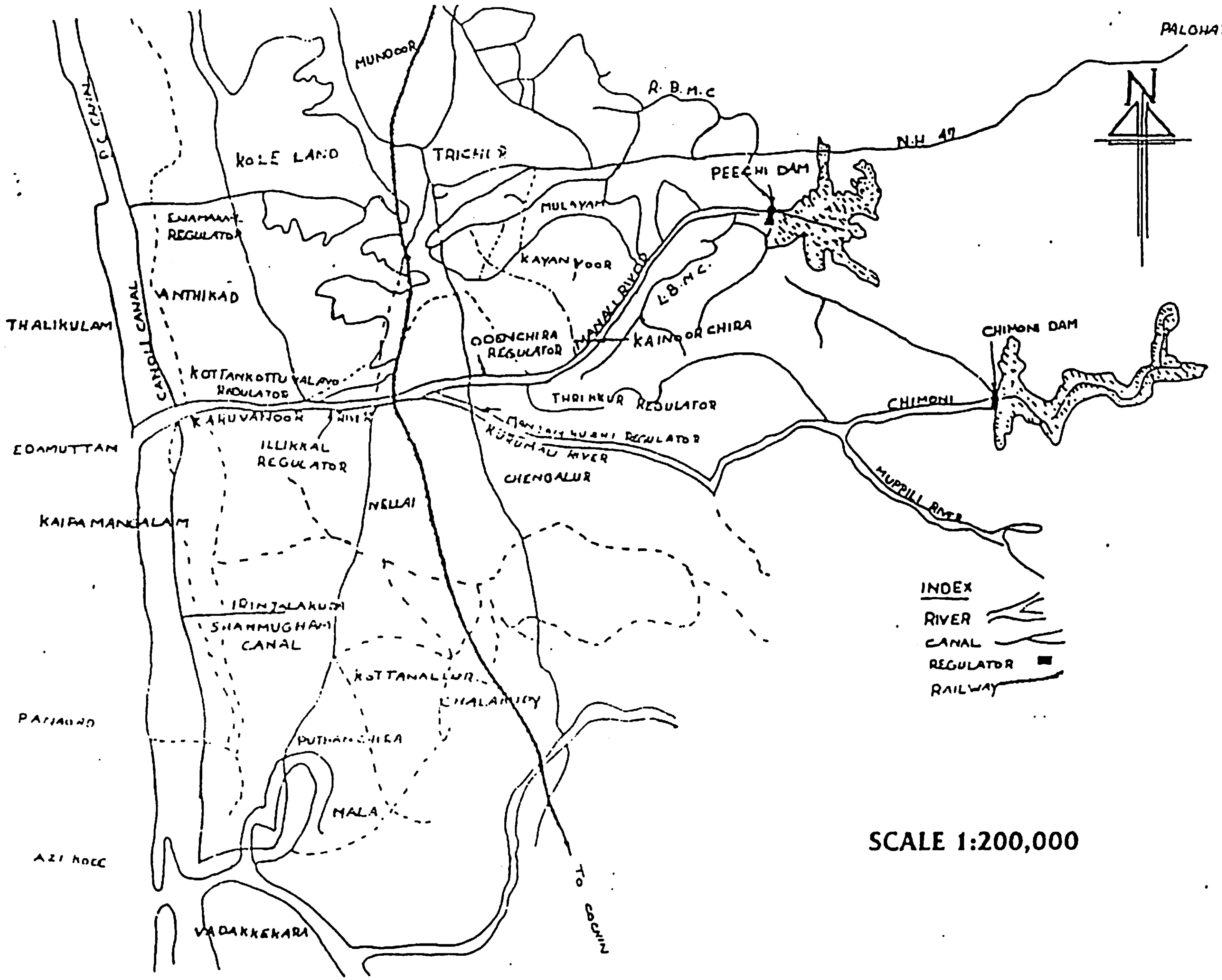


Fig.1 Location map of Karuvannur river basin

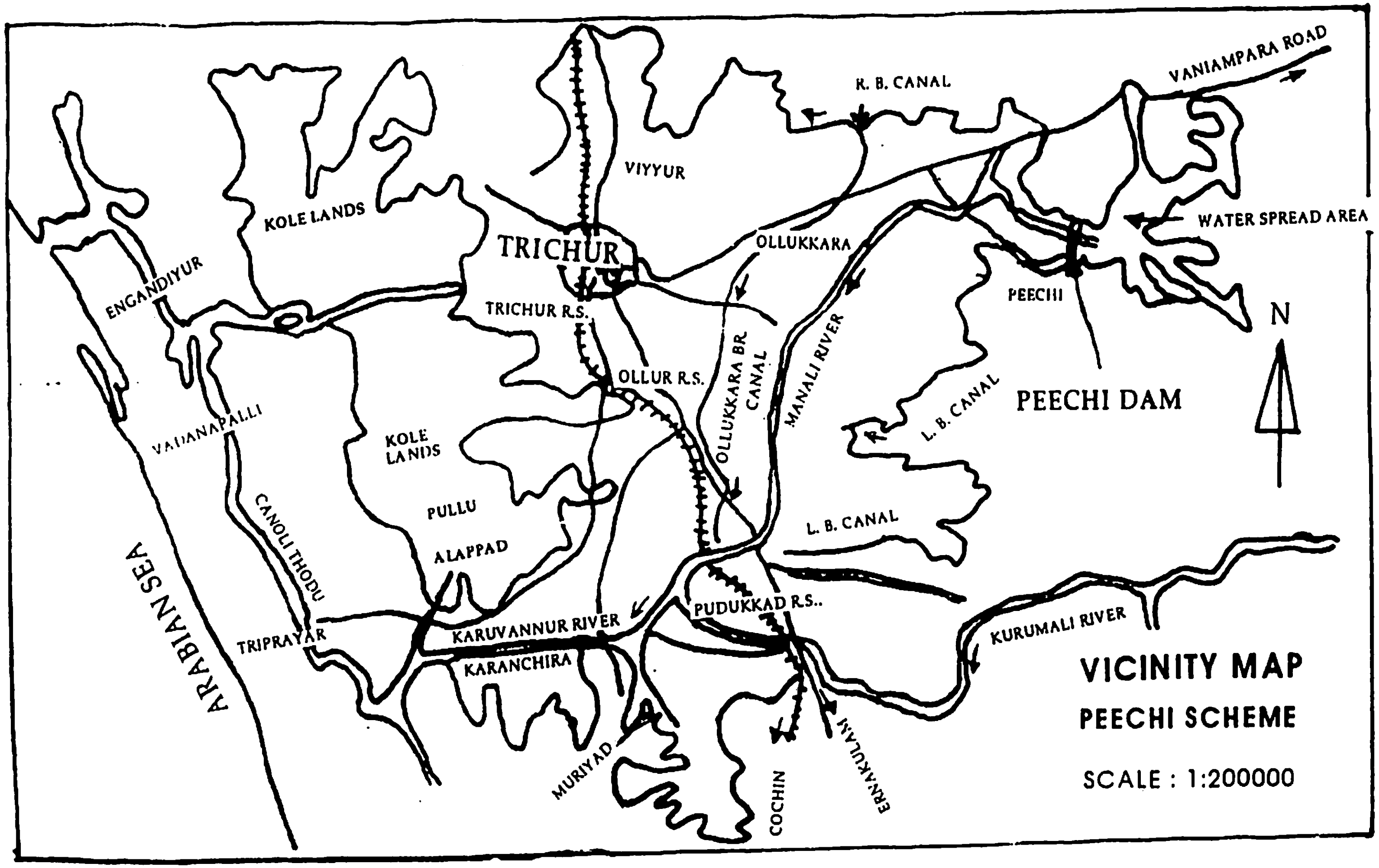


Fig.2 Vicinity map of Peechi dam

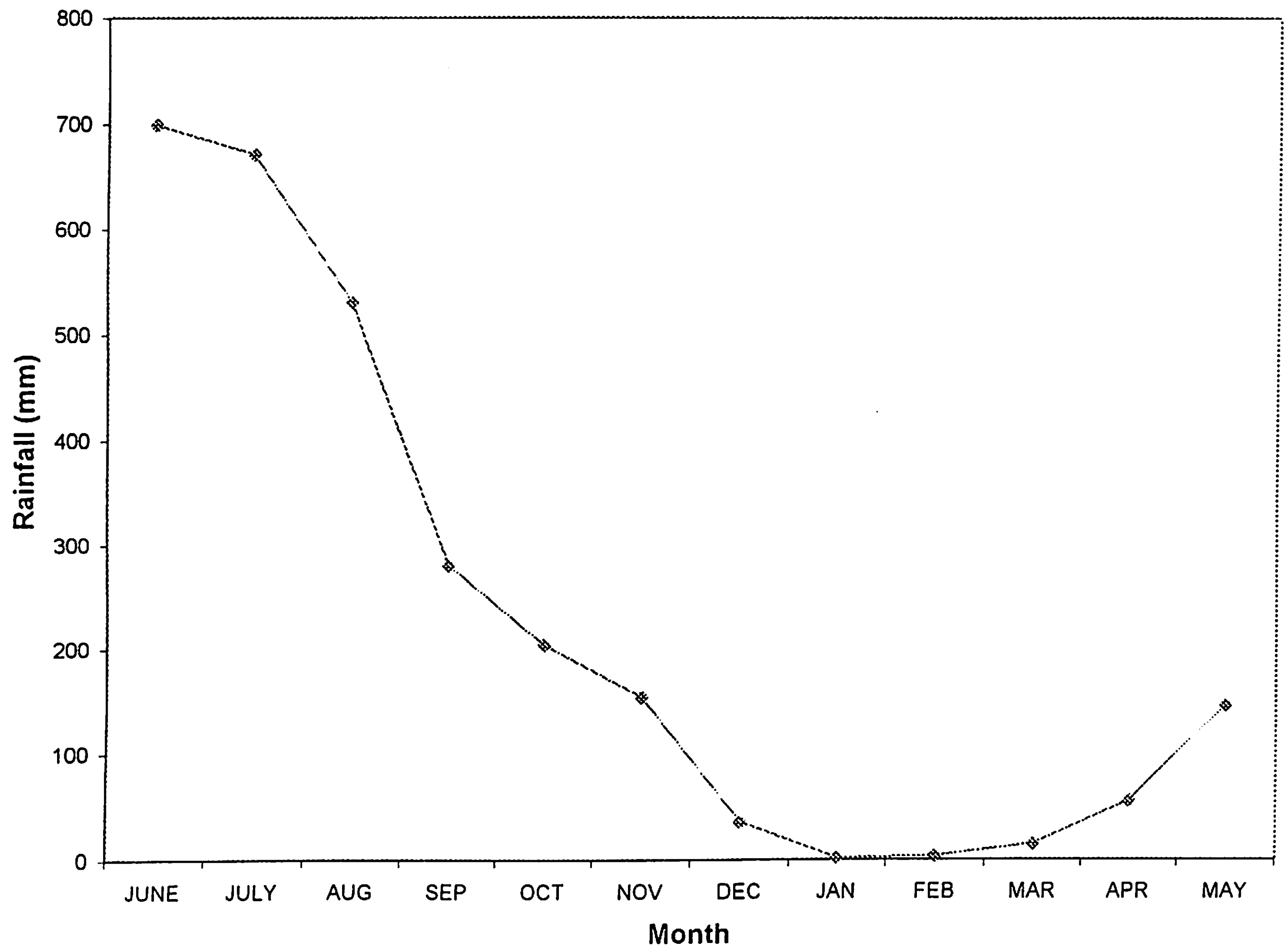


Fig.3 Mean monthly rainfall pattern

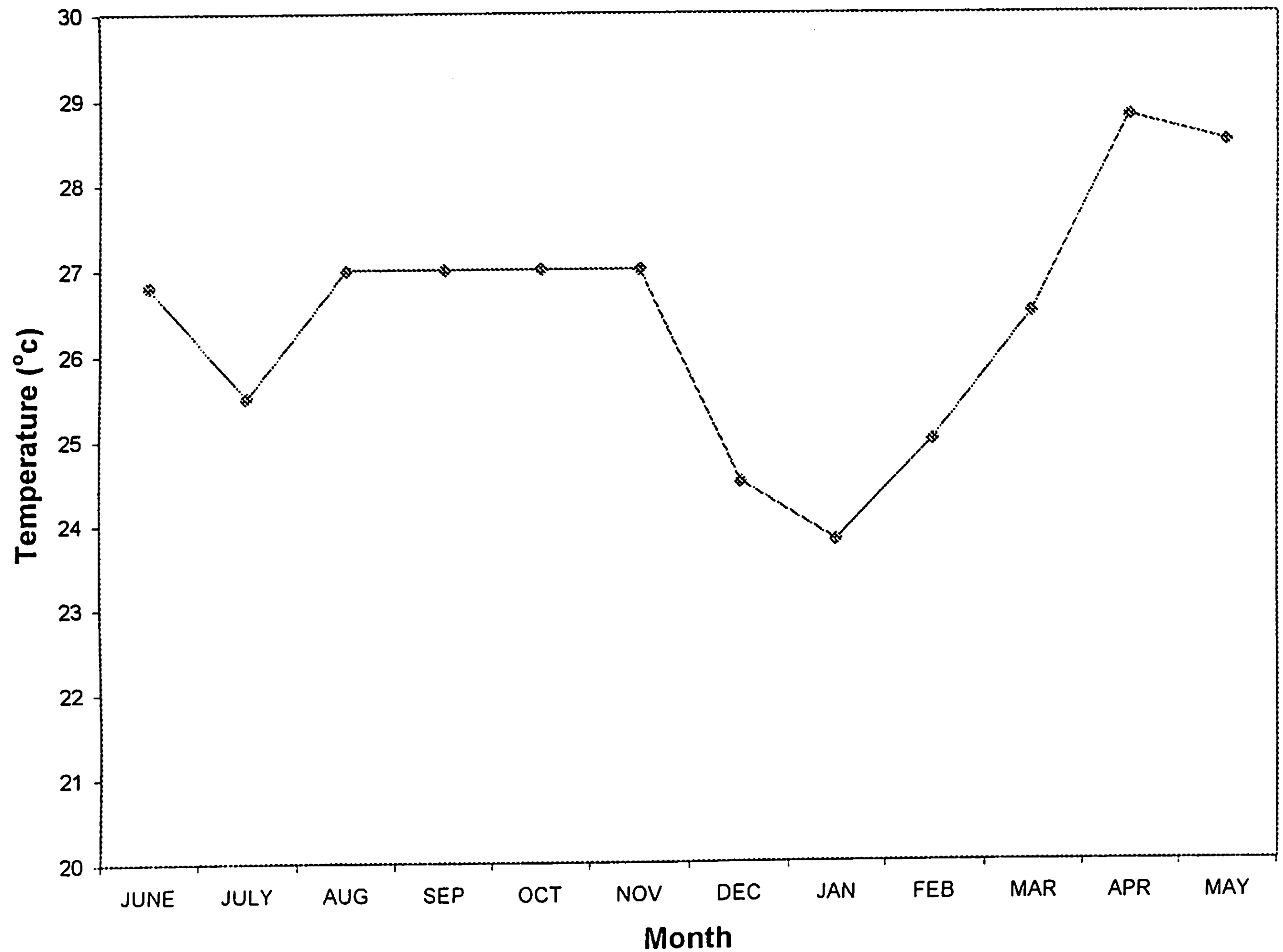


Fig.4 Mean monthly temperature

3.3 Topography

The command area has moderate slopes in upper reaches and flattens towards the bottom valley. Dominant slopes occurring in different physiographic regions are furnished in Table 1. The kole lands, which are a part of the command area, lie between 60 cm to 120 cm below sea level.

3.4 Geology

Based on the geological formations the area is divided into three regions.

3.4.2 Upper region

The major rock type in the upper region of the watershed consists of quartz-feldspar hypersthene granulite, pyroxene granulite and magnetite quartztite of charnockite group, pink granite gneiss and gabbro.

3.4.3 Middle region

Garnetibiotite gneiss of migmatite complex and laterite forms the major rock type of the middle region.

3.4.4 Lower region

The lower region is made of laterite and coastal sand and alluvium.

3.5 Soils

The main type of soils found in the location are as follows.

3.5.1 The lateritic soil

In Thrissur district the predominant soil is lateritic. It covers almost the entire midland areas of the district. These soils in general are well drained, low in all essential plant nutrients and organic matter. They exhibit very low cation exchange capacity and are generally acidic with a pH value ranging from 5 to 6.2.

Table.1 Dominant slopes in different physiographic regions

Upper region	Middle region	Lower region
Gently sloping (3-5%) To Steeply sloping (15-30%))	Nearly level (0-1 %) To Moderately steeply sloping (10-15 %)	Nearly level (0-1 %) To Gently sloping (3-5%)

3.5.2 Brown Hydromorphic Soils

It is the second prominent soil group found in the district. These soils are confined to the valleys between the midlands and in the low lying areas of the coastal strip in the district. They have been formed as a result of transportation and sedimentation of materials from adjoining hill slopes and also through deposition by rivers. In majority of the area the water table is high and there is low drainage conditions. Hence these soils exhibit characteristic features like grey layers, presence of mottlings, streaks, organic matter deposition, iron manganese conditions etc. These soils are very deep and brownish in colour. The surface texture varies from sandy loam to clay. Their pH value ranges between 5.2 and 6.4 and are acidic in nature.

3.5.3 Riverine Alluvium

They are moderately well drained soils which are distributed mainly on the banks of rivers, their tributaries and kole lands. They are light to medium textured with good physical properties and contain organic matter, nitrogen and potash moderately. The soils of kole area are mainly the product of weathering of river alluvial deposits and colluvium. The deposits mainly have clayey texture. In higher locations the deposits are mostly of coarser texture.

3.6 Water Resources

3.6.1 Surface water resources

The quantity of water received from Manali river is sufficient to fill this reservoir to full capacity during the period of south - west monsoon. Water is supplied for irrigation for the first crop during the period of August to September on demand and continuously for second crop from September to December in turn system. Water is delivered to the branch canals and then to the field through field channels.

3.6.2 Ground water resources

Investigations about the exploration and utilization of ground water resources of this area are still being done.

3.7 Land use / Land cover

3.7.1 Upper region

Nearly 95 % of the upper region is covered by forest, of which about 70 % is occupied by deciduous forests, 15 % by evergreen/ semi green forest and 10 % by forest plantation.

3.7.2 Middle region

About 96 % of the area is covered with agricultural land which is mainly under mixed agricultural / horticultural plantations. Deciduous forests cover rest of the area.

3.7.3 Lower region

The lower region consists of agricultural lands, which is predominantly under mixed agricultural/ horticultural plantations inter spread with narrow valleys where paddy is grown.

3.8 Cropping Pattern

In the command area of the project paddy is the main crop, but crops like coconut, arecanut, tapioca, banana, pulses, vegetables etc. are also cultivated extensively. Two crops of paddy are grown and generally as the kole area lies below M.S.L, it will be water logged and hence no crops are raised during rainy months. The Ayacut map of the project is given in Fig.5. The existing cropping pattern of the basin is shown in Table 2.

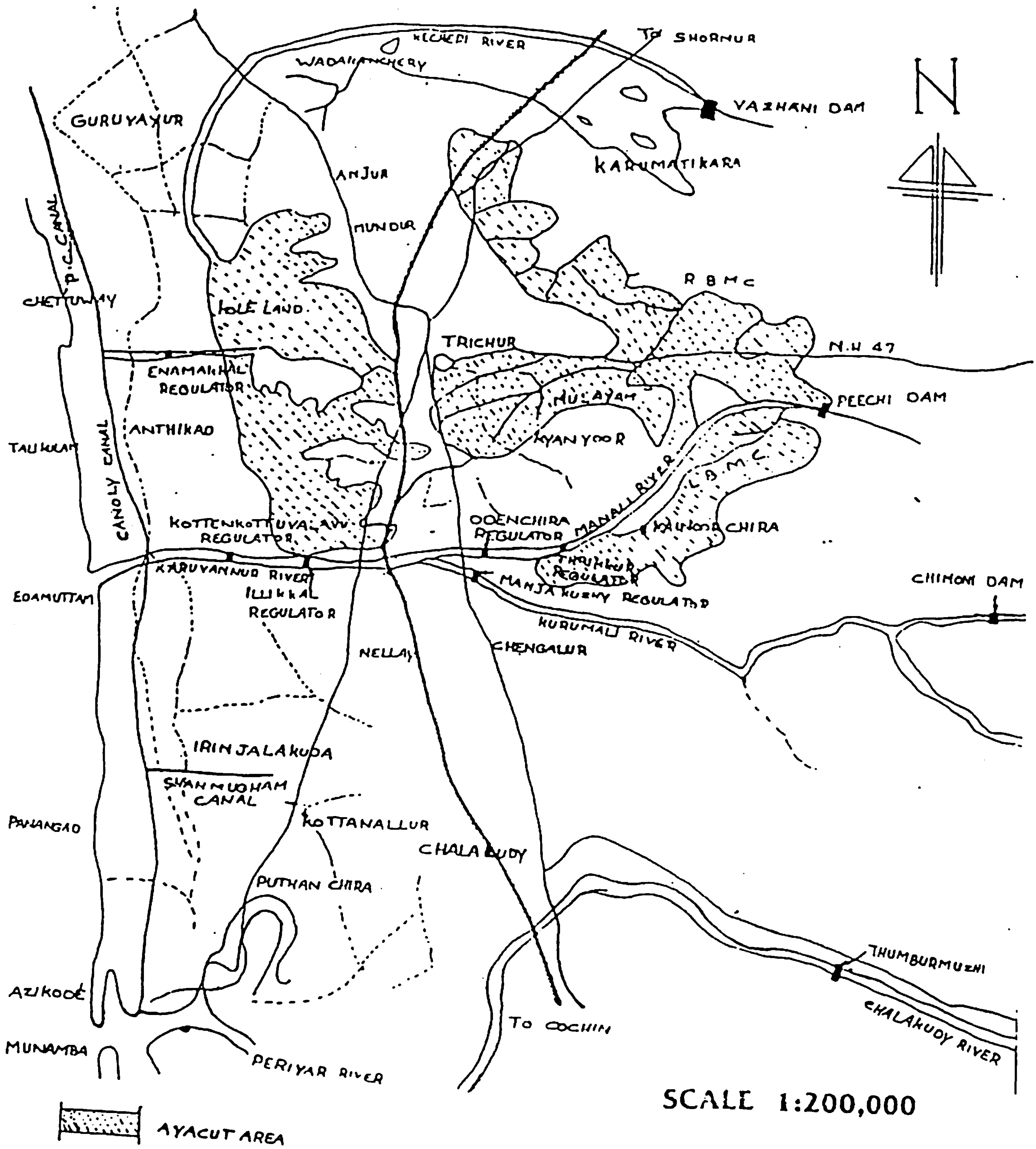


Fig. 5 The Ayacut map of Peechi project

Table: 2 Existing Cropping Pattern of the basin:

Crop	Cultivated Area (Ha)
Paddy	16344
Coconut	1675
Pulse	432
Arecnut	123
Banana	121
Vegetable	64
Total	18,459

3.9 Salient features of the project

The salient features of the Peechi project are furnished in Table 3.

3.10 Meteorological and hydrologic observations

3.10.1 Rainfall

The main source of water in the site is rainfall. The rainfall data for 35 years from 1964 to 1999 was collected from Hydraulics-II Division of Kerala Engineering Research Institute, Peechi. These observations were from a recording type rain gauge. These datas are furnished in Appendix -I

3.10.2 Evaporation

Evaporation measurements from the US Weather Bureau Class A pan was also collected from Hydraulics-II Division of Kerala Engineering Research Institute, Peechi. The datas are presented in Appendix –II and the mean monthly evaporation is plotted in Fig.6.

3.10.3 Stream flow

The stream flow data for the years, 1964 to 1999 was collected from Head Work Division, Kerala Engineering Research Institute, Peechi and from the office of the Executive Engineer, Major Irrigation Division, Chembukavu, Thrissur. The datas collected are shown in Appendix-III. The mean monthly inflow data is plotted and shown in Fig.7.

3.10.4 Water demands and supply

The information about water demand for various requirements in the project command area were collected. Data of drinking water demand and supply were collected from Public Water Works, Thrissur and Head Works Division, Kerala Engineering Research Institute, Peechi respectively. Information on water supplied for irrigation and crop water requirement along with crop area in ha was collected from the Head Works Division of Kerala Engineering Research Institute, Peechi.

Table.3 Salient features of the project

The Dam			
Length of the dam	213.36m (700ft)		
Bed level of dam site	39.62m (130ft)		
Crest level at spillway	76.20m (250ft)		
Top of the dam	80.47m (264ft)		
Top width of the dam	4.27m (14ft)		
Full reservoir level	79.25m (260ft)		
Maximum water level	79.25m (260ft)		
Size of the spillway gates	4 No.s. 10.06m x 3.05m (33ft x 10ft)		
Type of spillway	Ogee overflow		
Type of dam	Straight gravity, Rubble masonry		
The Lake			
Drainage area	107 sq km (41.35 sq miles)		
Water spread area	12.95 sq km (5 sq miles)		
Average annual rainfall	292 cm (115 in)		
Annual runoff	209.5M cu m (7400M cft)		
Maximum storage	109.813M cu m (3878M cft)		
Maximum flood discharge	368.119 cu m / sec (13000 cft / sec)		
Irrigation Outlets			
	Sill level	Size of outlet	Discharge
Right Bank	+56.39m (+185ft)	1.22 m dia (4ft dia)	7.08 cu m / sec (250 cft/sec)
Left Bank	+67.06m (+220ft)	0.91 m dia (3ft dia)	3.54 cu m / sec (125 cft/sec)
Thrissur water supply	+53.34 m (+175ft)		

Contd. Table.3

Canal system		
	Right Bank canal	Left Bank canal
Total length of main canals	37 km (23 miles)	45.06 km (28 miles)
Bed width of main canals	3.66 m (12 t)	3.66 m to 2.74 m (12 ft to 9 ft)
Total length of branch canals	75.64 km (47 miles)	65.98 km (41 miles)

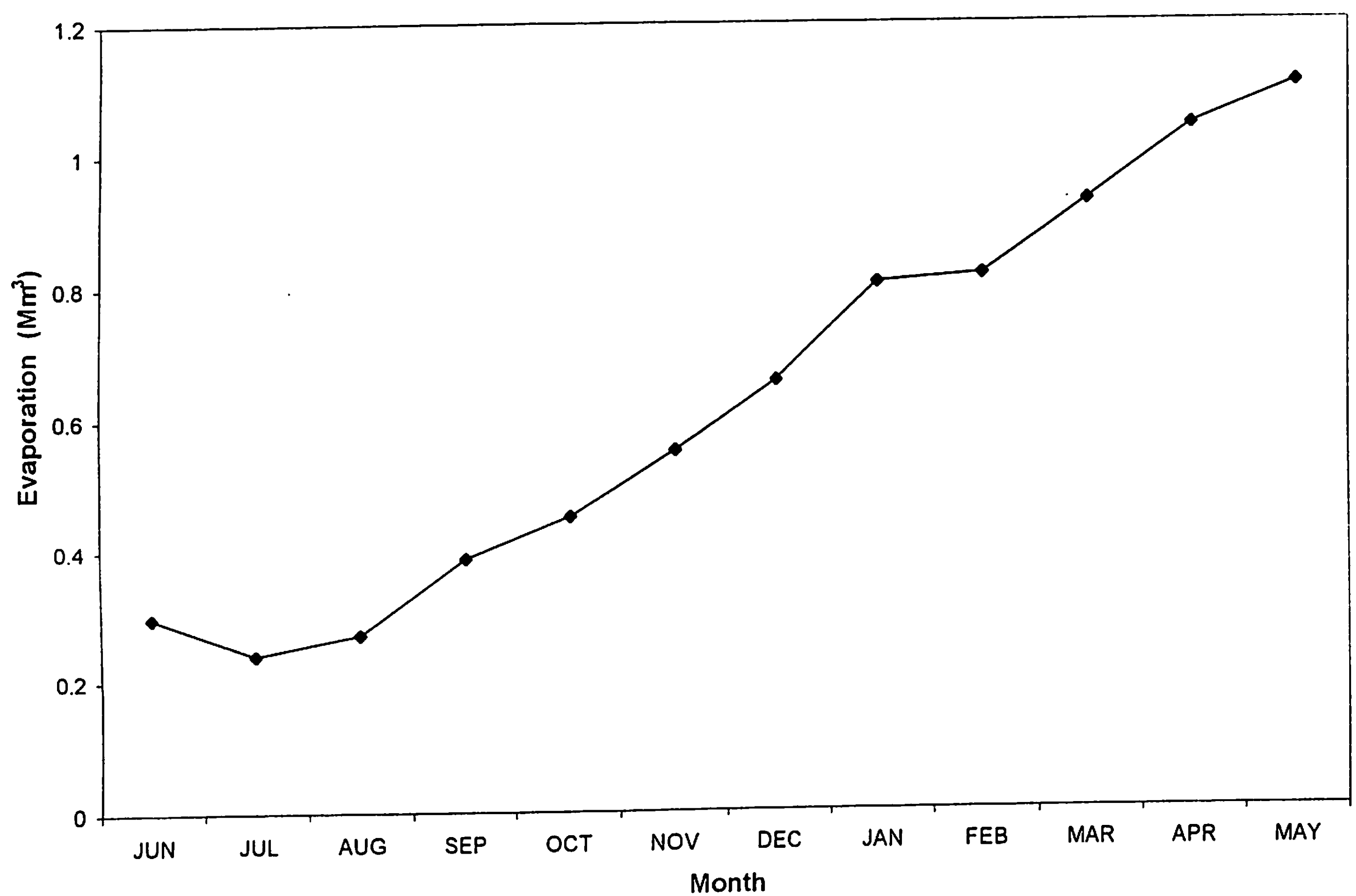


Fig.6 Mean monthly evaporation from the reservoir

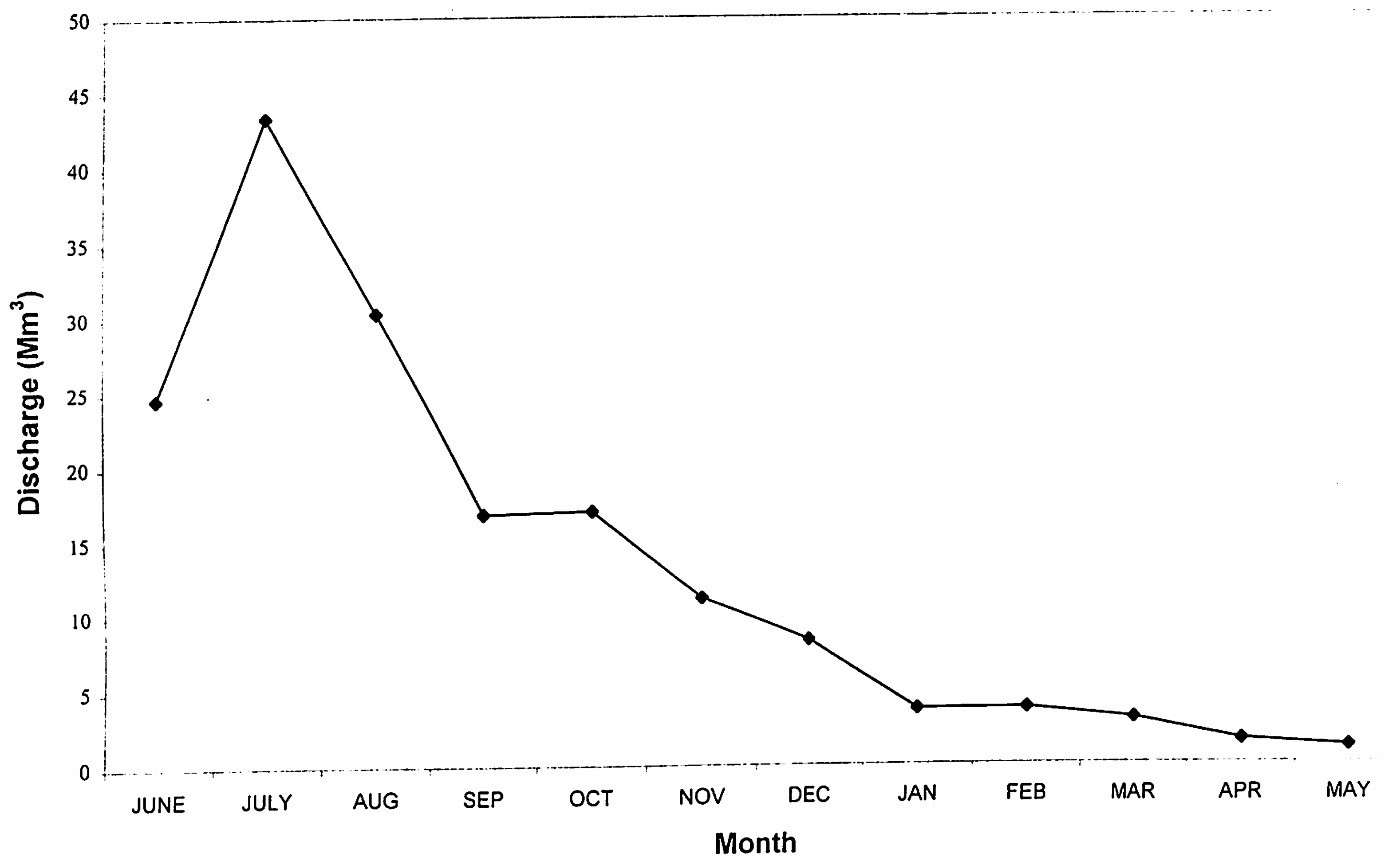


Fig.7 Mean monthly inflow to the reservoir

The crop water requirement of the basin is presented in Table 4. Water demand and supply for pisciculture and recreation demand was also collected from the Head Works Division of Kerala Engineering Research Institute, Peechi. The monthly water demands for different purposes are presented in Table 5. The actual release from the reservoir is shown in Appendix - IV

3.11 Simulation of the reservoir system

The reservoir operation simulation model is designed for monthly operation with historic mean monthly streamflows. By running the model with the monthly streamflow data various releases for different purposes are obtained. These set of recommended reservoir releases are computed by taking the historic streamflow data from 1964 to 1999.

Multi-objective demands:

The multi-objective demands of the reservoir system are

Drinking water demand of Thrissur township.

Irrigation demands of kole lands of Thrissur

Pisciculture demand at the reservoir site.

Recreation demands for parks at Peechi dam site.

A schematic representation of the system representing different objectives is shown in Fig.8. The monthly demand for each objective was collected from the concerned departments as cited in section 3.10.4. 70 % conveyance efficiency is considered for the system.

Table : 4 Crop water Requirement (Mm^3)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Paddy	0.63	21.28	21.94	16.21						1.77	4.03	9.46
Coconut	0.04	0.2	0.48	0.05								
Pulses	0.17	0.22	0.18	0.18	0.18							
Arecanut	0.01	0.2	0.02	0.02	0.02							
Banana	0.017	0.01	0.01	0.01	0.01					0.01	0.01	0.01
Vegetables	0.003	0.004	0.003	0.003	0.003							
Total	0.87	21.914	22.633	16.473	0.213	0	0	0	0	1.78	4.04	9.47

Table.5 Monthly water demands for different purposes in Mm^3

Month	Drinking	Irrigation	Pisciculture	Recreatio	Total
Jun	1.89	0	0.2	0.002	2.092
Jul	1.89	0	0.2	0.002	2.092
Aug	1.89	0	0.2	0.002	2.092
Sep	1.89	0	0.2	0.002	2.092
Oct	1.89	2.54	0.2	0.002	4.63
Nov	1.89	5.77	0.2	0.002	7.86
Dec	1.89	13.53	0.2	0.002	15.62
Jan	1.89	1.24	0.2	0.002	3.33
Feb	1.89	31.30	0.2	0.002	33.39
Mar	1.89	32.33	0.2	0.002	34.42
Apr	1.89	23.53	0.2	0.002	25.62
May	1.89	0.30	0.2	0.002	2.39
Total	22.68	110.54	2.4	0.024	
Grand total					135.64

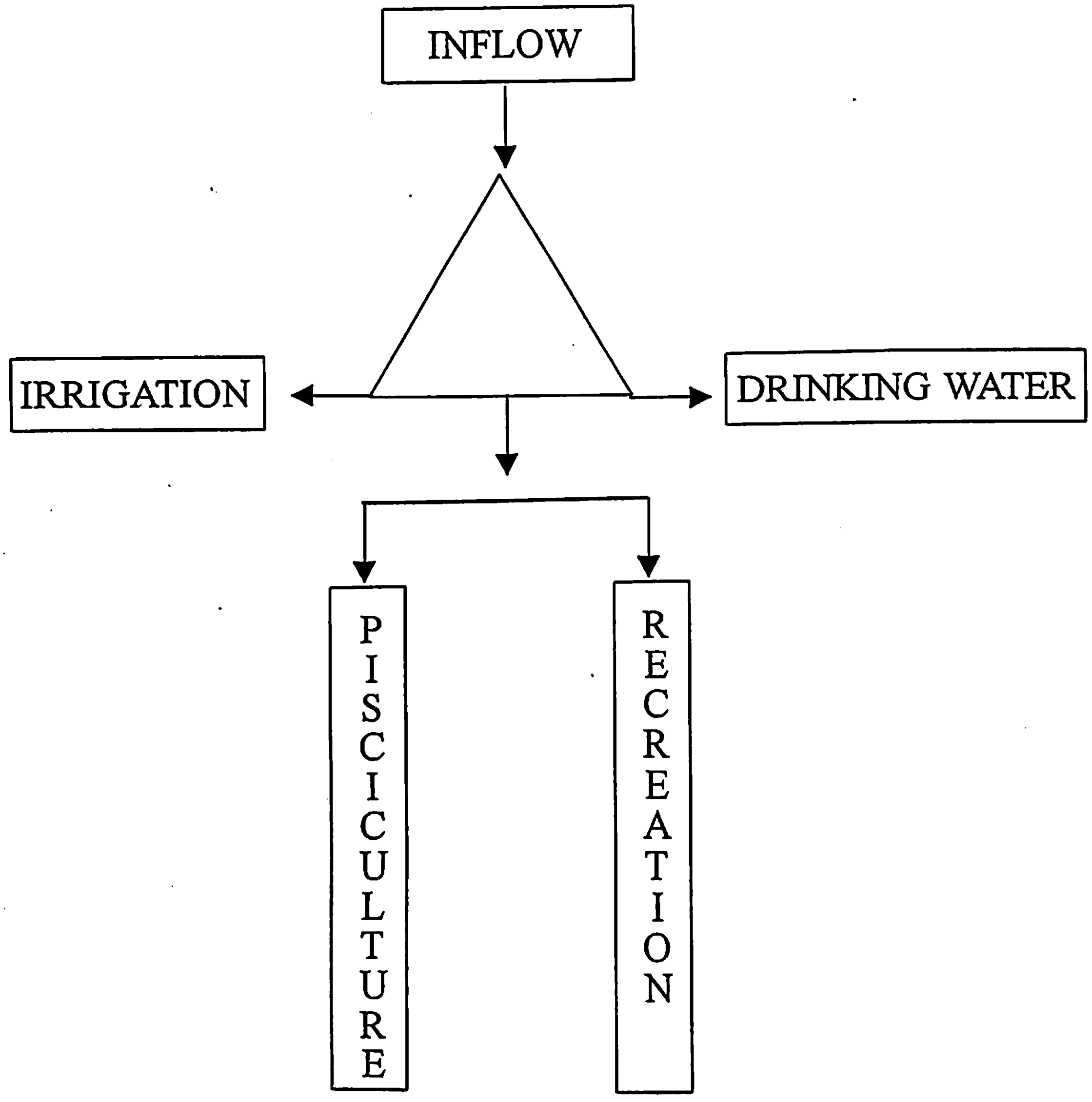


Fig. 8 Schematic representation of the reservoir system

3.12 Formulation

Reservoir rules

The reservoir rules assumed for formulation of the problem are as follows.

1. Drinking water release is made for each month depending upon the demand which can be assumed as a constant or as a variable.
2. 25 % of the drinking water demand is kept aside along with the dead storage and released if there is deficit in drinking water supply.
3. Irrigation releases are made for the current month according to the demand, storage and the inflow available.
4. Excess of water is released as spill if the water exceeds the specified capacity for the opening of the shutters.
5. During the month of May the storage is kept to the minimum level to receive the flood water.
6. Dead storage is the minimum storage required for pisciculture.
7. April- May is considered as the harvest season for fish and during rainy months the seeds are bred in the hatchery.

The problem has been formulated as a monthly operation model based on historic streamflows and the operating horizon has been taken as twelve monthly periods from June to May, which is considered as the water year. The water requirement for each purpose is taken as the target to be achieved by the model.

In each of the objectives the target is again sub - divided into 25 %, 50 %, 75 % and 100 % of the target and the slopes in each divisions are taken as their priority levels. The priority graph used in the program formulation is shown in Fig.9. Since there are releases for drinking, irrigation, pisciculture and recreation from the system in each month, a total of four targets and sixteen divisions of targets are seen in this manner. The objective of the model is to minimize the deviations of the releases from the targets for each demand. As the targets are different for each of the

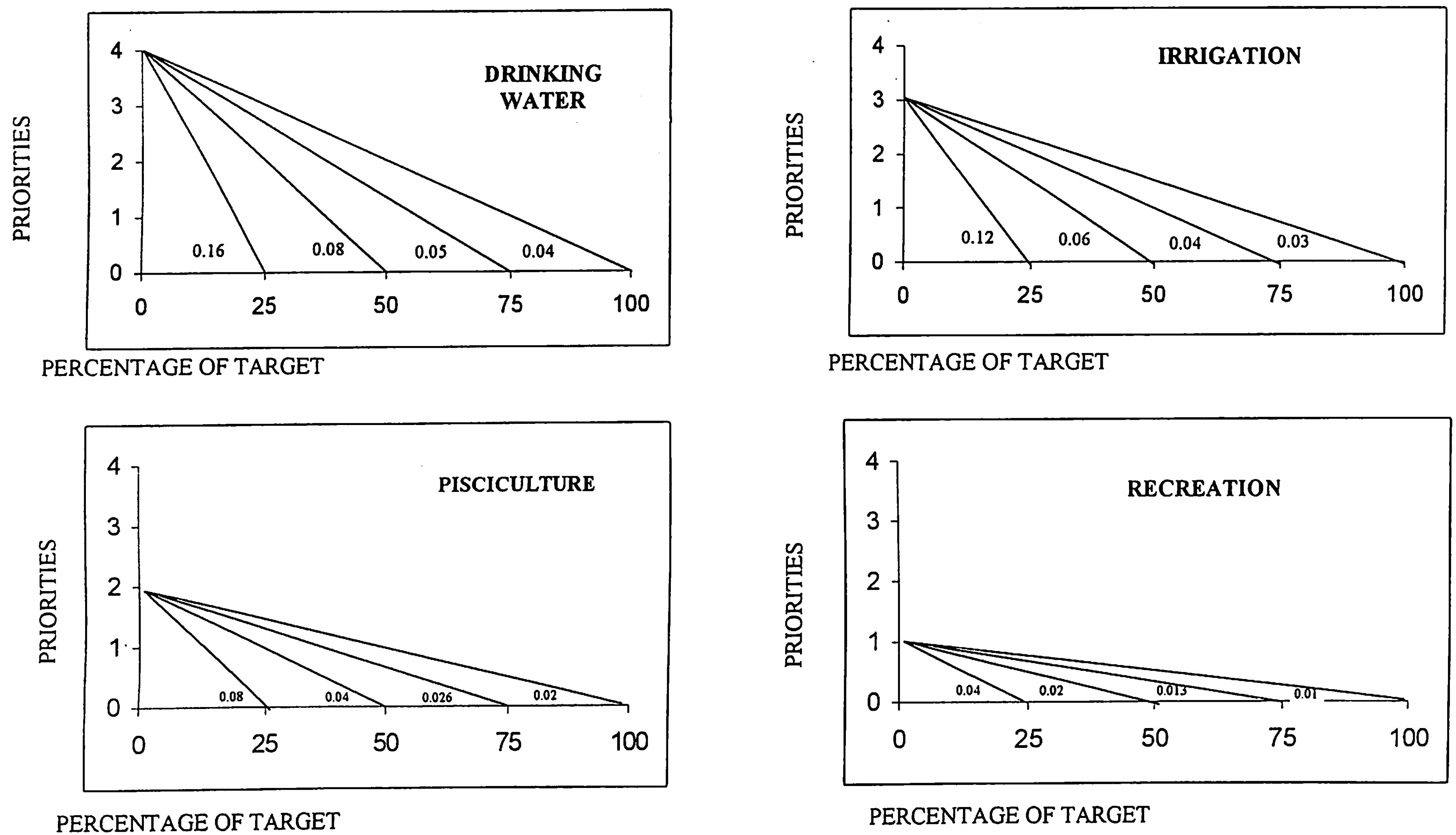


Fig. 9 Slope of different objectives showing the priorities

demand and in each month, the ratio of highest value of target to each of the remaining targets are taken. In other words, the greatest degree slope of the lines drawn to each levels of target i.e 25 %, 50 %, 75 % and 100 % from the priority points for each demand is considered first followed by the next greater degree of slope. To make the approach more clear, by referring to the priority graph, it is seen that the greatest value of slope of 0.160 is that of 25% of drinking water demand. Therefore the highest priority is assigned to 25% of drinking water demand followed by 25% of irrigation demand with next higher slope of 0.120 and so on till the sixteen divisions of the targets are completed. Therefore the priority level is assigned according to the decreasing degree of slopes. The flow diagram for algorithm of the model is shown in Fig. 10

The mathematical program has been formulated with all the known quantities on the right hand side of the continuity equation.

Continuity equation used in the formulation is

$$STORCM = IN + PM - EV - REL$$

STORCM	=	Storage in the reservoir for the current month
IN	=	Inflow to the reservoir for the current month
PM	=	Remaining storage of the previous month
EV	=	Evaporation from the reservoir for the current month
REL	=	Releases made from the reservoir for different objectives

3.13 Solution Algorithm

In the algorithm developed, the input values are inflow, evaporation and the demands for different water uses, keeping the dead storage and the capacity for opening the shutter as constants. The drinking, pisciculture and recreation demands for each month were kept constant where as the irrigation demand varied according to the crop water requirement of the particular month.

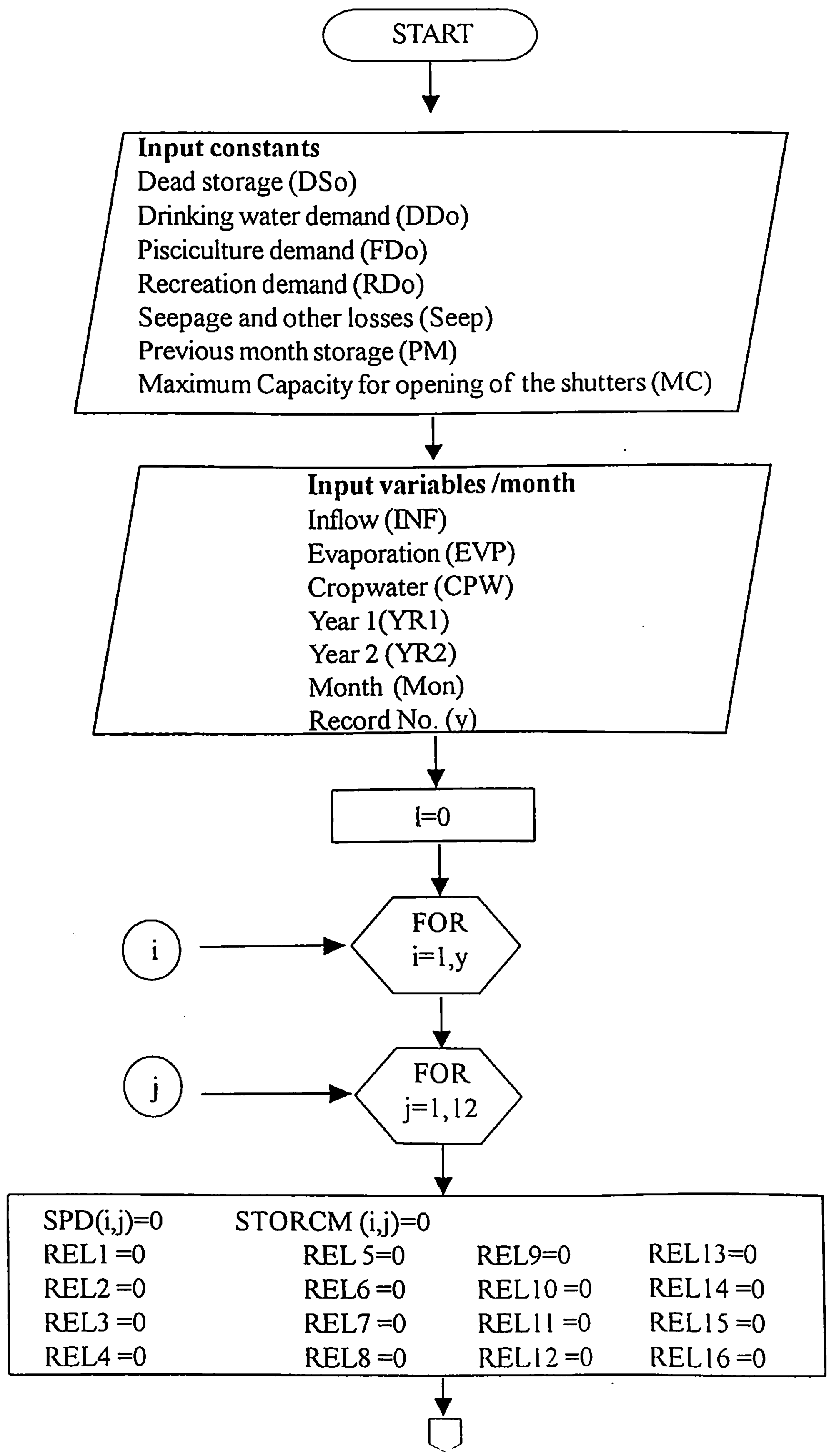
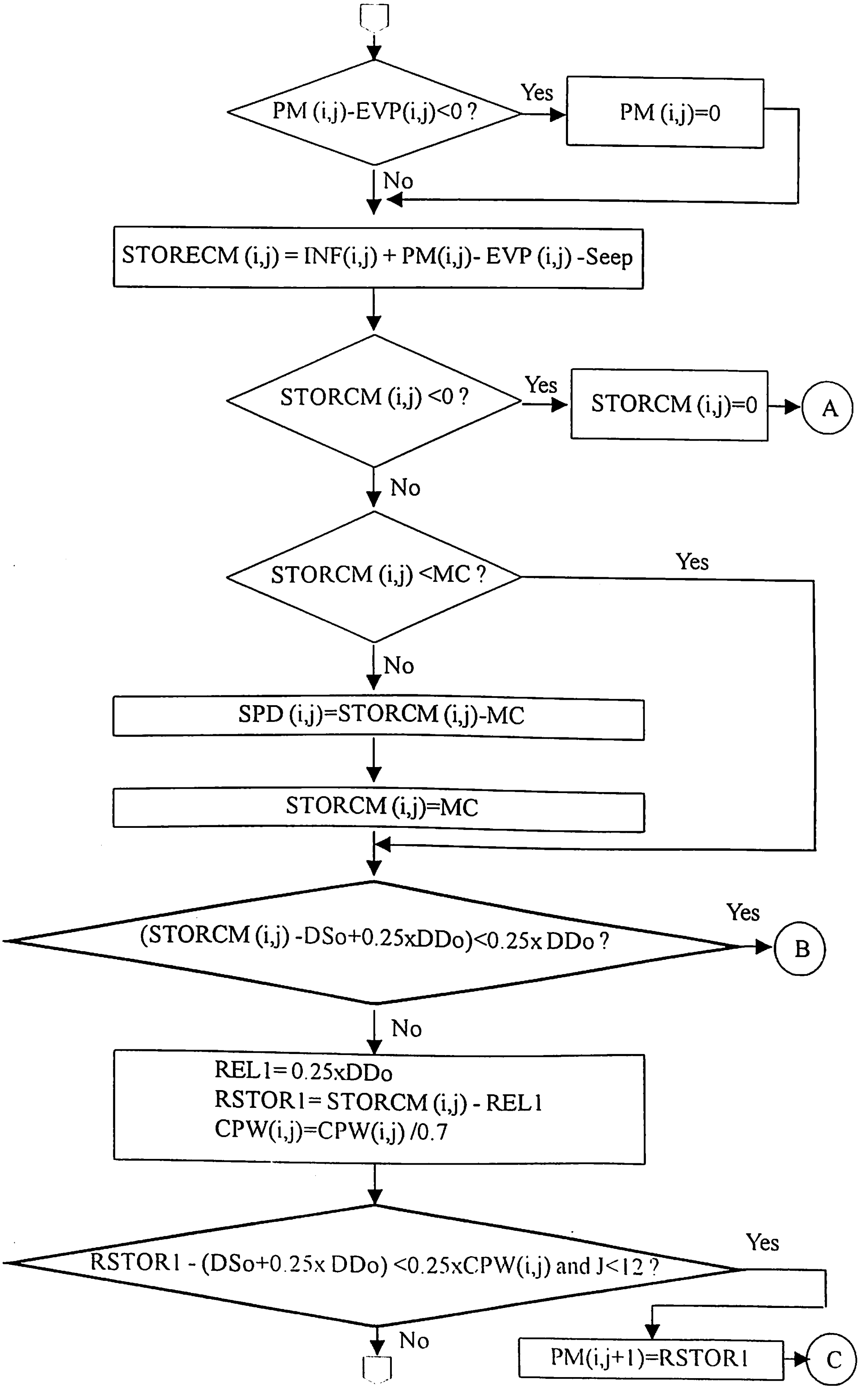
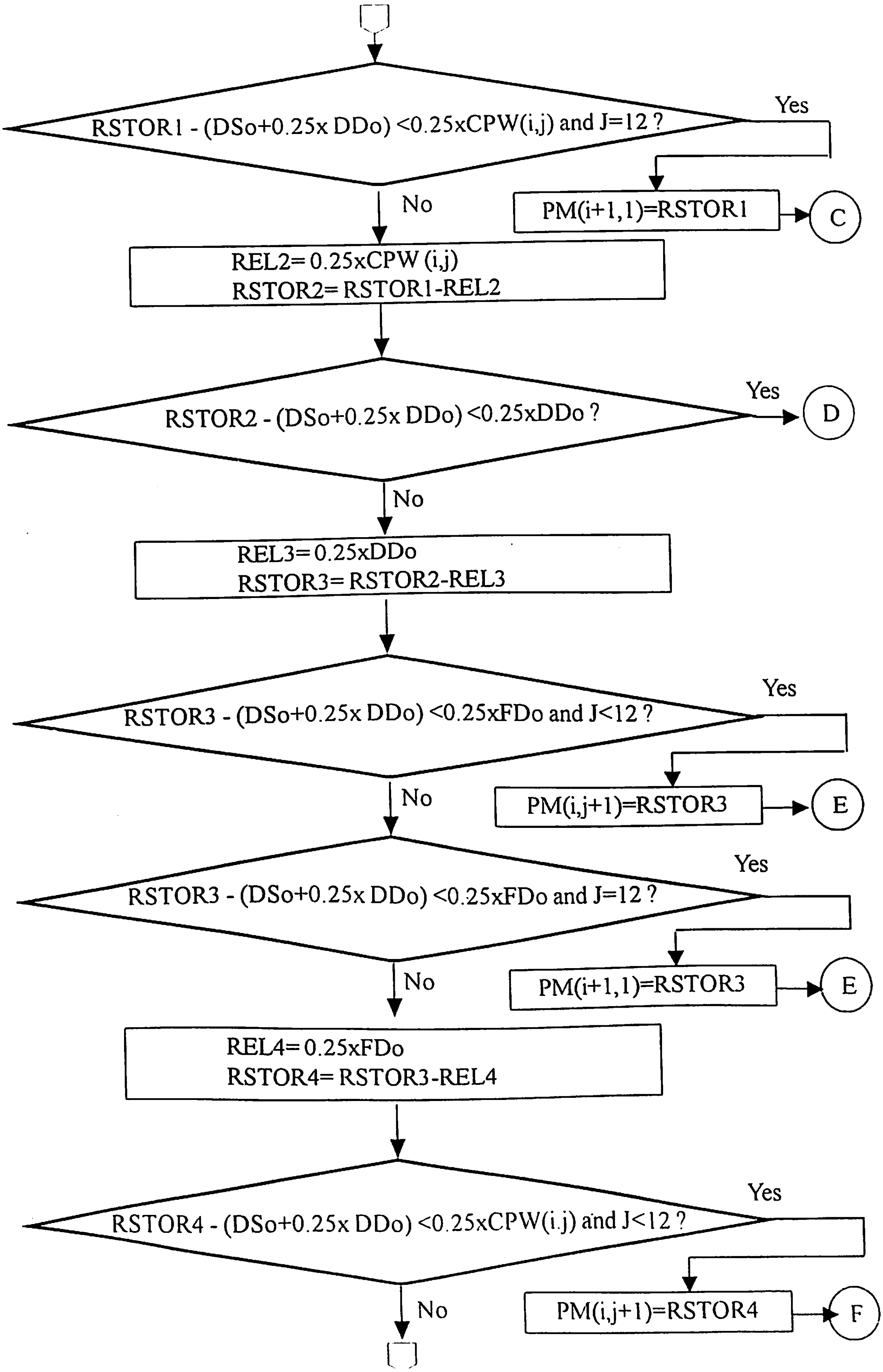


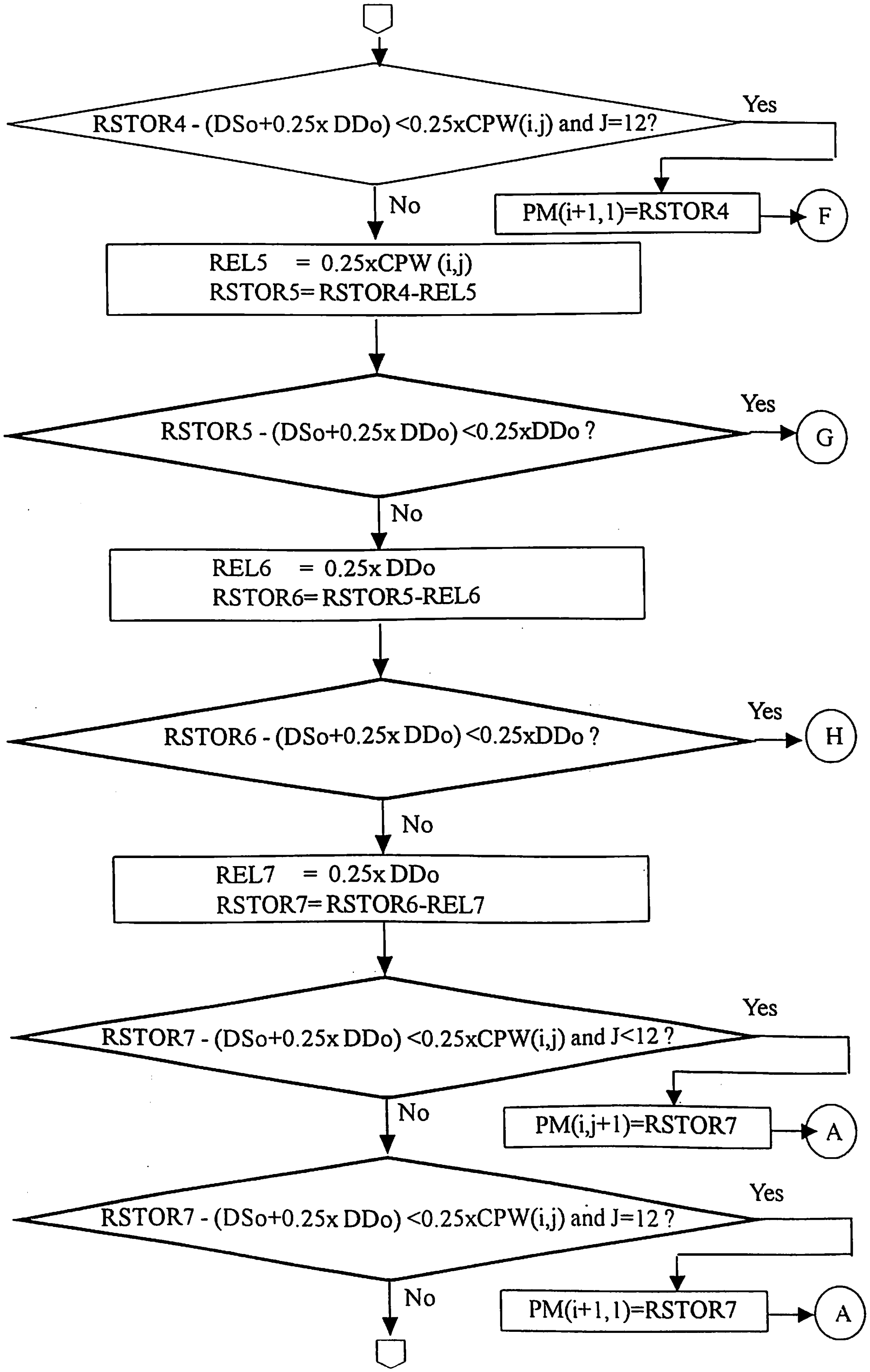
Fig. 10 Flow chart of the reservoir simulation model

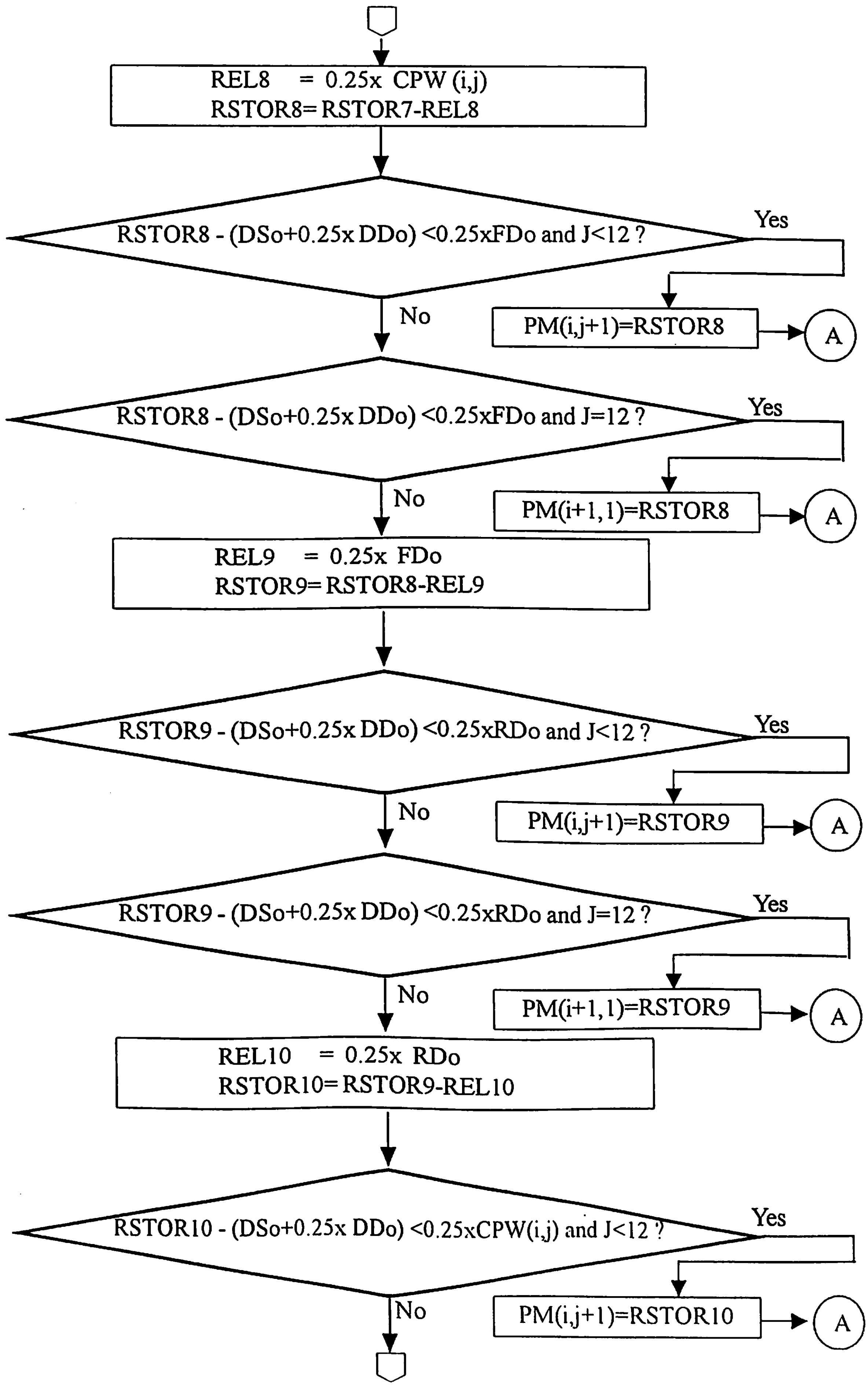


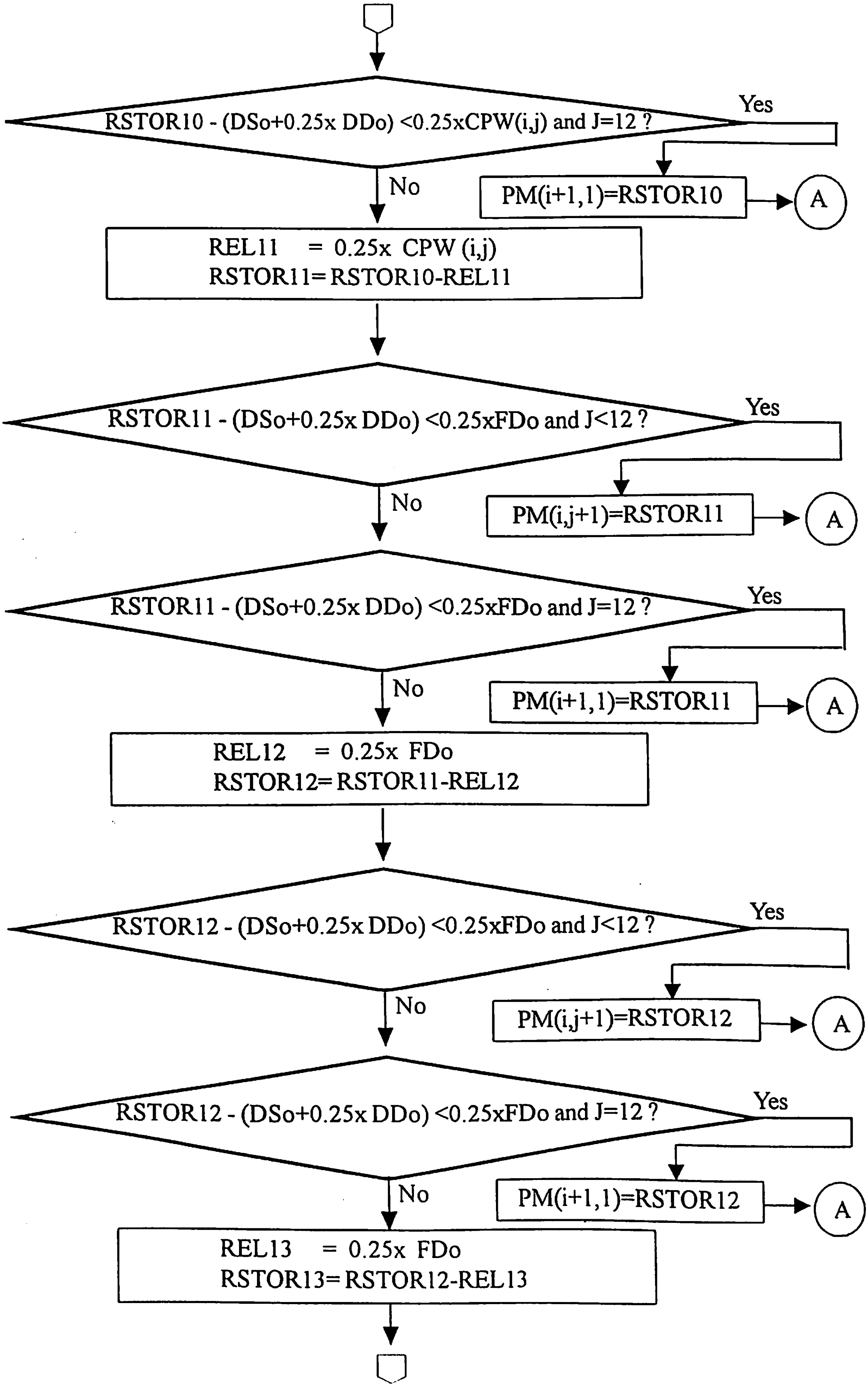
PM (i,j)-EVP(i,j)<0 ?
Yes
PM (i,j)=0
No
STORECM (i,j) = INF(i,j) + PM(i,j)- EVP (i,j) -Seep
STORCM (i,j) <0 ?
Yes
STORCM (i,j)=0
A
No
STORCM (i,j) <MC ?
Yes
No
SPD (i,j)=STORCM (i,j)-MC
STORCM (i,j)=MC
(STORCM (i,j) -DSo+0.25xDDo)<0.25x DDo ?
Yes
B
No
REL1=0.25xDDo
RSTOR1= STORCM (i,j) - REL1
CPW(i,j)=CPW(i,j) /0.7
RSTOR1 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J<12 ?
Yes
No
PM(i,j+1)=RSTOR1
C

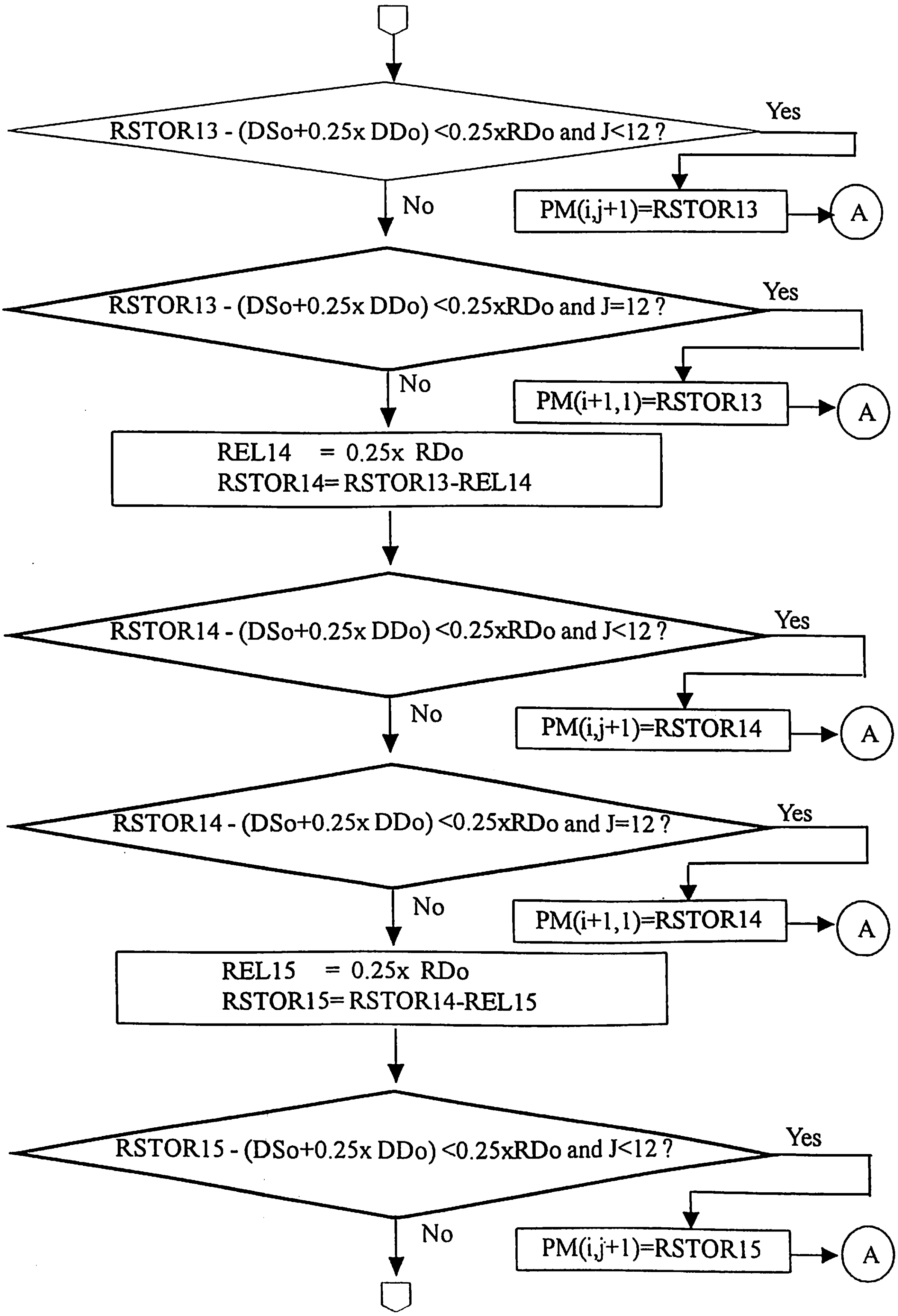


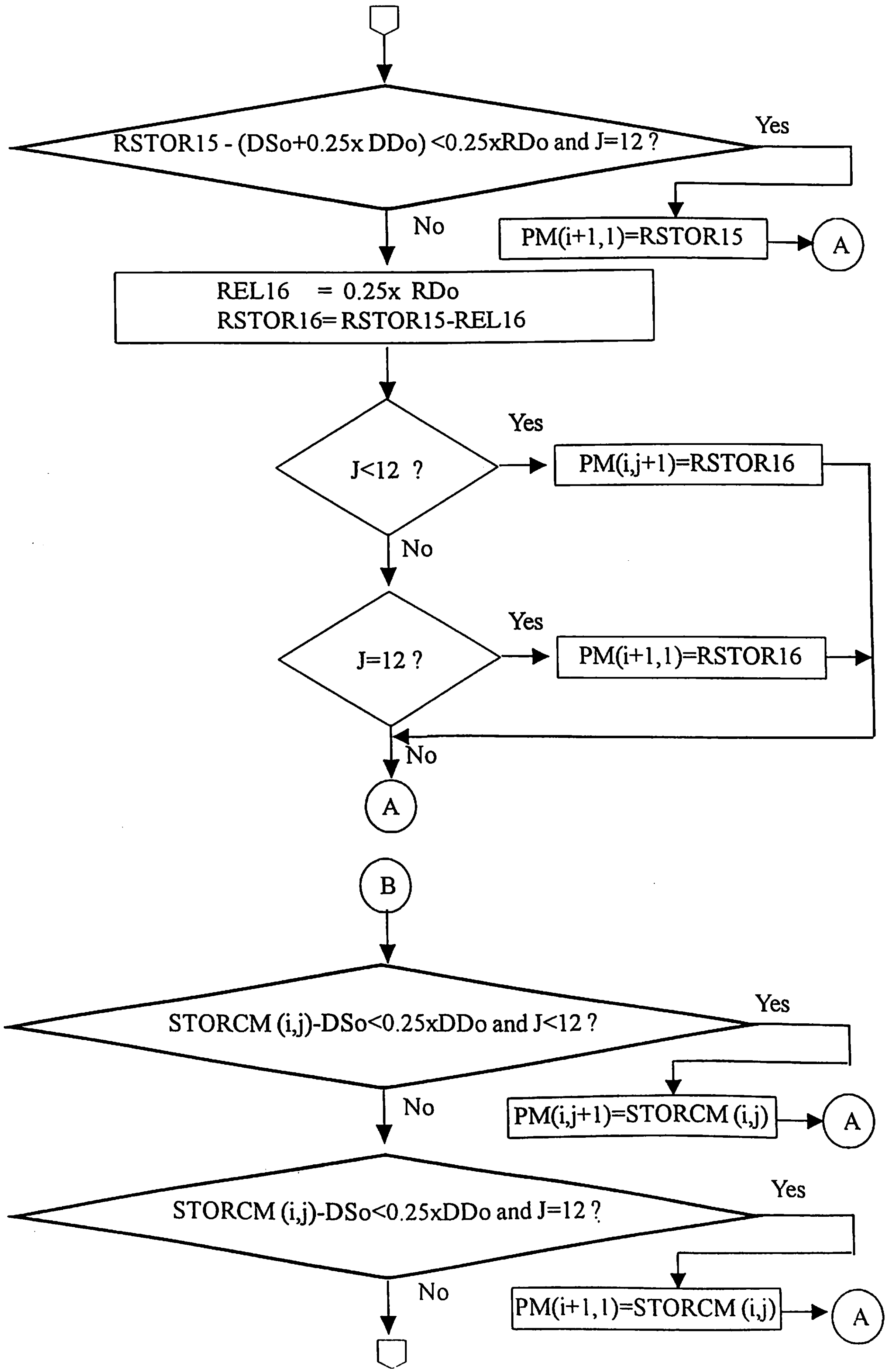
RSTOR1 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J=12 ?
Yes
No
PM(i+1,1)=RSTOR1
C
REL2= 0.25xCPW (i,j)
RSTOR2= RSTOR1-REL2
RSTOR2 - (DSo+0.25x DDo) <0.25xDDo ?
Yes
D
No
REL3= 0.25xDDo
RSTOR3= RSTOR2-REL3
RSTOR3 - (DSo+0.25x DDo) <0.25xFDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR3
E
RSTOR3 - (DSo+0.25x DDo) <0.25xFDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR3
E
REL4= 0.25xFDo
RSTOR4= RSTOR3-REL4
RSTOR4 - (DSo+0.25x DDo) <0.25xCPW(i.j) and J<12 ?
Yes
No
PM(i,j+1)=RSTOR4
F

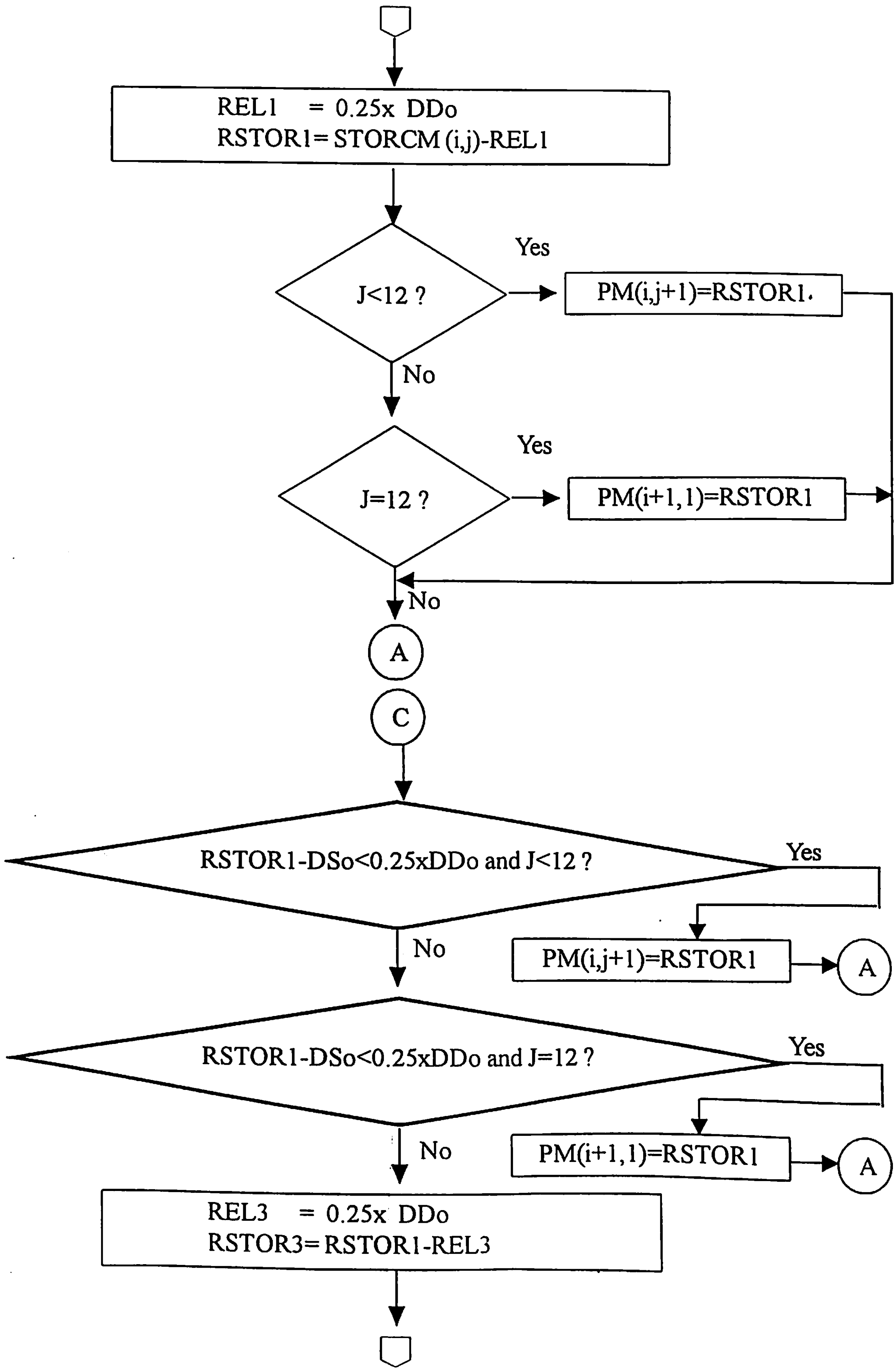

RSTOR4 - (DSo+0.25x DDo) <0.25xCPW(i.j) and J=12?
Yes
PM(i+1,1)=RSTOR4
F
No
REL5 = 0.25xCPW (i,j)
RSTOR5= RSTOR4-REL5
RSTOR5 - (DSo+0.25x DDo) <0.25xDDo ?
Yes
G
No
REL6 = 0.25x DDo
RSTOR6= RSTOR5-REL6
RSTOR6 - (DSo+0.25x DDo) <0.25xDDo ?
Yes
H
No
REL7 = 0.25x DDo
RSTOR7= RSTOR6-REL7
RSTOR7 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J<12 ?
Yes
PM(i,j+1)=RSTOR7
A
No
RSTOR7 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J=12 ?
Yes
PM(i+1,1)=RSTOR7
A
No

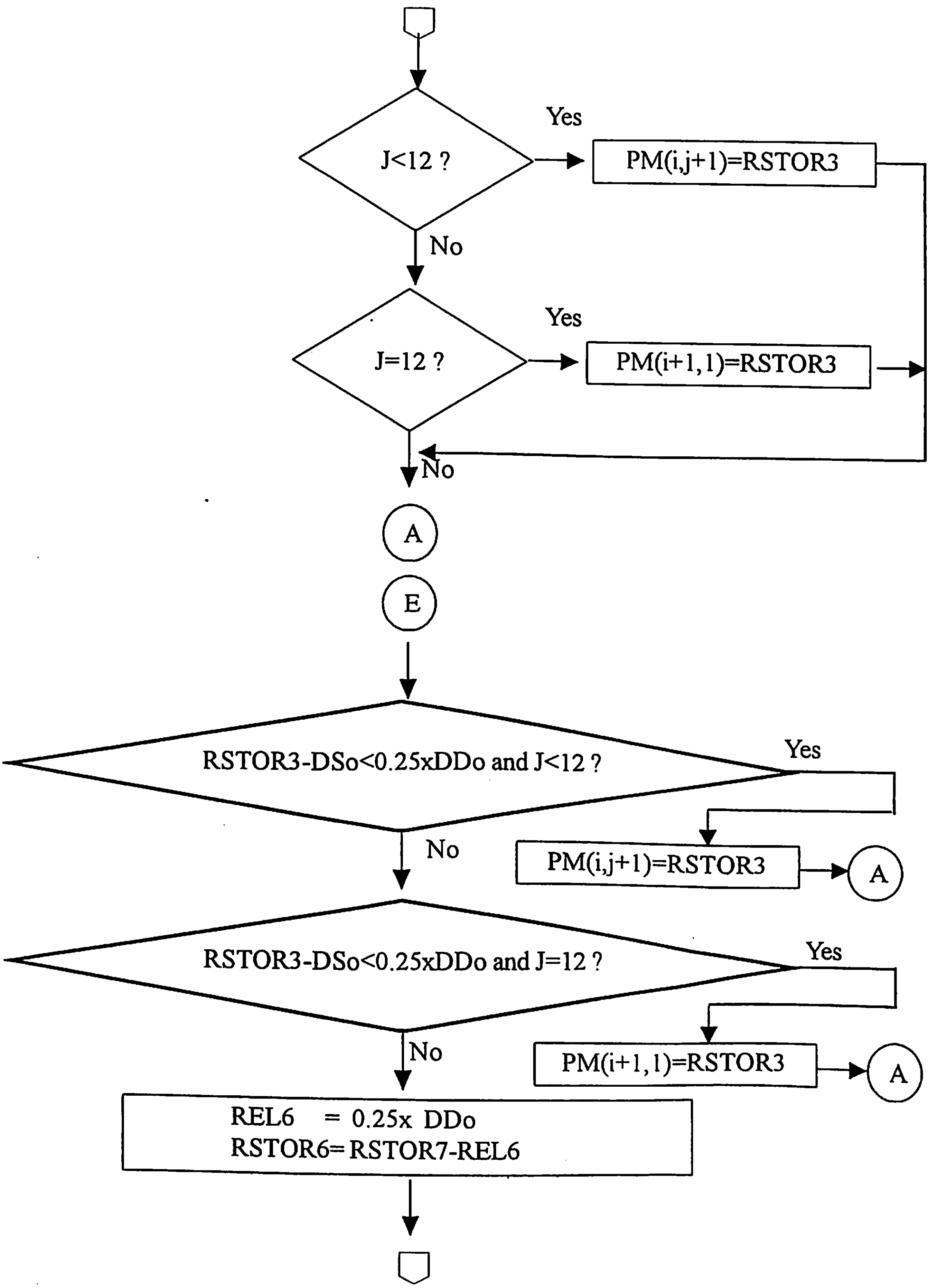

REL8 = 0.25x CPW (i,j)
RSTOR8= RSTOR7-REL8
RSTOR8 - (DSo+0.25x DDo) <0.25xFDo and J<12 ?
Yes
PM(i,j+1)=RSTOR8
A
No
RSTOR8 - (DSo+0.25x DDo) <0.25xFDo and J=12 ?
Yes
PM(i+1,1)=RSTOR8
A
No
REL9 = 0.25x FDo
RSTOR9= RSTOR8-REL9
RSTOR9 - (DSo+0.25x DDo) <0.25xRDo and J<12 ?
Yes
PM(i,j+1)=RSTOR9
A
No
RSTOR9 - (DSo+0.25x DDo) <0.25xRDo and J=12 ?
Yes
PM(i+1,1)=RSTOR9
A
No
REL10 = 0.25x RDo
RSTOR10= RSTOR9-REL10
RSTOR10 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J<12 ?
Yes
PM(i,j+1)=RSTOR10
A
No


RSTOR10 - (DSo+0.25x DDo) <0.25xCPW(i,j) and J=12 ?
Yes
No
PM(i+1,1)=RSTOR10
A
REL11 = 0.25x CPW (i,j)
RSTOR11=RSTOR10-REL11
RSTOR11 - (DSo+0.25x DDo) <0.25xFDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR11
A
RSTOR11 - (DSo+0.25x DDo) <0.25xFDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR11
A
REL12 = 0.25x FDo
RSTOR12=RSTOR11-REL12
RSTOR12 - (DSo+0.25x DDo) <0.25xFDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR12
A
RSTOR12 - (DSo+0.25x DDo) <0.25xFDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR12
A
REL13 = 0.25x FDo
RSTOR13=RSTOR12-REL13

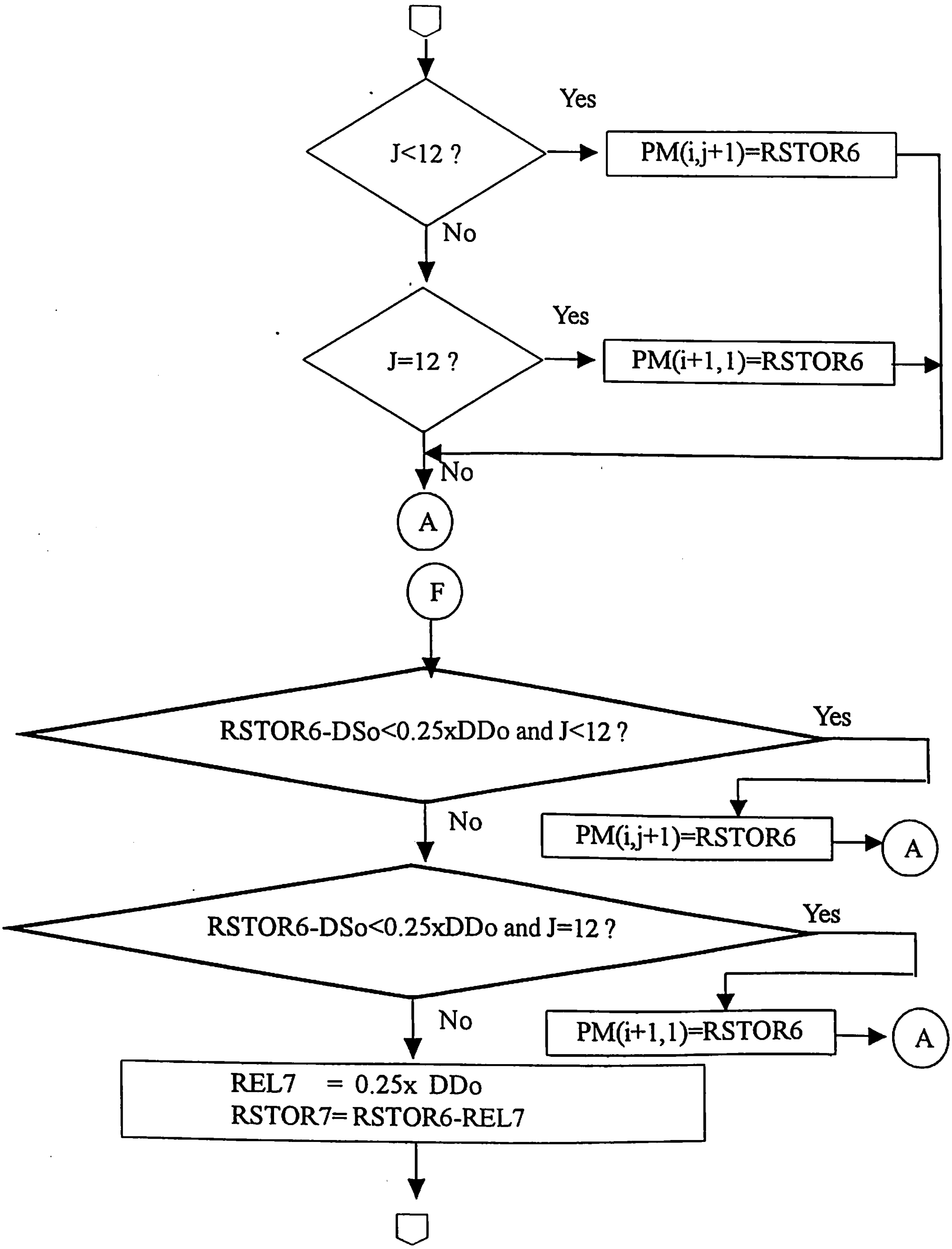

RSTOR13 - (DSo+0.25x DDo) <0.25xRDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR13
A
RSTOR13 - (DSo+0.25x DDo) <0.25xRDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR13
A
REL14 = 0.25x RDo
RSTOR14=RSTOR13-REL14
RSTOR14 - (DSo+0.25x DDo) <0.25xRDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR14
A
RSTOR14 - (DSo+0.25x DDo) <0.25xRDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR14
A
REL15 = 0.25x RDo
RSTOR15=RSTOR14-REL15
RSTOR15 - (DSo+0.25x DDo) <0.25xRDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR15
A


RSTOR15 - (DSo+0.25x DDo) <0.25xRDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR15
A
REL16 = 0.25x RDo
RSTOR16=RSTOR15-REL16
J<12 ?
Yes
PM(i,j+1)=RSTOR16
No
J=12 ?
Yes
PM(i+1,1)=RSTOR16
No
A
B
STORCM (i,j)-DSo<0.25xDDo and J<12 ?
Yes
No
PM(i,j+1)=STORCM (i,j)
A
STORCM (i,j)-DSo<0.25xDDo and J=12 ?
Yes
No
PM(i+1,1)=STORCM (i,j)
A

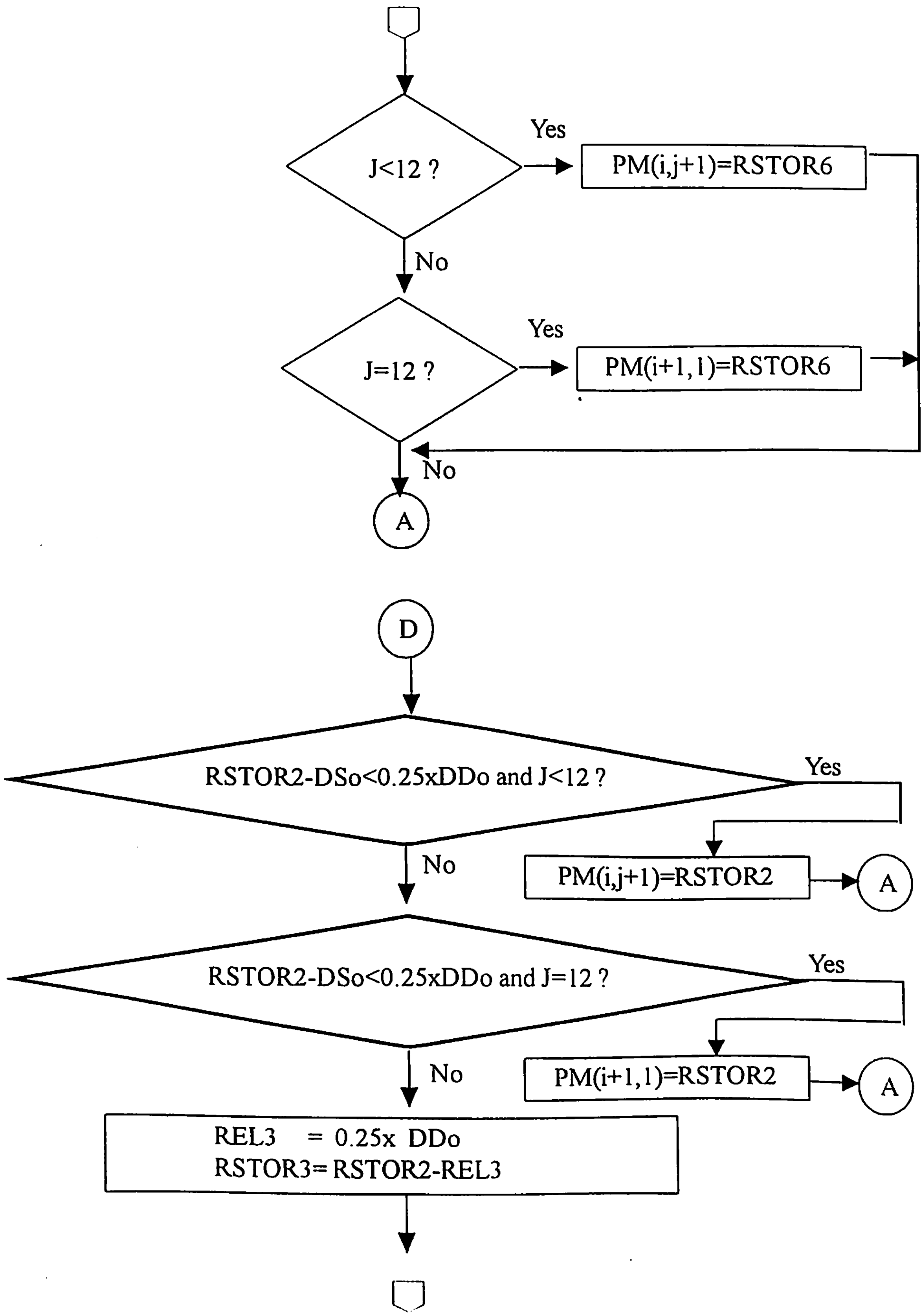

REL1 = 0.25x DDo
RSTOR1= STORCM (i,j)-REL1
J<12 ?
Yes
PM(i,j+1)=RSTOR1.
No
J=12 ?
Yes
PM(i+1,1)=RSTOR1
No
A
C
RSTOR1-DSo<0.25xDDo and J<12 ?
Yes
PM(i,j+1)=RSTOR1
A
No
RSTOR1-DSo<0.25xDDo and J=12 ?
Yes
PM(i+1,1)=RSTOR1
A
No
REL3 = 0.25x DDo
RSTOR3=RSTOR1-REL3

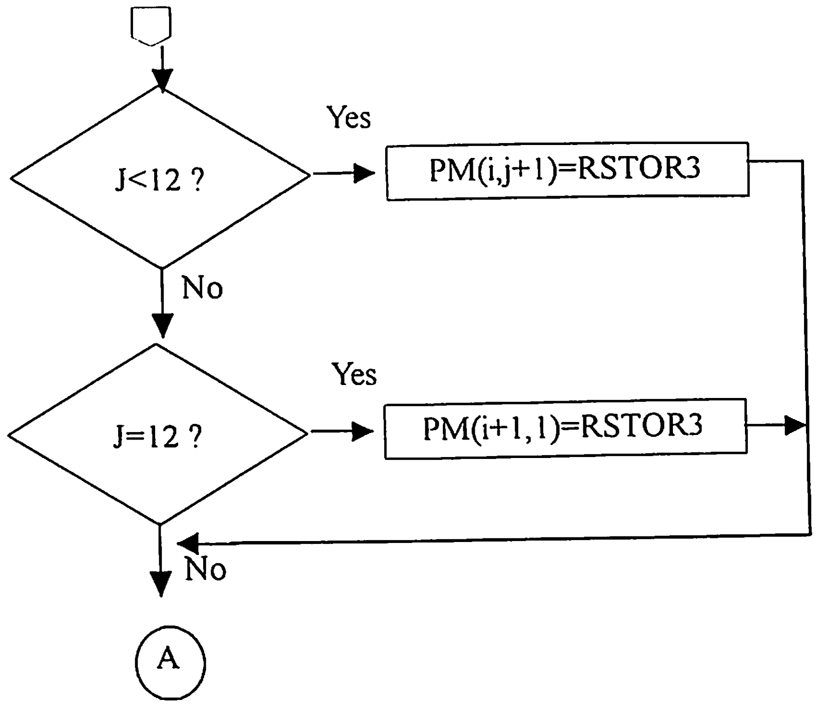


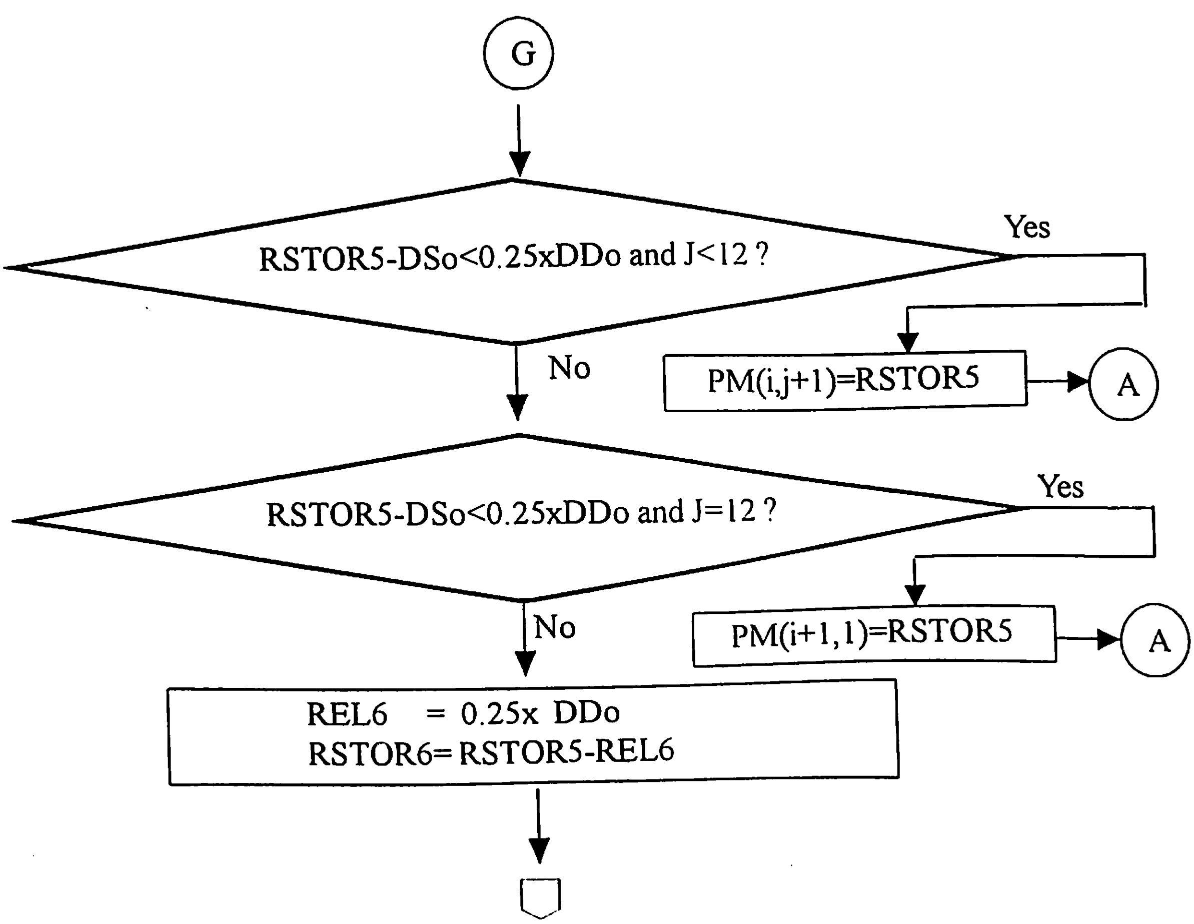
J<12 ?
Yes
PM(i,j+1)=RSTOR3
No
J=12 ?
Yes
PM(i+1,1)=RSTOR3
No
A
E
RSTOR3-DSo<0.25xDDo and J<12 ?
Yes
PM(i,j+1)=RSTOR3
A
No
RSTOR3-DSo<0.25xDDo and J=12 ?
Yes
PM(i+1,1)=RSTOR3
A
No
REL6 = 0.25x DDo
RSTOR6= RSTOR7-REL6

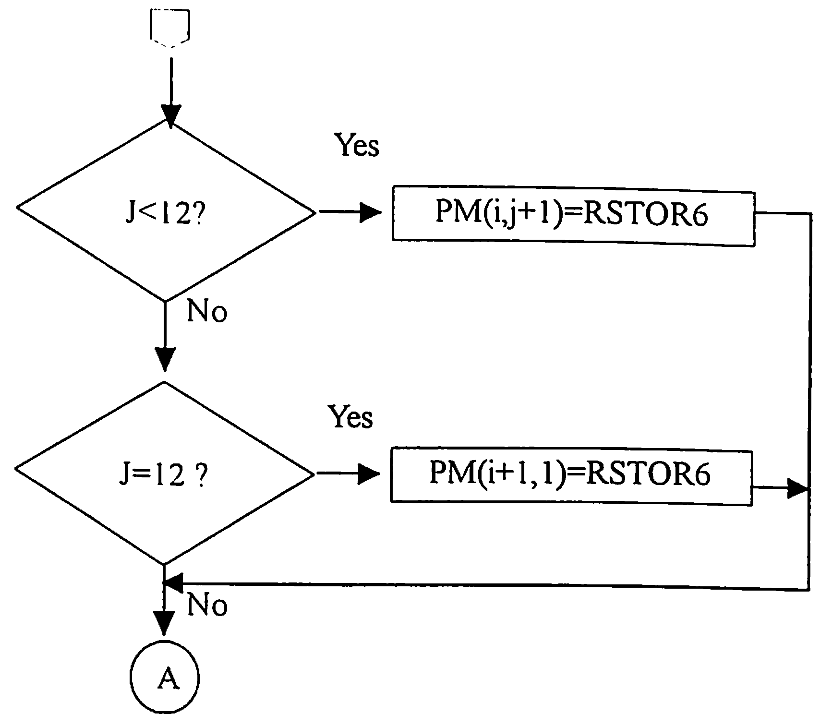


J<12 ?
Yes
PM(i,j+1)=RSTOR6
No
J=12 ?
Yes
PM(i+1,1)=RSTOR6
No
A
F
RSTOR6-DSo<0.25xDDo and J<12 ?
Yes
PM(i,j+1)=RSTOR6
A
No
RSTOR6-DSo<0.25xDDo and J=12 ?
Yes
PM(i+1,1)=RSTOR6
A
No
REL7 = 0.25x DDo
RSTOR7= RSTOR6-REL7

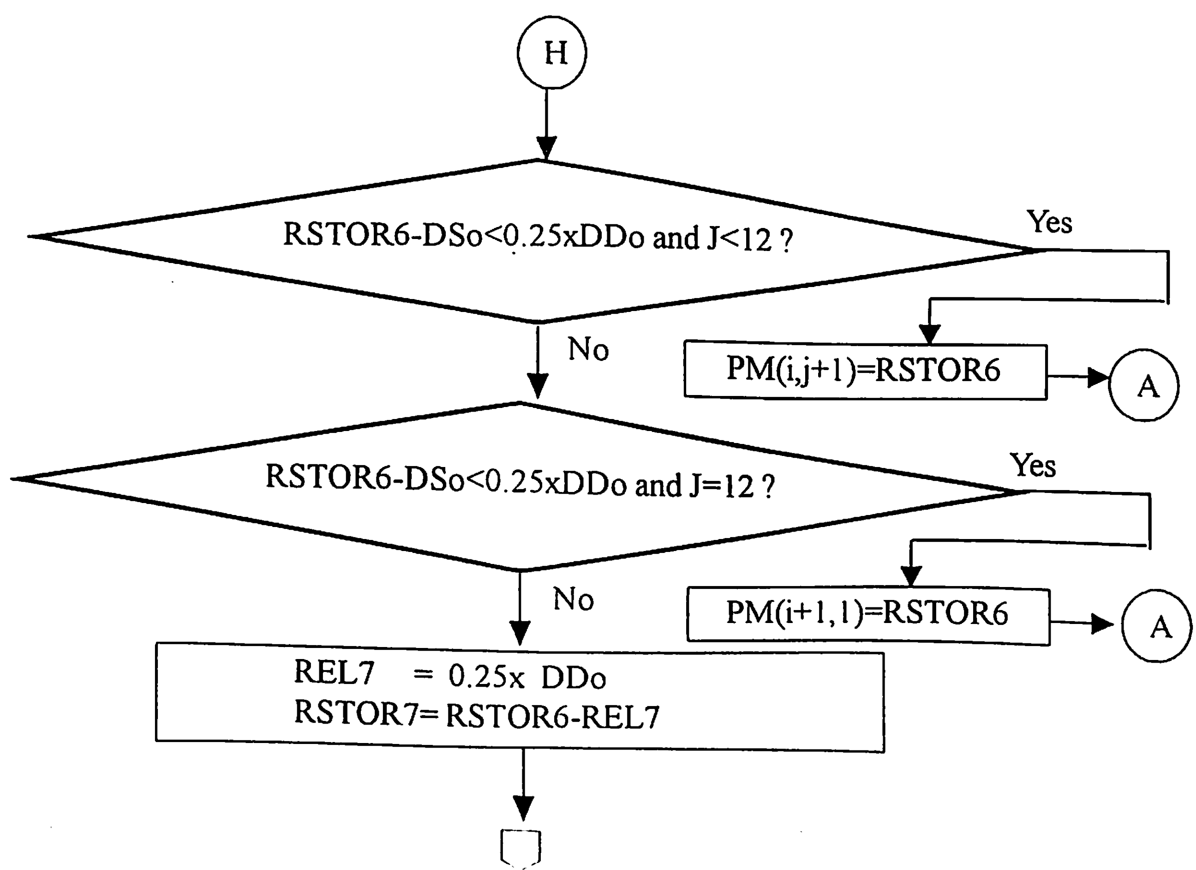

J<12 ?
Yes
PM(i,j+1)=RSTOR6
No
J=12 ?
Yes
PM(i+1,1)=RSTOR6
No
A
D
RSTOR2-DSo<0.25xDDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR2
A
RSTOR2-DSo<0.25xDDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR2
A
REL3 = 0.25x DDo
RSTOR3=RSTOR2-REL3


Yes
J<12 ?
PM(i,j+1)=RSTOR3
No
Yes
J=12 ?
PM(i+1,1)=RSTOR3
No
A

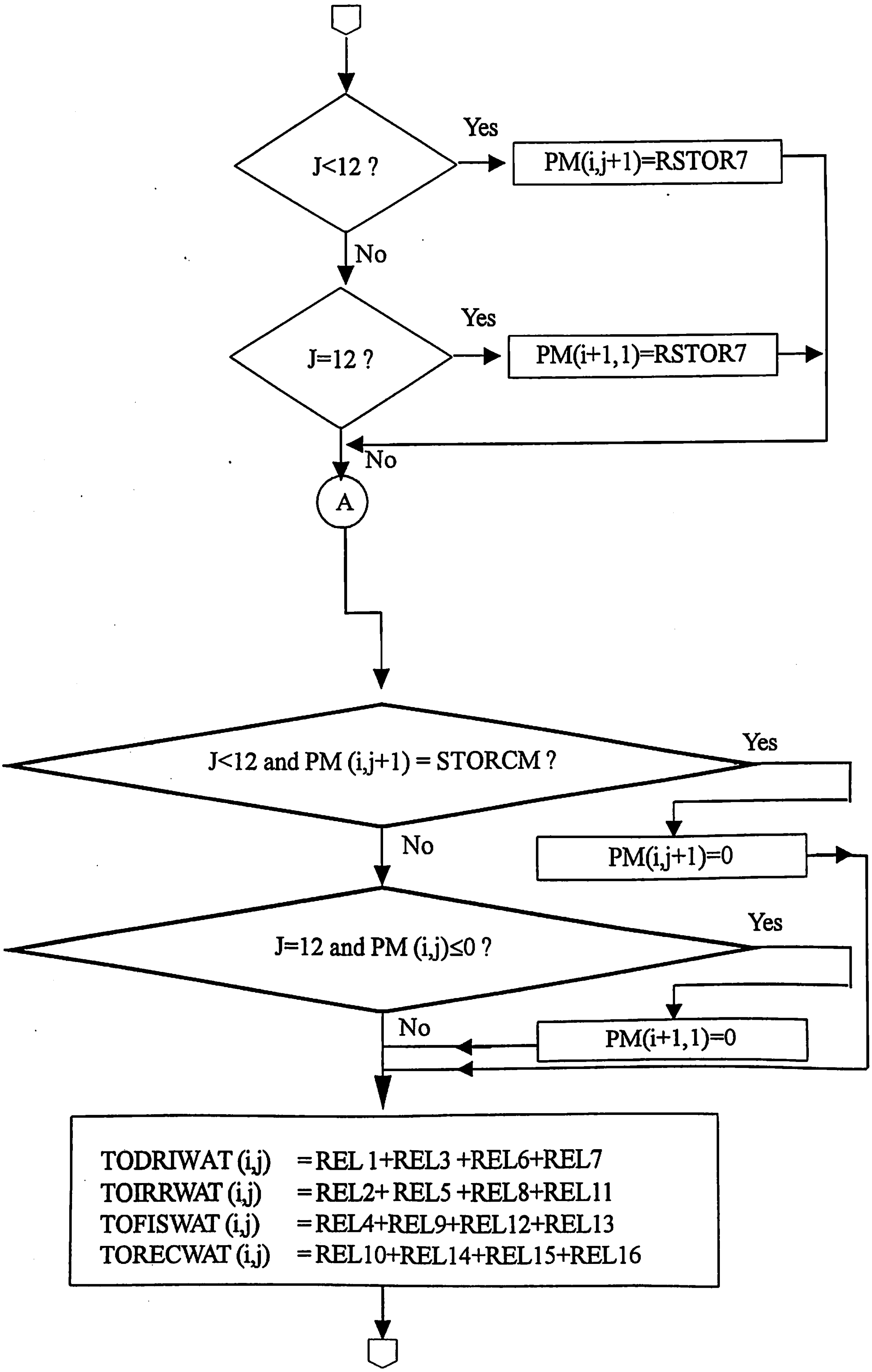

G
RSTOR5-DSo<0.25xDDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR5
A
RSTOR5-DSo<0.25xDDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR5
A
REL6 = 0.25x DDo
RSTOR6= RSTOR5-REL6



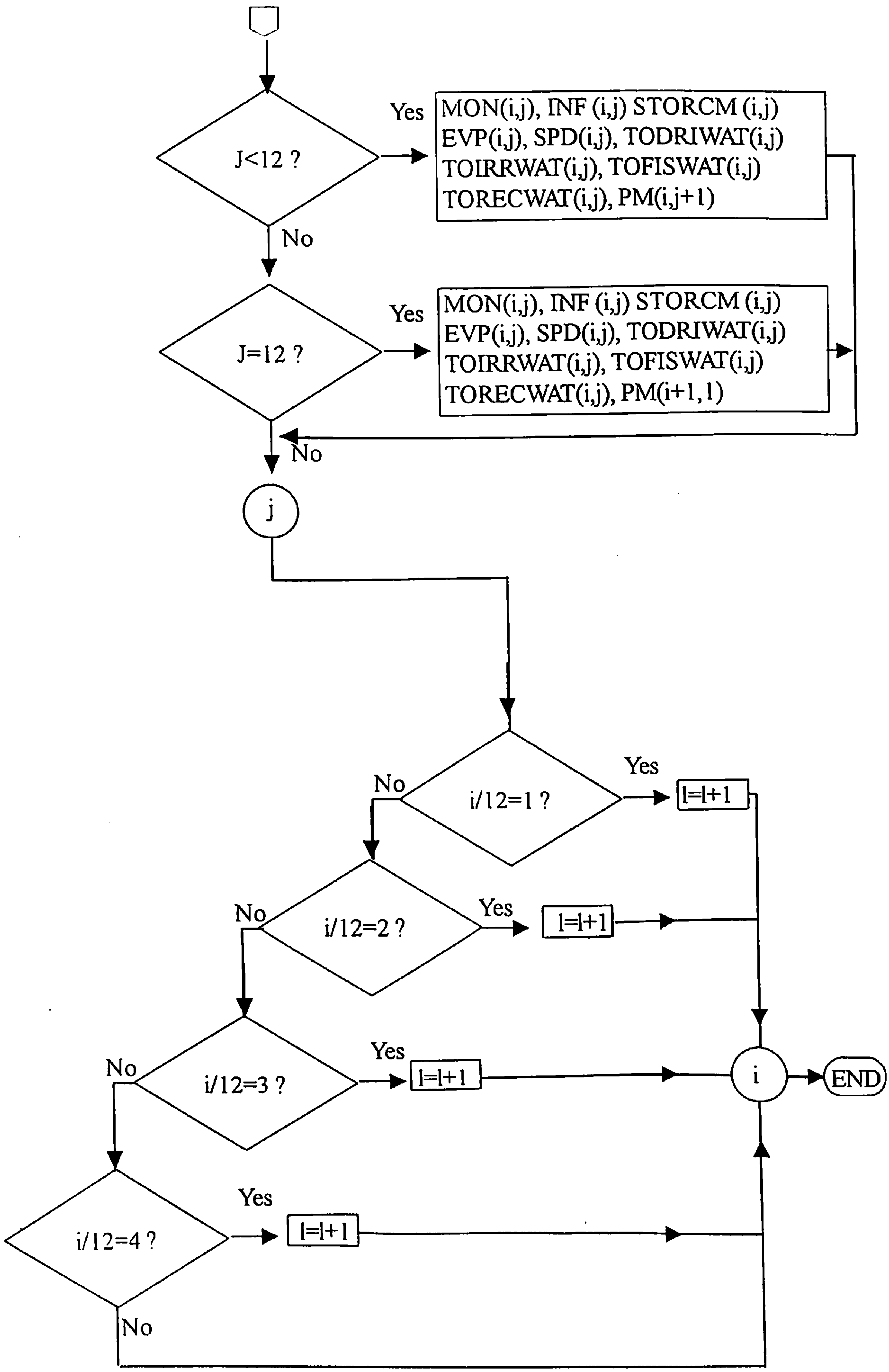
J<12?
Yes
PM(i,j+1)=RSTOR6
No
J=12 ?
Yes
PM(i+1,1)=RSTOR6
No
A



H
RSTOR6-DSo<0.25xDDo and J<12 ?
Yes
No
PM(i,j+1)=RSTOR6
A
RSTOR6-DSo<0.25xDDo and J=12 ?
Yes
No
PM(i+1,1)=RSTOR6
A
REL7 = 0.25x DDo
RSTOR7= RSTOR6-REL7



J<12 ?
Yes
PM(i,j+1)=RSTOR7
No
J=12 ?
Yes
PM(i+1,1)=RSTOR7
No
A
J<12 and PM (i,j+1) = STORCM ?
Yes
PM(i,j+1)=0
No
J=12 and PM (i,j)≤0 ?
Yes
PM(i+1,1)=0
No
TODRIWAT (i,j) =REL1+REL3+REL6+REL7
TOIRRWAT (i,j) =REL2+REL5+REL8+REL11
TOFISWAT (i,j) =REL4+REL9+REL12+REL13
TORECWAT (i,j) =REL10+REL14+REL15+REL16



J<12 ?
Yes
MON(i,j), INF (i,j) STORCM (i,j)
EVP(i,j), SPD(i,j), TODRIWAT(i,j)
TOIRRWAT(i,j), TOFISWAT(i,j)
TORECWAT(i,j), PM(i,j+1)
No
J=12 ?
Yes
MON(i,j), INF (i,j) STORCM (i,j)
EVP(i,j), SPD(i,j), TODRIWAT(i,j)
TOIRRWAT(i,j), TOFISWAT(i,j)
TORECWAT(i,j), PM(i+1,1)
No
j
i/12=1 ?
Yes
No
l=l+1
i/12=2 ?
Yes
No
l=l+1
i/12=3 ?
Yes
No
l=l+1
i
END
i/12=4 ?
Yes
l=l+1
No

The water in the beginning of a month is assumed as the previous month's remaining storage. If the difference between the previous month's storage and evaporation is less than zero then previous month's storage is considered as zero, as otherwise the program may yield a negative value. Therefore the remaining storage for the previous month is taken as zero.

The current month storage is the difference between the sum of inflow and previous month's storage and evaporation from the reservoir. While checking, if it is found that the current month's storage is less than zero, then the current month's storage is considered as zero for the same reason as mentioned above. In such a case water is not available for any of the releases and the algorithm switches over to next month. Whereas if the current month's storage is more than zero then it is checked with the maximum capacity for opening of the shutters. If the storage is more than the specified capacity it is recommended to release the excess water as spillway discharge.

As a next step it is checked whether the difference between the current month's storage and sum of dead storage and 25 % of drinking water (the drinking water kept aside for emergency release, stored along with dead storage) is less than 25% of drinking water demand. After checking if it is found to be less, then once again it is checked whether the difference between current month's storage and dead storage is less than 25 % of drinking water demand. If the water is found to be less, it releases 25% of drinking water and then the algorithm switches over to the next month. On the other hand if the water is found to be more then first release is given to satisfy 25 % of drinking water demand. Hence the remaining storage (RSTOR1) at present is the difference between current month storage and the first release. According to the priority graph the second release is for irrigation requirement. Here again, the difference of first remaining storage (RSTOR1) and sum of dead storage and 25 % of drinking water demand is checked with 25 % of irrigation demand. If the irrigation demand is found to be more, again 25% of drinking water demand is released and the algorithm switches over to the next month. If it is the other case then second release of 25 % of irrigation demand is done. The same procedure is followed in the case of pisciculture and recreation demand.

So the subsequent releases from third till sixteenth are made for different purposes according to their priority assigned by the priority graph. Therefore, the total drinking water for a month is contributed by first, third, sixth and seventh releases. The irrigation is met by second, fifth, eighth and eleventh releases. For pisciculture it is the fourth, ninth, twelfth and thirteenth release and for recreation purpose it is tenth, fourteenth, fifteenth and sixteenth release. 100 % of the monthly demand for different objectives is met if this cycle is continued for whole of the month. Similarly, after continuing for twelve months in a year the algorithm switches over to next year as per the requirement.

The program is written in Visual Basic-6.0 and the entire analysis was carried out in a personal computer. Historical data of 35 years from 1964-1965 to 1998-1999 (Appendices II and III) were used to run the program. The results give the monthly releases and deficits of different demands.

Results & Discussion

RESULTS AND DISCUSSION

The problem of reservoir operation arises mainly because of scarcity of water and conflicts among purposes. A suitable operating policy is essential for the optimal utilisation of available surface water resources. In the present study, an attempt has been made to demonstrate the usefulness and applicability of simulation technique in solving water resources problems.

A simulation model was constructed including all the vital aspects pertaining to the system and excluding the trivial details. The behaviour of the model with changes in different parameters was studied and the inferences are presented in this chapter.

4.1 Water demands

The different demands of water considered for the study were

1.Drinking water

2.Irrigation

3.Pisciculture and

4.Recreation

The drinking water demand was taken as a constant value of 1.89 Mm^3 per month and it accounts to a total of 22.68Mm^3 for twelve months.

The irrigation demand varies according to the season and the crop. In the kole lands paddy is not cultivated from June to September due to water logging and other crops do not require water during this period, as there is enough precipitation. Therefore crop water requirement and hence irrigation demand during these months is zero

(Table 4). Irrigation demand from October till May varied according to the crop, stage of crop and precipitation received. The maximum irrigation demand was observed in the month of March (Table 5). The total irrigation demand was assumed to be a constant for all years and it comes to 110.56 Mm^3 (Table 5).

Pisciculture and recreation demands were also considered as constant throughout the year, with a demand of 0.2 Mm^3 and 0.002 Mm^3 per month respectively. This figures out to be 2.4 Mm^3 and 0.024 Mm^3 respectively per annum (Table5). A total water demand of 135.69 Mm^3 was observed for a year.

4.2 Reservoir storage

The concept of continuity is used in the storage equation. The current month storage in the reservoir is the difference between the inflow into the system and the outflow from the system. The outflow includes the losses and the releases from the system. The storage for each month has been calculated and is presented in Table 6. The remaining storage for each month is given in column ten of the same table. It was also seen that in the monsoon months the initial storage comes to about 106 Mm^3which is the cutoff capacity for the discharge of spill. From December till June the spill discharge is generally nil. The month of May is found to have the least storage and this makes the reservoir ready to receive the inflow during the next rainy season.

4.3 Development of a simulation model for a multipurpose reservoir

Peechi reservoir, built across Manali river in Thrissur district of Kerala is taken as the study project.

4.3.1 Formulation

The policies adopted in the formulation of reservoir rules are as follows

1. Drinking water demand was assumed as a constant of 1.89 Mm^3 per month

2. Along with the dead storage of 0.63 Mm^3, twenty five percent of the drinking water demand, which comes to 0.4725 Mm^3, was kept aside at the beginning of every month. This additional storage was to cover the shortage in drinking water during months of acute deficiency.
3. The distribution of water for the different demands was done based on the priority levels obtained from the priority graphs. In general drinking water was given the highest priority with irrigation, pisciculture and recreation following one after another as shown in Table 7.
4. The quantity of water let out for irrigation depended on the demand, which in turn depended on the crop water requirement in each month.
5. The hatched eggs of fish were introduced into the reservoir when the rains commence and the inflow was high. Harvesting was done in the months of low inflow and high evaporation. The dead storage is sufficient for the fishes to grow.
6. The capacity limit for spillway discharge is 106 Mm^3. The spillway shutters are opened when the water in the reservoir exceeds this limit.

4.3.2 The simulation model

The program was written in Visual Basic 6.0 (Appendix-V) and tested with historical data of 35 years. The model yielded values of water releases for the different demands. The model can be said to be sensitive as data for all the years could be fed and results obtained without any hindrance.

4.4 Testing of the model

The inputs of the model included the year, month, inflow, evaporation, storage, maximum capacity, previous month storage, seepage and other losses etc. The demand for different objectives was also needed. After one run, for a particular month, the model gave directions as to the number of releases that can be given for each demand and the volume of water for each release. In months with sufficient

Table.6 Reservoir simulation model results

INPUT CONSTANTS:

Dead storage (Mm3)	: 0.63	Seepage and other losses (Mm3)	: 0.35
Drinking water demand (Mm3)	: 1.89	Previous month storage (Mm3)	: 0.63
Pisciculture demand (Mm3)	: 0.2	Maximum capacity for the opening of hutters(Mm3)	: 106
Recreation demand (Mm3)	: 0.002		

YEAR:1964- 1965

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	21.436	0.234	0	21.482	1.89	0	0.2	0.002	19.39
JUL	50.83	0.042	0	69.828	1.89	0	0.2	0.002	67.736
AUG	28.36	0.0264	0	95.7196	1.89	0	0.2	0.002	93.6276
SEP	21.423	0.38	8.3206	106.	1.89	0	0.2	0.002	103.908
OCT	11.64	0.49	8.708	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	10.46	0.5	4.9751	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	4.32	0.63	0	101.4766	1.89	13.5286	0.2	0.002	85.856
JAN	5.68	0.585	0	90.601	1.89	1.2429	0.2	0.002	87.2661
FEB	5.41	0.732	0	91.5941	1.89	31.3057	0.2	0.002	58.1964
MAR	2.36	0.846	0	59.3604	1.89	32.3329	0.2	0.002	24.9356
APR	1.42	0.923	0	25.0826	1.89	17.6496	0.1	0.0005	5.4424
MAY	1.87	1.03	0	5.9324	1.89	0.3043	0.2	0.002	3.5361

INFL- Inflow (Mm3)
EVP-Evaporation (Mm3)
SPILL-Spillway discharge (Mm3)
INIST-Initial storage (Mm3)
DRINK- Drinking (Mm3)
IRRIG-Irrigation (Mm3)
REC-Recreation (Mm3)
REMST-Remaining storage (Mm3)
PISCI-Pisciculture (Mm3)

Contd. Table.6

YEAR:1965- 1966

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	17.849	0.1342	0	20.9009	1.89	0	0.2	0.002	18.8089
JUL	50.567	0.3562	0	68.6697	1.89	0	0.2	0.002	66.5777
AUG	20.354	0.9732	0	85.6085	1.89	0	0.2	0.002	83.5165
SEP	20.419	0.5621	0	103.0234	1.89	0	0.2	0.002	100.9314
OCT	9.954	0.6731	3.8623	106	1.89	2.5429	0.2	0.002	101.3651
NOV	18.352	0.7236	12.6435	106	1.89	5.7714	0.2	0.002	98.1366
DEC	3.984	0.7834	0	100.9872	1.89	13.5286	0.2	0.002	85.3666
JAN	3.654	0.907	0	87.7636	1.89	1.2429	0.2	0.002	84.4287
FEB	1.352	0.8673	0	84.5634	1.89	31.3057	0.2	0.002	51.1657
MAR	0.0265	1.632	0	49.2102	1.89	32.3329	0.2	0.002	14.7854
APR	1.698	1.253	0	14.8804	1.89	11.7664	0.05	0	1.1739
MAY	1.542	0.963	0	1.4029	0.4725	0	0	0	0.9304

YEAR:1966- 1967

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	24.356	0.2746	0	24.6618	1.89	0	0.2	0.002	22.5698
JUL	55.675	0.0136	0	77.8812	1.89	0	0.2	0.002	75.7892
AUG	20.1867	0.5632	0	95.0627	1.89	0	0.2	0.002	92.9707
SEP	14.25	0.634	0.2367	106	1.89	0	0.2	0.002	103.908
OCT	19.56	0.782	16.336	106	1.89	2.5429	0.2	0.002	101.3651
NOV	3.584	0.547	0	104.0521	1.89	5.7714	0.2	0.002	96.1887
DEC	6.697	0.5432	0	101.9925	1.89	13.5286	0.2	0.002	86.3719
JAN	4.786	0.873	0	89.9349	1.89	1.2429	0.2	0.002	86.6001
FEB	2.435	0.9231	0	87.762	1.89	31.3057	0.2	0.002	54.3643
MAR	1.34	1.463	0	53.8913	1.89	32.3329	0.2	0.002	19.4664
APR	0.2547	1.242	0	18.1291	1.89	11.7664	0.05	0	4.4227
MAY	0.2147	1.046	0	3.2414	1.89	0.1521	0.05	0	1.1492

Contd. Table.6

YEAR:1967- 1968

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	19.257	0.3462	0	19.71	1.89	0	0.2	0.002	17.618
JUL	56.258	0.164	0	73.362	1.89	0	0.2	0.002	71.27
AUG	37.458	0.246	2.132	106	1.89	0	0.2	0.002	103.908
SEP	12.354	0.563	9.349	106	1.89	0	0.2	0.002	103.908
OCT	10.258	0.542	7.274	106	1.89	2.5429	0.2	0.002	101.3651
NOV	5.241	0.462	0	105.7941	1.89	5.7714	0.2	0.002	97.9307
DEC	6.2547	0.764	0	103.0714	1.89	13.5286	0.2	0.002	87.4508
JAN	4.257	0.9463	0	90.4115	1.89	1.2429	0.2	0.002	87.0767
FEB	2.3147	0.846	0	88.1954	1.89	31.3057	0.2	0.002	54.7977
MAR	0.2367	0.372	0	54.3124	1.89	32.3329	0.2	0.002	19.8875
APR	0.645	1.86	0	18.3225	1.89	11.7664	0.05	0	4.6161
MAY	1.47	1.9	0	3.8361	1.89	0.3043	0.2	0.002	1.4398

YEAR:1968- 1969

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	48.321	0.139	0	49.2718	1.89	0	0.2	0.002	47.1798
JUL	23.354	0.2643	0	69.9195	1.89	0	0.2	0.002	67.8275
AUG	23.78	0.5321	0	90.7254	1.89	0	0.2	0.002	88.6334
SEP	15.897	0.6843	0	103.4961	1.89	0	0.2	0.002	101.4041
OCT	13.56	0.733	7.8811	106	1.89	2.5429	0.2	0.002	101.3651
NOV	10.78	0.701	5.0941	106	1.89	5.7714	0.2	0.002	98.1366
DEC	18.1	0.721	9.1656	106	1.89	13.5286	0.2	0.002	90.3794
JAN	1.987	0.934	0	91.0824	1.89	1.2429	0.2	0.002	87.7476
FEB	1.5471	1.362	0	87.5827	1.89	31.3057	0.2	0.002	54.185
MAR	2.254	1.433	0	54.656	1.89	32.3329	0.2	0.002	20.2311
APR	1.35	1.365	0	19.8661	1.89	11.7664	0.05	0	6.1597
MAY	1.687	1.4	0	6.0967	1.89	0.3043	0.2	0.002	3.7004

Contd. Table.6

YEAR:1969- 1970

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	24.369	0.382	0	27.3374	1.89	0	0.2	0.002	25.2454
JUL	38.364	1.642	0	61.6174	1.89	0	0.2	0.002	59.5254
AUG	34.36	0.347	0	93.1884	1.89	0	0.2	0.002	91.0964
SEP	16.38	0.139	0.9874	106	1.89	0	0.2	0.002	103.908
OCT	9.365	0.953	5.97	106	1.89	2.5429	0.2	0.002	101.3651
NOV	14.255	0.646	8.6241	106	1.89	5.7714	0.2	0.002	98.1366
DEC	8.241	0.946	0	105.0816	1.89	13.5286	0.2	0.002	89.461
JAN	5.541	1.47	0	93.182	1.89	1.2429	0.2	0.002	89.8471
FEB	6.368	0.846	0	95.0191	1.89	31.3057	0.2	0.002	61.6214
MAR	2.254	1.002	0	62.5234	1.89	32.3329	0.2	0.002	28.0986
APR	0.4102	1.016	0	27.1428	1.89	23.5329	0.2	0.002	1.5179
MAY	0.1768	1	0	0.3447	0	0	0	0	0.3447

YEAR:1970- 1971

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	19.354	0.3645	0	18.6395	1.89	0	0.2	0.002	16.5475
JUL	37.64	0.192	0	53.6455	1.89	0	0.2	0.002	51.5535
AUG	36.241	0.301	0	87.1435	1.89	0	0.2	0.002	85.0515
SEP	13.147	0.345	0	97.5035	1.89	0	0.2	0.002	95.4115
OCT	8.365	0.643	0	102.7835	1.89	2.5429	0.2	0.002	98.1486
NOV	12.874	0.562	4.1106	106	1.89	5.7714	0.2	0.002	98.1366
DEC	3.412	0.964	0	100.2346	1.89	13.5286	0.2	0.002	84.614
JAN	6.247	0.843	0	89.668	1.89	1.2429	0.2	0.002	86.3331
FEB	3.014	1.462	0	87.5351	1.89	31.3057	0.2	0.002	54.1374
MAR	1.47	1.5	0	53.7574	1.89	32.3329	0.2	0.002	19.3326
APR	0.314	1.42	0	17.8766	1.89	11.7664	0.05	0	4.1701
MAY	0.147	1.56	0	2.4071	1.4175	0.1521	0.05	0	0.7875

Contd. Table.6

YEAR:1971- 1972

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	17.789	0.356	0	17.8705	1.89	0	0.2	0.002	15.7785
JUL	75.456	0.623	0	90.2615	1.89	0	0.2	0.002	88.1695
AUG	37.248	0.164	18.9035	106	1.89	0	0.2	0.002	103.908
SEP	25.247	0.322	22.483	106	1.89	0	0.2	0.002	103.908
OCT	14.354	0.742	11.17	106	1.89	2.5429	0.2	0.002	101.3651
NOV	8.964	0.963	3.0161	106	1.89	5.7714	0.2	0.002	98.1366
DEC	6.147	0.843	0	103.0906	1.89	13.5286	0.2	0.002	87.47
JAN	3.148	1.06	0	89.208	1.89	1.2429	0.2	0.002	85.8731
FEB	4.251	1.09	0	88.6841	1.89	31.3057	0.2	0.002	55.2864
MAR	1.024	1.846	0	54.1144	1.89	32.3329	0.2	0.002	19.6896
APR	0.3657	1.94	0	17.7653	1.89	11.7664	0.05	0	4.0588
MAY	0.166	1.98	0	1.8948	0.945	0.0761	0	0	0.8738

YEAR:1972- 1973

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	33.32	0.232	0	33.6118	1.89	0	0.2	0.002	31.5198
JUL	34.453	0.461	0	65.1618	1.89	0	0.2	0.002	63.0698
AUG	25.453	0.334	0	87.8388	1.89	0	0.2	0.002	85.7468
SEP	5.324	0.764	0	89.9568	1.89	0	0.2	0.002	87.8648
OCT	16.238	0.546	0	103.2068	1.89	2.5429	0.2	0.002	98.5719
NOV	13.458	0.589	5.0909	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	7.786	0.84	0	104.7326	1.89	13.5286	0.2	0.002	89.112
JAN	7.258	0.94	0	95.08	1.89	1.2429	0.2	0.002	91.7451
FEB	2.546	0.98	0	92.9611	1.89	31.3057	0.2	0.002	59.5634
MAR	1.232	1.36	0	59.0854	1.89	32.3329	0.2	0.002	24.6606
APR	0.154	1.4	0	23.0646	1.89	17.6496	0.1	0.0005	3.4244
MAY	0.152	1.41	0	1.8164	0.945	0.0761	0	0	0.7954

Contd. Table.6

YEAR:1973- 1974

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	30.364	0.163	0	30.6464	1.89	0	0.2	0.002	28.5544
JUL	39.25	0.12	0	67.3344	1.89	0	0.2	0.002	65.2424
AUG	25.147	0.142	0	89.8974	1.89	0	0.2	0.002	87.8054
SEP	22.14	0.14	3.4554	106.	1.89	0	0.2	0.002	103.908
OCT	20.147	0.746	16.959	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	11.147	0.834	5.3281	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	10.258	0.946	1.0986	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	4.124	0.98	0	93.1734	1.89	1.2429	0.2	0.002	89.8386
FEB	6.214	0.97	0	94.7326	1.89	31.3057	0.2	0.002	61.3349
MAR	1.365	1.4	0	60.9499	1.89	32.3329	0.2	0.002	26.525
APR	0.258	1.536	0	24.897	1.89	17.6496	0.1	0.0005	5.2569
MAY	0.0014	1.63	0	3.2783	1.89	0.2282	0.05	0	1.11

YEAR:1974- 1975

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	32.256	0.146	0	32.87	1.89	0	0.2	0.002	30.778
JUL	39.247	0.346	0	69.329	1.89	0	0.2	0.002	67.237
AUG	15.14	0.542	0	81.485	1.89	0	0.2	0.002	79.393
SEP	9.247	0.646	0	87.644	1.89	0	0.2	0.002	85.552
OCT	5.458	0.613	0	90.047	1.89	2.5429	0.2	0.002	85.4122
NOV	8.254	0.731	0	92.5852	1.89	5.7714	0.2	0.002	84.7218
DEC	6.369	0.83	0	89.9108	1.89	13.5286	0.2	0.002	74.2902
JAN	4.54	0.96	0	77.5202	1.89	1.2429	0.2	0.002	74.1853
FEB	5.425	0.92	0	78.3403	1.89	31.3057	0.2	0.002	44.9426
MAR	1.347	0.94	0	44.9996	1.89	32.3329	0.2	0.002	10.5748
APR	0.8741	1.36	0	9.7389	1.4175	5.8832	0.05	0	2.3881
MAY	0.625	1.48	0	1.1831	0.4725	0	0	0	0.7106

Contd. Table.6

YEAR:1975- 1976

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	26.354	0.156	0	26.5586	1.89	0	0.2	0.002	24.4666
JUL	74.25	0.004	0	98.3626	1.89	0	0.2	0.002	96.2706
AUG	18.365	0.142	8.0676	106.	1.89	0	0.2	0.002	103.908
SEP	14.258	0.04	11.776	106.	1.89	0	0.2	0.002	103.908
OCT	25.369	0.33	22.597	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	24.16	0.562	18.6131	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	27.15	0.642	18.2946	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	2.147	0.691	0	91.4854	1.89	1.2429	0.2	0.002	88.1506
FEB	1.385	0.731	0	88.4546	1.89	31.3057	0.2	0.002	55.0569
MAR	0.0125	0.798	0	53.9214	1.89	32.3329	0.2	0.002	19.4965
APR	0.0127	0.946	0	18.2132	1.89	11.7664	0.05	0	4.5068
MAY	0.005	0.997	0	3.1648	1.89	0.1521	0.05	0	1.0726

YEAR:1976- 1977

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	14.329	0.234	0	14.8176	1.89	0	0.2	0.002	12.7256
JUL	26.216	0.146	0	38.4456	1.89	0	0.2	0.002	36.3536
AUG	25.	0.341	0	60.6626	1.89	0	0.2	0.002	58.5706
SEP	8.219	0.375	0	66.0646	1.89	0	0.2	0.002	63.9726
OCT	12.45	0.264	0	75.8086	1.89	2.5429	0.2	0.002	71.1738
NOV	3.354	0.316	0	73.8618	1.89	5.7714	0.2	0.002	65.9983
DEC	2.385	0.3	0	67.7333	1.89	13.5286	0.2	0.002	52.1128
JAN	4.215	0.542	0	55.4358	1.89	1.2429	0.2	0.002	52.1009
FEB	5.145	0.831	0	56.0649	1.89	31.3057	0.2	0.002	22.6672
MAR	4.16	0.88	0	25.5972	1.89	16.1664	0.05	0	7.4908
APR	0.0116	0.926	0	6.2264	0.945	0	0	0	5.2814
MAY	0.102	0.97	0	4.0634	1.89	0.3043	0.2	0.002	1.6671

Contd. Table.6

YEAR:1977- 1978

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	36.214	0.194	0	37.3371	1.89	0	0.2	0.002	35.2451
JUL	22.354	0.246	0	57.0031	1.89	0	0.2	0.002	54.9111
AUG	12.146	0.382	0	66.3251	1.89	0	0.2	0.002	64.2331
SEP	14.158	0.364	0	77.6771	1.89	0	0.2	0.002	75.5851
OCT	13.564	0.521	0	88.2781	1.89	2.5429	0.2	0.002	83.6431
NOV	12.147	0.673	0	94.7672	1.89	5.7714	0.2	0.002	86.9038
DEC	12.45	0.722	0	98.2818	1.89	13.5286	0.2	0.002	82.6612
JAN	4.369	0.84	0	85.8402	1.89	1.2429	0.2	0.002	82.5054
FEB	2.147	0.96	0	83.3424	1.89	31.3057	0.2	0.002	49.9447
MAR	1.64	0.98	0	50.2547	1.89	32.3329	0.2	0.002	15.8298
APR	0.6472	1.33	0	14.797	1.89	11.7664	0.05	0	1.0906
MAY	0.3147	1.42	0	0	0	0	0	0	0

YEAR:1978- 1979

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	55	0.262	0	54.388	1.89	0	0.2	0.002	52.296
JUL	51.257	0.132	0	103.071	1.89	0	0.2	0.002	100.979
AUG	46.147	0.244	40.532	106.	1.89	0	0.2	0.002	103.908
SEP	15.147	0.46	12.245	106.	1.89	0	0.2	0.002	103.908
OCT	18.124	0.441	15.241	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	8.365	0.52	2.8601	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	13.147	0.49	4.4436	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	5.145	0.637	0	94.5374	1.89	1.2429	0.2	0.002	91.2026
FEB	4.258	0.66	0	94.4506	1.89	31.3057	0.2	0.002	61.0529
MAR	1.36	0.74	0	61.3229	1.89	32.3329	0.2	0.002	26.898
APR	0.235	0.81	0	25.973	1.89	17.6496	0.1	0.0005	6.3329
MAY	0.684	0.93	0	5.7369	1.89	0.3043	0.2	0.002	3.3406

Contd. Table.6

YEAR:1979- 1980

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	38.321	0.463	0	40.8486	1.89	0	0.2	0.002	38.7566
JUL	41.3256	0.141	0	79.5912	1.89	0	0.2	0.002	77.4992
AUG	23.14	0.36	0	99.9292	1.89	0	0.2	0.002	97.8372
SEP	24.214	0.34	15.3612	106.	1.89	0	0.2	0.002	103.908
OCT	15.147	0.573	12.132	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	12.354	0.641	6.7281	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	10.125	0.721	1.1906	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	2.0936	0.846	0	91.277	1.89	1.2429	0.2	0.002	87.9422
FEB	0.3861	0.946	0	87.0323	1.89	31.3057	0.2	0.002	53.6346
MAR	0.2895	0.952	0	52.6221	1.89	32.3329	0.2	0.002	18.1972
APR	1.0691	1.28	0	17.6363	1.89	11.7664	0.05	0	3.9299
MAY	1.3146	0.98	0	3.9145	1.89	0.3043	0.2	0.002	1.5182

YEAR:1980- 1981

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	49.0514	0.0264	0	50.1932	1.89	0	0.2	0.002	48.1012
JUL	19.7737	0.562	0	66.9629	1.89	0	0.2	0.002	64.8709
AUG	29.5963	0.16	0	93.9572	1.89	0	0.2	0.002	91.8652
SEP	15.5218	0.15	0.887	106	1.89	0	0.2	0.002	103.908
OCT	28.686	0.242	26.002	106	1.89	2.5429	0.2	0.002	101.3651
NOV	27.22	0.241	21.9941	106	1.89	5.7714	0.2	0.002	98.1366
DEC	27.06	0.346	18.5006	106	1.89	13.5286	0.2	0.002	90.3794
JAN	2.8117	0.746	0	92.0951	1.89	1.2429	0.2	0.002	88.7603
FEB	1.3478	0.891	0	88.8671	1.89	31.3057	0.2	0.002	55.4694
MAR	0.0676	0.942	0	54.245	1.89	32.3329	0.2	0.002	19.8201
APR	0.8006	1.34	0	18.9307	1.89	11.7664	0.05	0	5.2243
MAY	0.6898	1.38	0	4.1841	1.89	0.3043	0.2	0.002	1.7878

Contd. Table.6

YEAR:1981- 1982

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	58.0185	0.016	0	59.4403	1.89	0	0.2	0.002	57.3483
JUL	44.6827	0.12	0	101.561	1.89	0	0.2	0.002	99.469
AUG	39.3337	0.24	32.2127	106.	1.89	0	0.2	0.002	103.908
SEP	38.2317	0.26	35.5297	106.	1.89	0	0.2	0.002	103.908
OCT	13.3743	0.42	10.5123	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	14.4485	0.41	9.0536	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	3.7321	0.52	0	100.9987	1.89	13.5286	0.2	0.002	85.3781
JAN	2.9346	0.63	0	87.3327	1.89	1.2429	0.2	0.002	83.9978
FEB	1.623	0.72	0	84.5508	1.89	31.3057	0.2	0.002	51.1531
MAR	0.4672	0.84	0	50.4303	1.89	32.3329	0.2	0.002	16.0055
APR	0.9828	0.72	0	15.9183	1.89	11.7664	0.05	0	2.2118
MAY	0.7645	0.81	0	1.8163	0.945	0.0761	0	0	0.7953

YEAR:1982- 1983

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	28.02	0.113	0	28.3523	1.89	0	0.2	0.002	26.2603
JUL	42.043	0.28	0	67.6733	1.89	0	0.2	0.002	65.5813
AUG	11.672	0.214	0	76.6893	1.89	0	0.2	0.002	74.5973
SEP	14.032	0.213	0	88.0663	1.89	0	0.2	0.002	85.9743
OCT	11.362	0.464	0	96.5223	1.89	2.5429	0.2	0.002	91.8874
NOV	11.829	0.321	0	103.0454	1.89	5.7714	0.2	0.002	95.182
DEC	7.462	0.642	0	101.652	1.89	13.5286	0.2	0.002	86.0314
JAN	4.7538	0.732	0	89.7032	1.89	1.2429	0.2	0.002	86.3684
FEB	2.595	0.842	0	87.7714	1.89	31.3057	0.2	0.002	54.3736
MAR	6.956	0.921	0	60.0586	1.89	32.3329	0.2	0.002	25.6338
APR	0.3908	0.961	0	24.7136	1.89	17.6496	0.1	0.0005	5.0734
MAY	0.8698	0.981	0	4.6122	1.89	0.3043	0.2	0.002	2.216

Contd. Table.6

YEAR:1983- 1984

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	14.462	0.634	0	15.694	1.89	0	0.2	0.002	13.602
JUL	35.777	0.162	0	48.867	1.89	0	0.2	0.002	46.775
AUG	55.615	0.004	0	102.036	1.89	0	0.2	0.002	99.944
SEP	31.144	0.172	24.566	106.	1.89	0	0.2	0.002	103.908
OCT	6.617	0.593	3.582	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	9.883	0.742	4.1561	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	4.062	0.79	0	101.0586	1.89	13.5286	0.2	0.002	85.438
JAN	1.748	0.834	0	86.002	1.89	1.2429	0.2	0.002	82.6671
FEB	2.668	0.801	0	84.1841	1.89	31.3057	0.2	0.002	50.7864
MAR	2.133	0.816	0	51.7534	1.89	32.3329	0.2	0.002	17.3286
APR	0.742	0.814	0	16.9066	1.89	11.7664	0.05	0	3.2001
MAY	0.196	0.942	0	2.1041	0.945	0.0761	0	0	1.0831

YEAR:1984- 1985

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	16.302	0.342	0	16.6931	1.89	0	0.2	0.002	14.6011
JUL	51.337	0.162	0	65.4261	1.89	0	0.2	0.002	63.3341
AUG	25.848	0.243	0	88.5891	1.89	0	0.2	0.002	86.4971
SEP	14.622	0.421	0	100.3481	1.89	0	0.2	0.002	98.2561
OCT	23.201	0.251	14.8561	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	7.328	0.643	1.7001	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	7.005	0.621	0	104.1706	1.89	13.5286	0.2	0.002	88.55
JAN	3.817	0.742	0	91.275	1.89	1.2429	0.2	0.002	87.9401
FEB	4.5051	0.831	0	91.2642	1.89	31.3057	0.2	0.002	57.8665
MAR	1.262	0.921	0	57.8575	1.89	32.3329	0.2	0.002	23.4327
APR	0.23	1.36	0	21.9527	1.89	17.6496	0.1	0.0005	2.3125
MAY	0.623	1.21	0	1.3755	0.4725	0	0	0	0.903

Contd. Table.6

YEAR:1985- 1986

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	35.24	0.341	0	35.452	1.89	0	0.2	0.002	33.36
JUL	41.4112	0.14	0	74.2812	1.89	0	0.2	0.002	72.1892
AUG	30.791	0.361	0	102.2692	1.89	0	0.2	0.002	100.1772
SEP	12.705	0.432	6.1002	106.	1.89	0	0.2	0.002	103.908
OCT	13.311	0.416	10.453	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	5.384	0.642	0	105.7571	1.89	5.7714	0.2	0.002	97.8937
DEC	7.438	0.531	0	104.4507	1.89	13.5286	0.2	0.002	88.8301
JAN	1.006	0.831	0	88.6551	1.89	1.2429	0.2	0.002	85.3203
FEB	2.625	0.821	0	86.7743	1.89	31.3057	0.2	0.002	53.3766
MAR	2.4564	0.816	0	54.667	1.89	32.3329	0.2	0.002	20.2421
APR	0.6464	0.932	0	19.6065	1.89	11.7664	0.05	0	5.9001
MAY	0.76	0.914	0	5.3961	1.89	0.3043	0.2	0.002	2.9998

YEAR:1986- 1987

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	12.7542	0.246	0	15.158	1.89	0	0.2	0.002	13.066
JUL	20.616	0.212	0	33.12	1.89	0	0.2	0.002	31.028
AUG	28.4695	0.132	0	59.0155	1.89	0	0.2	0.002	56.9235
SEP	7.829	0.562	0	63.8405	1.89	0	0.2	0.002	61.7485
OCT	17.864	0.229	0	79.0335	1.89	2.5429	0.2	0.002	74.3986
NOV	12.5664	0.28	0	86.335	1.89	5.7714	0.2	0.002	78.4716
DEC	4.9994	0.68	0	82.441	1.89	13.5286	0.2	0.002	66.8204
JAN	2.798	0.731	0	68.5374	1.89	1.2429	0.2	0.002	65.2026
FEB	5.914	0.714	0	70.0526	1.89	31.3057	0.2	0.002	36.6549
MAR	4.364	0.846	0	39.8229	1.89	32.3329	0.2	0.002	5.398
APR	6.8912	0.533	0	11.4062	1.4175	5.8832	0.05	0	4.0555
MAY	0.235	0.92	0	3.0205	1.89	0.1521	0.05	0	0.9284

Contd. Table.6

YEAR:1987- 1988

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	10.1062	0.326	0	10.3586	1.89	0	0.2	0.002	8.2666
JUL	18.2007	0.121	0	25.9963	1.89	0	0.2	0.002	23.9043
AUG	19.887	0.112	0	43.3293	1.89	0	0.2	0.002	41.2373
SEP	9.955	0.467	0	50.3753	1.89	0	0.2	0.002	48.2833
OCT	13.335	0.264	0	61.0043	1.89	2.5429	0.2	0.002	56.3694
NOV	9.214	0.646	0	64.5874	1.89	5.7714	0.2	0.002	56.724
DEC	7.251	0.734	0	62.891	1.89	13.5286	0.2	0.002	47.2704
JAN	3.416	0.842	0	49.4944	1.89	1.2429	0.2	0.002	46.1595
FEB	3.179	0.723	0	48.2655	1.89	31.3057	0.2	0.002	14.8678
MAR	9.707	0.71	0	23.5148	1.89	16.1664	0.05	0	5.4084
APR	6.627	0.89	0	10.7954	1.4175	5.8832	0.05	0	3.4447
MAY	0.93	0.892	0	3.1327	1.89	0.1521	0.05	0	1.0405

YEAR:1988- 1989

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	30.661	0.321	0	31.0305	1.89	0	0.2	0.002	28.9385
JUL	27.859	0.164	0	56.2835	1.89	0	0.2	0.002	54.1915
AUG	39.752	0.021	0	93.5725	1.89	0	0.2	0.002	91.4805
SEP	41.3803	0.001	26.8981	106	1.89	0	0.2	0.002	103.908
OCT	13.1847	0.315	10.4277	106	1.89	2.5429	0.2	0.002	101.3651
NOV	8.703	0.53	3.1881	106	1.89	5.7714	0.2	0.002	98.1366
DEC	2.192	0.82	0	99.1586	1.89	13.5286	0.2	0.002	83.538
JAN	2.347	0.56	0	84.975	1.89	1.2429	0.2	0.002	81.6401
FEB	1.646	0.51	0	82.4261	1.89	31.3057	0.2	0.002	49.0284
MAR	7.6	0.81	0	55.4684	1.89	32.3329	0.2	0.002	21.0436
APR	0.287	0.87	0	20.1106	1.89	11.7664	0.05	0	6.4041
MAY	0.545	0.92	0	5.6791	1.89	0.3043	0.2	0.002	3.2829

Contd. Table.6

YEAR:1989- 1990

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	29.16	0.16	0	31.9329	1.89	0	0.2	0.002	29.8409
JUL	61.363	0.11	0	90.7439	1.89	0	0.2	0.002	88.6519
AUG	21.326	0.13	3.4979	106.	1.89	0	0.2	0.002	103.908
SEP	11.754	0.3	9.012	106.	1.89	0	0.2	0.002	103.908
OCT	17.731	0.12	15.169	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	7.109	0.63	1.4941	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	5.468	0.5	0	102.7546	1.89	13.5286	0.2	0.002	87.134
JAN	2.347	0.8	0	88.331	1.89	1.2429	0.2	0.002	84.9961
FEB	1.231	0.83	0	85.0471	1.89	31.3057	0.2	0.002	51.6494
MAR	2.531	0.81	0	53.0204	1.89	32.3329	0.2	0.002	18.5956
APR	0.252	0.93	0	17.5676	1.89	11.7664	0.05	0	3.8611
MAY	2.925	0.8	0	5.6361	1.89	0.3043	0.2	0.002	3.2399

YEAR:1990- 1991

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	17.491	0.362	0	20.189	1.89	0	0.2	0.002	17.9269
JUL	58.834	0.141	0	76.2699	1.89	0	0.2	0.002	74.1779
AUG	29.724	0.236	0	103.3159	1.89	0	0.2	0.002	101.2239
SEP	3.515	0.641	0	103.7479	1.89	0	0.2	0.002	101.6559
OCT	11.885	0.39	6.8023	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	11.73	0.35	6.3951	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	3.237	0.651	0	100.3726	1.89	13.5286	0.2	0.002	84.752
JAN	2.836	0.732	0	86.506	1.89	1.2429	0.2	0.002	83.1711
FEB	3.162	0.641	0	85.3421	1.89	31.3057	0.2	0.002	51.9444
MAR	3.763	0.621	0	54.7364	1.89	32.3329	0.2	0.002	20.3116
APR	1.608	0.432	0	21.1376	1.89	17.6496	0.1	0.0005	1.4974
MAY	0.463	0.841	0	0.7694	0	0	0	0	0.7694

Contd. Table.6

YEAR:1991- 1992

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	18.989	0.341	0	19.0674	1.89	0	0.2	0.002	16.9754
JUL	74.695	0.04	0	91.2804	1.89	0	0.2	0.002	89.1884
AUG	52.594	0.166	35.2664	106.	1.89	0	0.2	0.002	103.908
SEP	7.625	0.463	4.72	106.	1.89	0	0.2	0.002	103.908
OCT	11.6095	0.32	8.8475	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	8.907	0.43	3.4921	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	8.954	0.436	0.3046	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	3.19	0.846	0	92.3734	1.89	1.2429	0.2	0.002	89.0386
FEB	3.12	0.321	0	91.4876	1.89	31.3057	0.2	0.002	58.0899
MAR	5.977	0.396	0	63.3209	1.89	32.3329	0.2	0.002	28.896
APR	0.5	0.91	0	28.136	1.89	23.5329	0.2	0.002	2.5111
MAY	0.4942	0.97	0	1.6853	0.945	0	0	0	0.6643

YEAR:1992- 1993

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	13.1748	0.263	0	13.6318	1.89	0	0.2	0.002	11.5398
JUL	66.204	0.121	0	77.2728	1.89	0	0.2	0.002	75.1808
AUG	41.586	0.192	10.2248	106.	1.89	0	0.2	0.002	103.908
SEP	15.355	0.211	12.702	106.	1.89	0	0.2	0.002	103.908
OCT	20.356	0.2	17.714	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	18.8132	0.216	13.6123	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	8.69	0.732	0	105.7446	1.89	13.5286	0.2	0.002	90.124
JAN	2.104	0.849	0	91.029	1.89	1.2429	0.2	0.002	87.6941
FEB	4.358	0.79	0	90.9121	1.89	31.3057	0.2	0.002	57.5144
MAR	2.734	0.942	0	58.9564	1.89	32.3329	0.2	0.002	24.5316
APR	2.135	0.916	0	25.4006	1.89	17.6496	0.1	0.0005	5.7604
MAY	2.6048	0.99	0	7.0252	1.89	0.3043	0.2	0.002	4.6289

Contd. Table.6

YEAR:1993- 1994

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	9.389	0.462	0	13.2059	1.89	0	0.2	0.002	11.1139
JUL	39.314	0.143	0	49.9349	1.89	0	0.2	0.002	47.8429
AUG	28.952	0.231	0	76.2139	1.89	0	0.2	0.002	74.1219
SEP	6.341	0.53	0	79.5829	1.89	0	0.2	0.002	77.4909
OCT	19.355	0.34	0	96.1559	1.89	2.5429	0.2	0.002	91.5211
NOV	8.957	0.563	0	99.5651	1.89	5.7714	0.2	0.002	91.7017
DEC	4.186	0.734	0	94.8037	1.89	13.5286	0.2	0.002	79.1831
JAN	3.104	0.834	0	81.1031	1.89	1.2429	0.2	0.002	77.7682
FEB	2.584	0.721	0	79.2812	1.89	31.3057	0.2	0.002	45.8835
MAR	3.239	0.834	0	47.9385	1.89	32.3329	0.2	0.002	13.5137
APR	2.11	0.92	0	14.3537	1.89	11.7664	0.05	0	0.6472
MAY	0.9852	1.34	0	0	0	0	0	0	0

YEAR:1994- 1995

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	25.112	0.264	0	24.498	1.89	0	0.2	0.002	22.406
JUL	72.879	0.101	0	94.834	1.89	0	0.2	0.002	92.742
AUG	32.6507	0.193	18.8497	106.	1.89	0	0.2	0.002	103.908
SEP	21.9324	0.34	19.1504	106.	1.89	0	0.2	0.002	103.908
OCT	12.4	0.48	9.478	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	9.8667	0.56	4.3218	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	4.8169	0.64	0	101.9635	1.89	13.5286	0.2	0.002	86.3429
JAN	4.067	0.62	0	89.4399	1.89	1.2429	0.2	0.002	86.105
FEB	3.503	0.534	0	88.724	1.89	31.3057	0.2	0.002	55.3263
MAR	4.691	0.522	0	59.1453	1.89	32.3329	0.2	0.002	24.7205
APR	2.317	0.734	0	25.9535	1.89	17.6496	0.1	0.0005	6.3133
MAY	3.544	0.721	0	8.7863	1.89	0.3043	0.2	0.002	6.39

Contd. Table.6

YEAR:1995- 1996

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	11.565	0.462	0	17.143	1.89	0	0.2	0.002	15.051
JUL	41.3266	0.243	0	55.7846	1.89	0	0.2	0.002	53.6926
AUG	26.5495	0.394	0	79.4981	1.89	0	0.2	0.002	77.4061
SEP	26.328	0.321	0	103.0631	1.89	0	0.2	0.002	100.9711
OCT	68.3664	0.101	62.8865	106	1.89	2.5429	0.2	0.002	101.3651
NOV	7.4385	0.4963	1.9573	106	1.89	5.7714	0.2	0.002	98.1366
DEC	10.4801	0.421	1.8457	106	1.89	13.5286	0.2	0.002	90.3794
JAN	3.51	0.643	0	92.8964	1.89	1.2429	0.2	0.002	89.5616
FEB	7.55	0.531	0	96.2306	1.89	31.3057	0.2	0.002	62.8329
MAR	5.05	0.589	0	66.9439	1.89	32.3329	0.2	0.002	32.519
APR	1.215	0.734	0	32.65	1.89	23.5329	0.2	0.002	7.0251
MAY	4.4712	0.62	0	10.5263	1.89	0.3043	0.2	0.002	8.1301

YEAR:1996- 1997

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	4.5816	0.643	0	11.7187	1.89	0	0.2	0.002	9.6267
JUL	23.035	0.342	0	31.9697	1.89	0	0.2	0.002	29.8777
AUG	19.44	0.531	0	48.4367	1.89	0	0.2	0.002	46.3447
SEP	27.715	0.34	0	73.3697	1.89	0	0.2	0.002	71.2777
OCT	23.177	0.31	0	93.7947	1.89	2.5429	0.2	0.002	89.1598
NOV	4.8283	0.53	0	93.1081	1.89	5.7714	0.2	0.002	85.2447
DEC	6.118	0.51	0	90.5027	1.89	13.5286	0.2	0.002	74.8821
JAN	4.504	0.64	0	78.3961	1.89	1.2429	0.2	0.002	75.0612
FEB	3.55	0.72	0	77.5412	1.89	31.3057	0.2	0.002	44.1435
MAR	5.932	0.53	0	49.1955	1.89	32.3329	0.2	0.002	14.7707
APR	4.8963	0.59	0	18.727	1.89	11.7664	0.05	0	5.0205
MAY	0.7789	0.84	0	4.6094	1.89	0.3043	0.2	0.002	2.2132

Contd. Table.6

YEAR:1997- 1998

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	4.631	0.632	0	5.8622	1.89	0	0.2	0.002	3.7702
JUL	52.151	0.161	0	55.4102	1.89	0	0.2	0.002	53.3182
AUG	46.6018	0.234	0	99.336	1.89	0	0.2	0.002	97.244
SEP	3.98	0.6	0	100.274	1.89	0	0.2	0.002	98.182
OCT	10.264	0.43	1.666	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	14.7748	0.41	9.3799	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	7.1786	0.58	0	104.3852	1.89	13.5286	0.2	0.002	88.7646
JAN	6.7528	0.52	0	94.6474	1.89	1.2429	0.2	0.002	91.3126
FEB	2.5956	0.734	0	92.8242	1.89	31.3057	0.2	0.002	59.4265
MAR	6.956	0.617	0	65.4155	1.89	32.3329	0.2	0.002	30.9906
APR	5.2906	0.432	0	35.4992	1.89	23.5329	0.2	0.002	9.8744
MAY	0.857	0.931	0	9.4504	1.89	0.3043	0.2	0.002	7.0541

YEAR:1998- 1999

MONTH	INFL	EVP	SPILL	INIST	DRINK	IRRIG	PISCI	REC	REMST
JUN	13.1383	0.364	0	19.4784	1.89	0	0.2	0.002	17.3864
JUL	40.2556	0.164	0	57.128	1.89	0	0.2	0.002	55.036
AUG	57.4543	0.012	6.1283	106.	1.89	0	0.2	0.002	103.908
SEP	27.2913	0.318	24.5313	106.	1.89	0	0.2	0.002	103.908
OCT	35.7219	0.26	33.0199	106.	1.89	2.5429	0.2	0.002	101.3651
NOV	10.075	0.64	4.4501	106.	1.89	5.7714	0.2	0.002	98.1366
DEC	13.542	0.364	4.9646	106.	1.89	13.5286	0.2	0.002	90.3794
JAN	0.2662	0.946	0	89.3496	1.89	1.2429	0.2	0.002	86.0148
FEB	10.9648	0.76	0	95.8696	1.89	31.3057	0.2	0.002	62.4719
MAR	5.5548	0.843	0	66.8337	1.89	32.3329	0.2	0.002	32.4088
APR	5.236	0.846	0	36.4488	1.89	23.5329	0.2	0.002	10.8239
MAY	4.251	0.941	0	13.7839	1.89	0.3043	0.2	0.002	11.3877

Table.7 Priority levels of different water demands.

Demand	Slope	Priority level
Drinking	0.16	1
Irrigation	0.12	2
Drinking	0.08	3
Pisciculture	0.08	4
Irrigation	0.06	5
Drinking	0.05	6
Drinking	0.04	7
Irrigation	0.04	8
Pisciculture	0.04	9
Recreation	0.04	10
Irrigation	0.03	11
Pisciculture	0.026	12
Pisciculture	0.02	13
Recreation	0.02	14
Recreation	0.013	15
Recreation	0.01	16

remaining storage and inflow, the demands were satisfied completely. In months of deficiency releases were made till only the dead storage remained. The twenty five percent of drinking water demand, which was kept aside at the beginning for emergencies was released when no more water was available for any of the releases. When the decisions were made for one month the program switches over to the next month. The results obtained after the program was run with historical input data of 35 years are presented in Table 6.

4.5 Analysis of the results

The simulation model was designed for monthly operation with historic data of 35 years going back from the water year 1998-1999. In most months all demands were satisfied to the full extent but months with acute water shortage was also seen. The model has distributed the available water most efficiently among the different demands. Certain typical months are taken for looking deeply into and are presented below.

The monthly variation of the demand, actual release made by the reservoir authorities, and simulated release for different purposes for the year 1994-1995 is shown in Figures 11 (a), 11(b), 11(c) & 11(d). The demands for drinking, irrigation, pisciculture and recreation were 22.68Mm^3, 110.56 Mm^3, 2.4 Mm^3 and 0.024 Mm^3 respectively (Table 5). The actual releases from the reservoir were 19.8 Mm^3, 167.98 Mm^3,1.3 Mm^3, 0.006 Mm^3 (Appendix- IV) for each purpose. It is seen that there was a gap between the demand and the water released. Drinking water requirement was not met upto the demand and much more water than needed was released in the name of irrigation. This disparity may have been due to the lack of experience of the management. It is seen that (Appendix- IV) after the initial rains, in the following months when demand was less, more water was released Therefore in the dry months shortage of water was experienced. Failings in planning can be the only reason for this ironical situation.

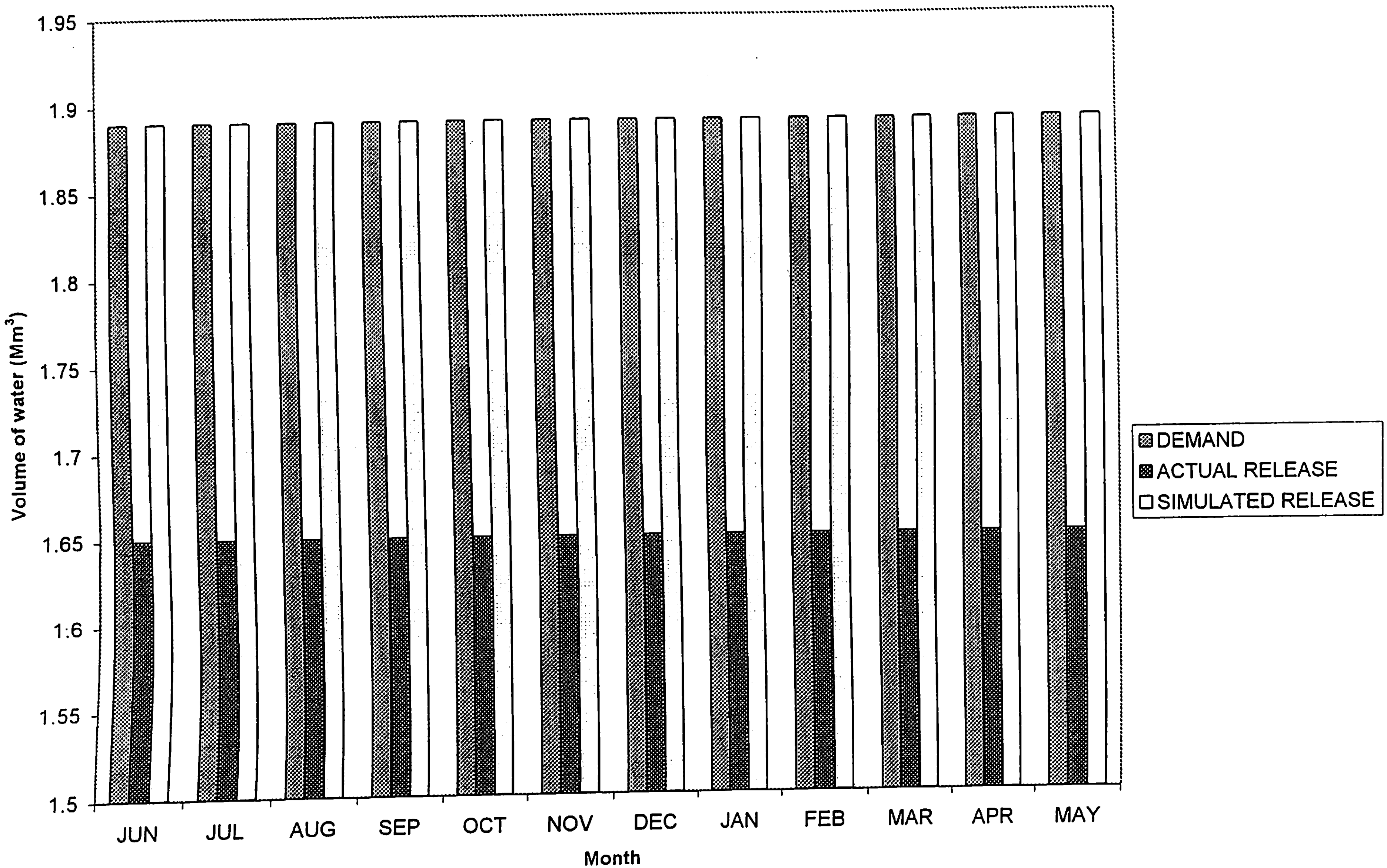


Fig. 11 (a) Comparison between demand, actual release and simulated release for drinking water (1994-1995)

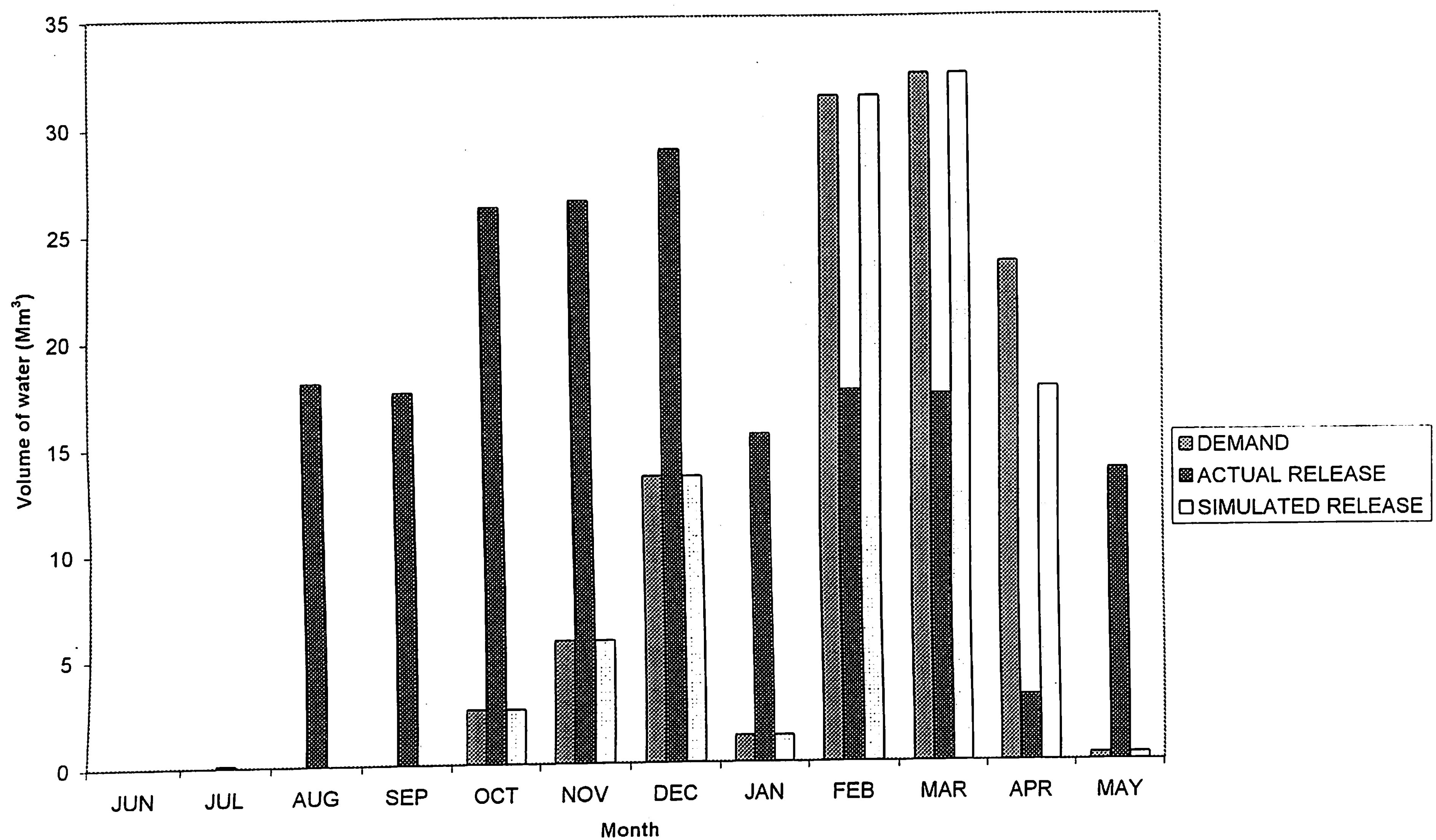


Fig. 11 (b) Comparison between demand, actual and simulated release for irrigation (1994-1995)

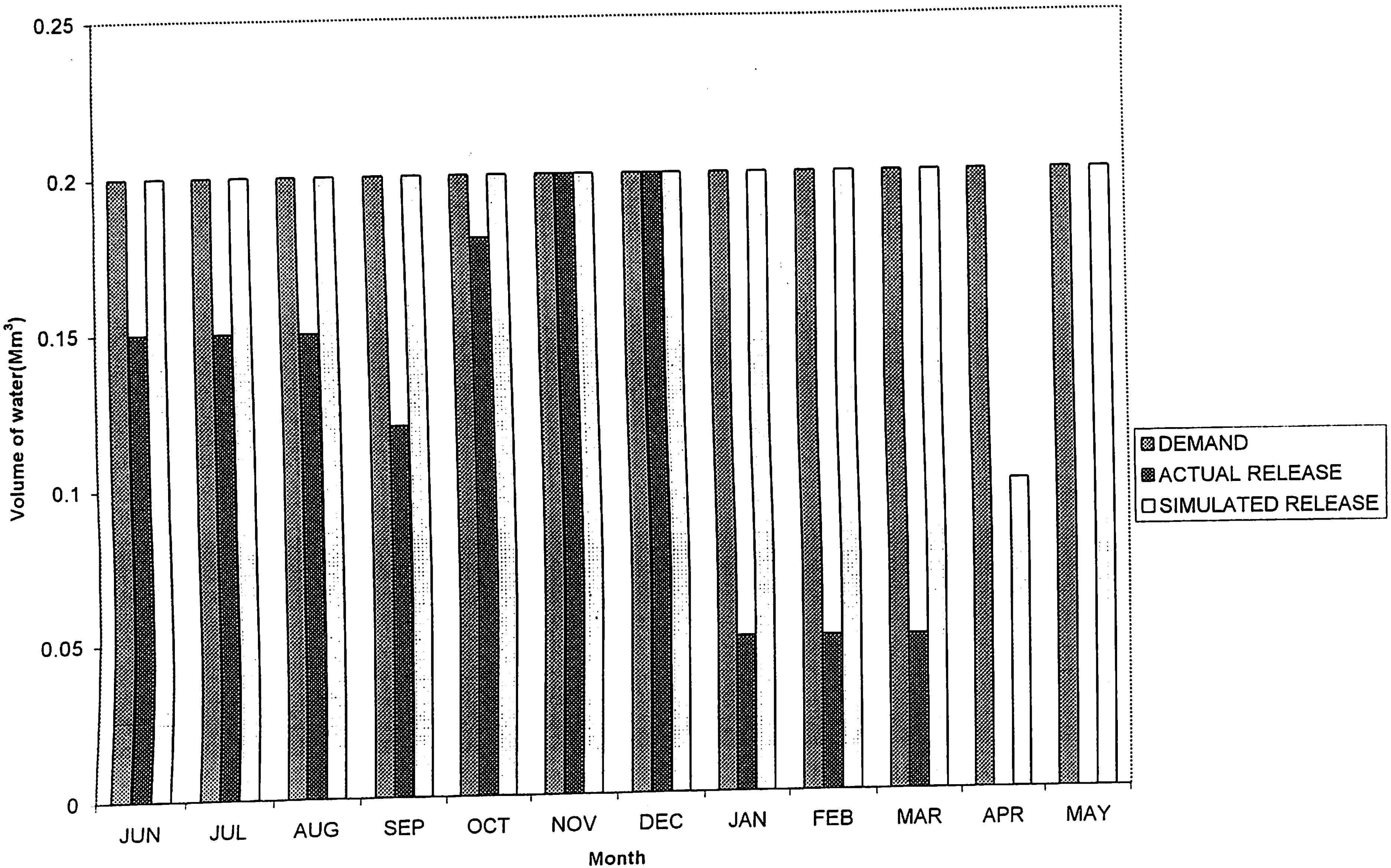


Fig. 11 (c) Comparison between demand, actual release and simulated release for pisciculture (1994-1995)

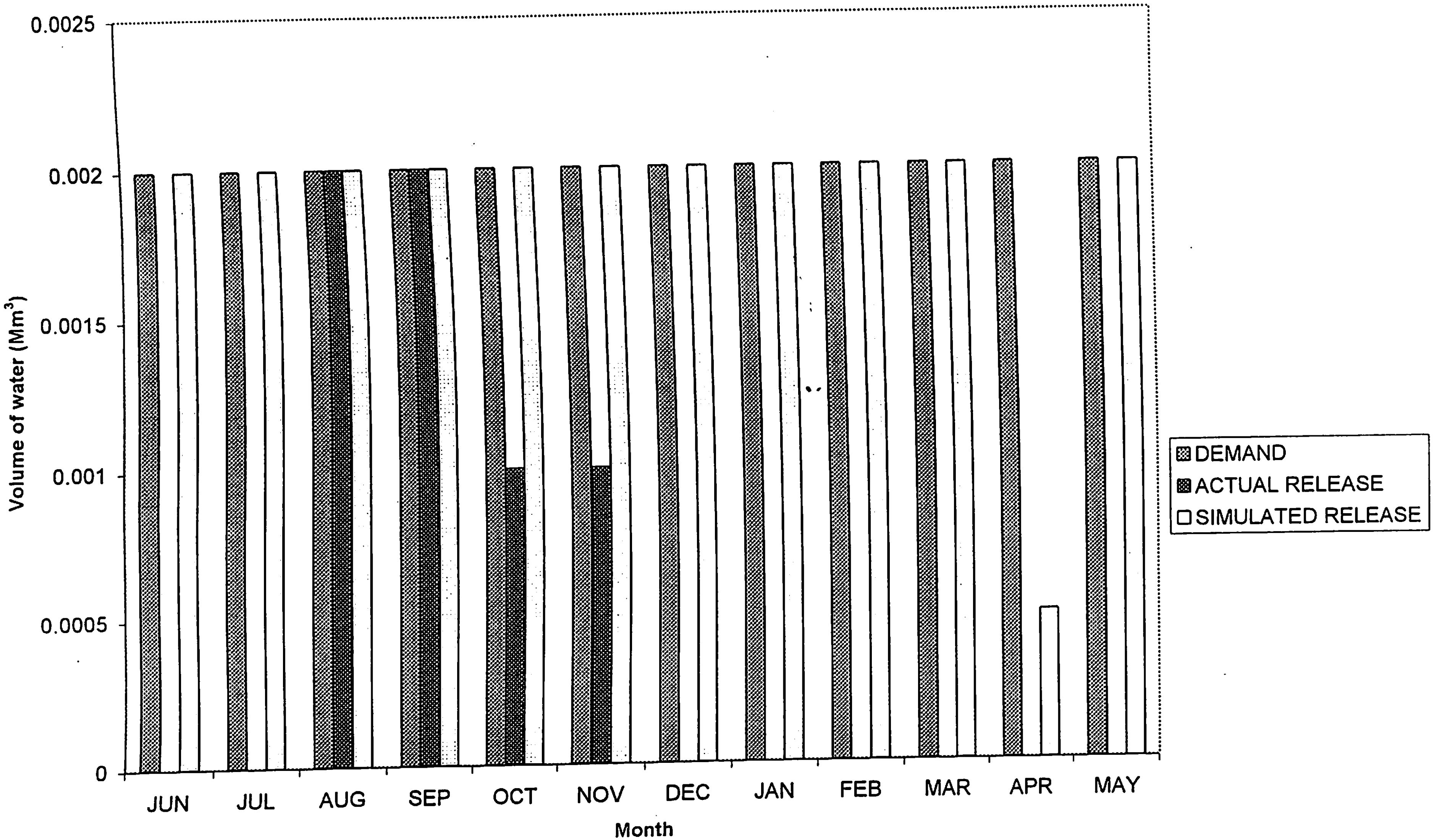


Fig. 11 (d) Comparison between demand, actual release and simulated release for recreation (1994-1995)

The targets achieved by the simulation model for this particular year are 100 percent, 94.68 percent, 95.83 percent, and 93.75 percent respectively for drinking, irrigation, pisciculture and recreation as illustrated in fig. 12. This year had good precipitation of 3374.8 mm and an inflow of 197.77 Mm^3 (Appendices- I & II). The simulated releases were 22.68 Mm^3, 104.68 Mm^3, 2.3 Mm^3, 0.0225 Mm^3 (Table 6) respectively. According to the simulation model there could be no deficit of drinking water for the whole year. Simulated release for irrigation satisfied the demand fully except in the month of April. The irrigation requirement was 23.533 Mm^3 in April, which is relatively a high value. Only 17.68 Mm^3 could be met giving a deficit of 25 percent of the demand. The simulation releases for pisciculture and recreation suffered deficit only in the month of April. Hence the model overcomes the shortcomings of manual planning and gives a well distributed schedule for all demands of water.

The demand, actual release and simulated release for the year 1996- 1997 is presented in Fig.13(a), 13(b), 13(c) & 13(d) for the various purposes. The demand comes as 22.68 Mm^3, 110.56 Mm^3, 2.4 Mm^3 and 0.024 Mm^3 (Table 5) respectively, whereas the actual release for different purposes were 19.8 Mm^3, 97.95 Mm^3, 1.3 Mm^3 & 0.006 Mm^3 (Appendix- IV) respectively. As usual the drinking water was not met as the monthly release was 1.65 Mm^3 whereas the demand per month was 1.89 Mm^3. In the same way irrigation, pisciculture and recreation demands were not satisfied and there was deficiency in the month of April. Irrigation suffered deficit in the summer months from February to May. Pisciculture satisfied the demand only in the months of November and December and recreation in the month of August and September. This was because there was no proper distribution of water according to the crop water requirement. Therefore scientific release of water has to be adopted for proper water utilisation.

The simulated model shows that 100 percent of the drinking water demand, 89.35 percent of irrigation demand, 93.75 percent of pisciculture demand and 91.66 percent of the recreation demand was achieved (Fig. 14). This was possible because

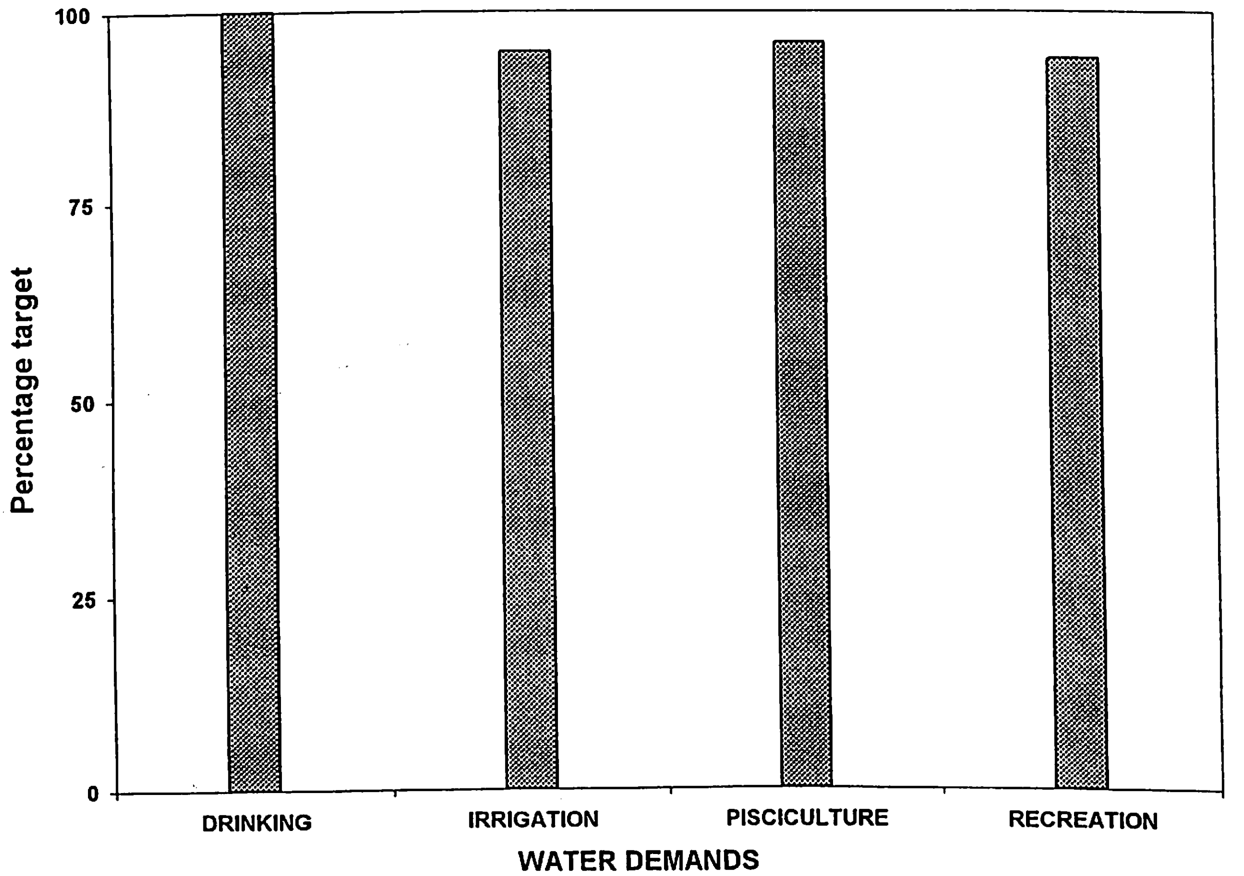


Fig. 12 Percentage target achieved for each purpose (1994-1995)

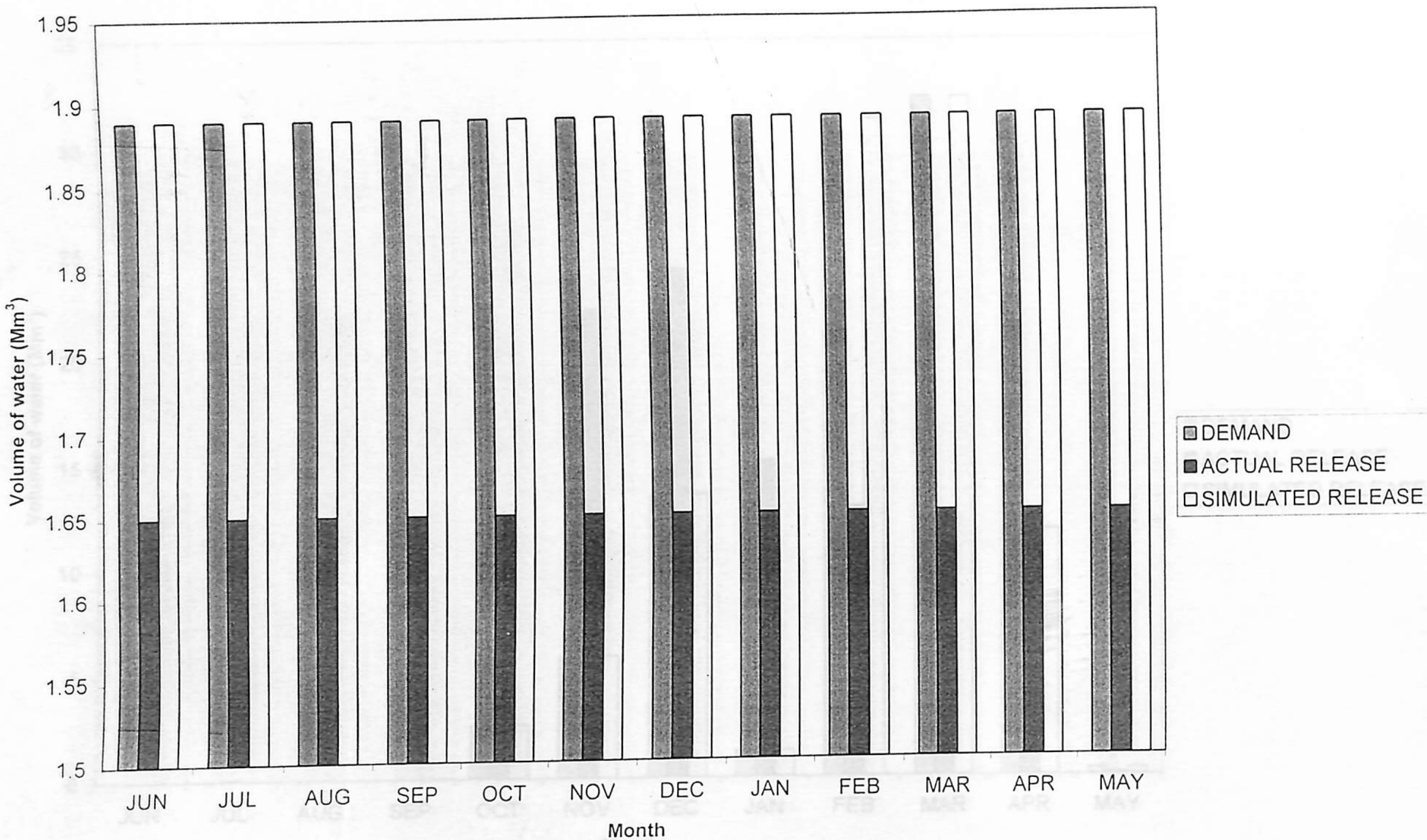


Fig. 13 (a) Comparison between demand, actual release and simulated release for drinking water (1996-1997)

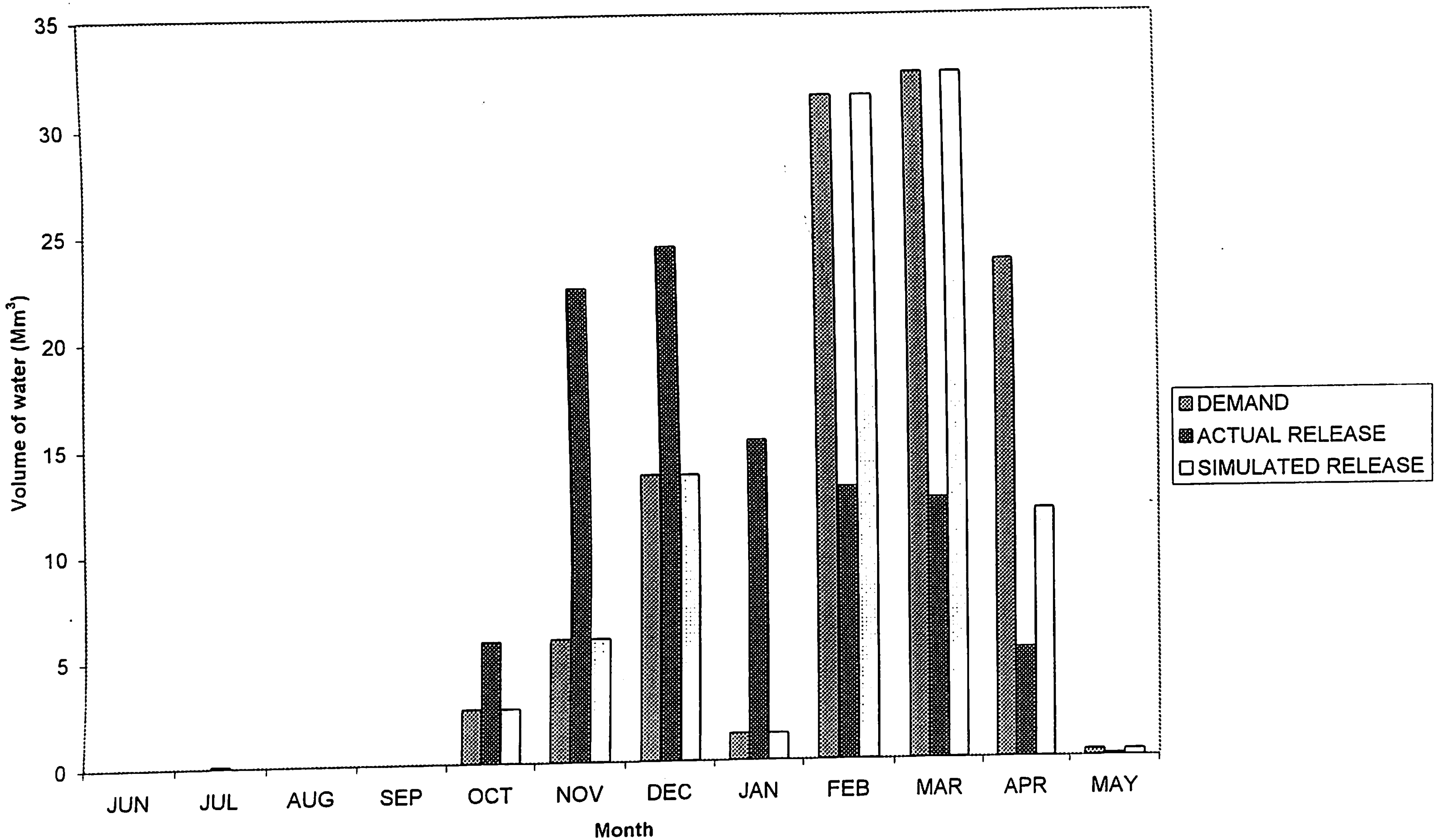


Fig. 13 (b) Comparison between demand, actual release and simulated release for irrigation (1996-1997)

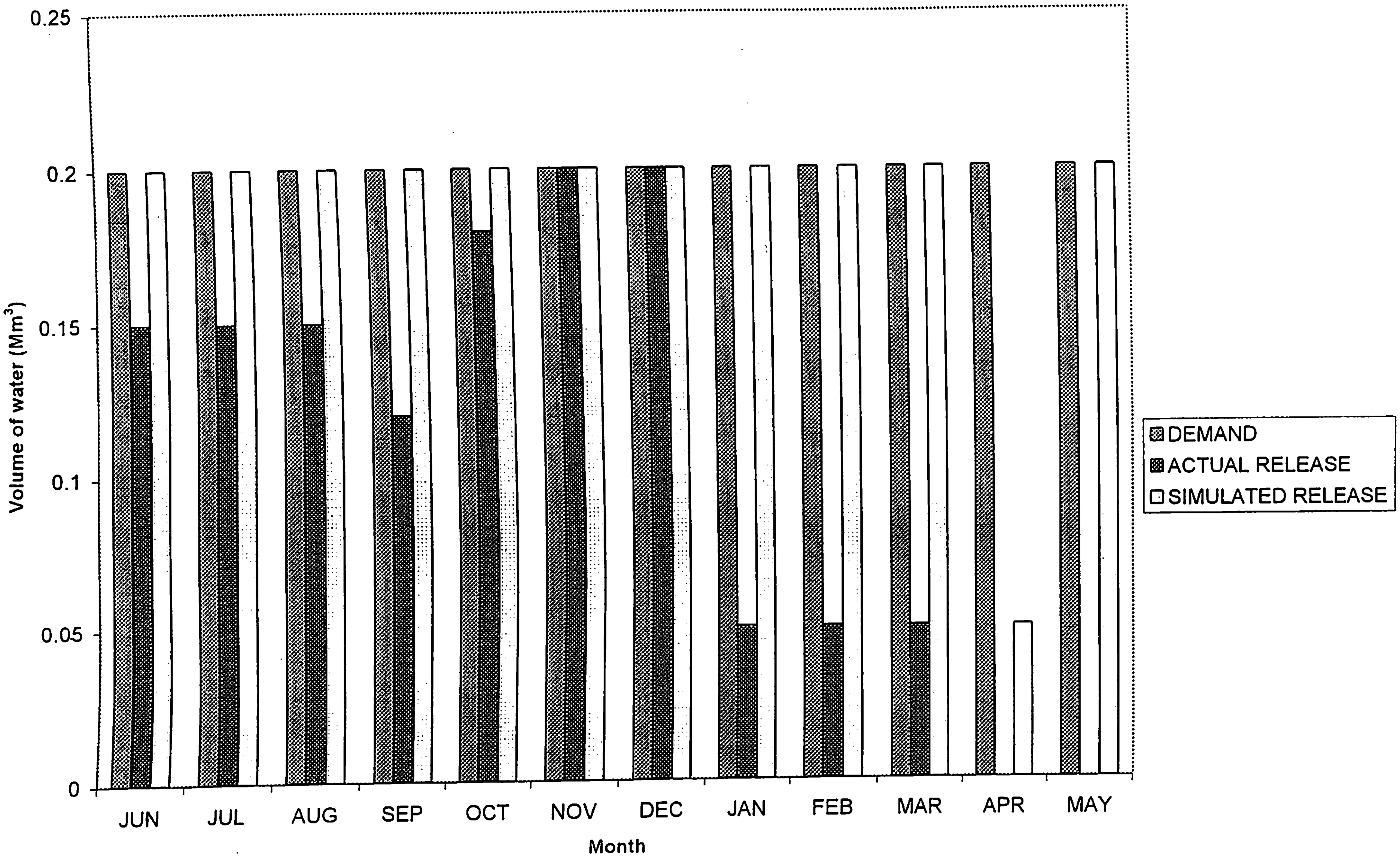


Fig. 13 (c) Comparison between demand, actual release, and simulated release for pisciculture (1996-1997)

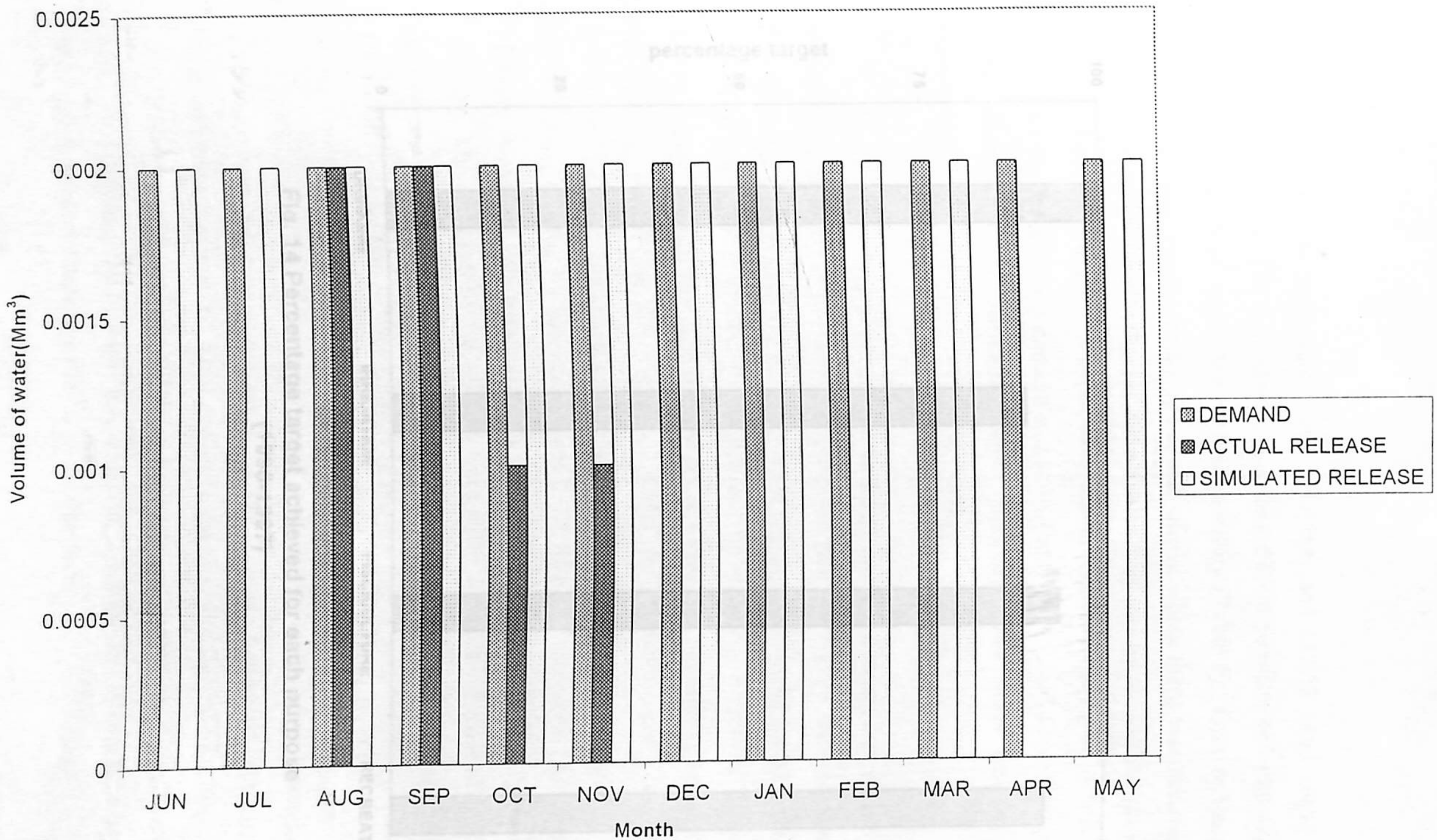


Fig. 13 (d) Comparison between demand, actual release and simulated release for recreation (1996-1997)

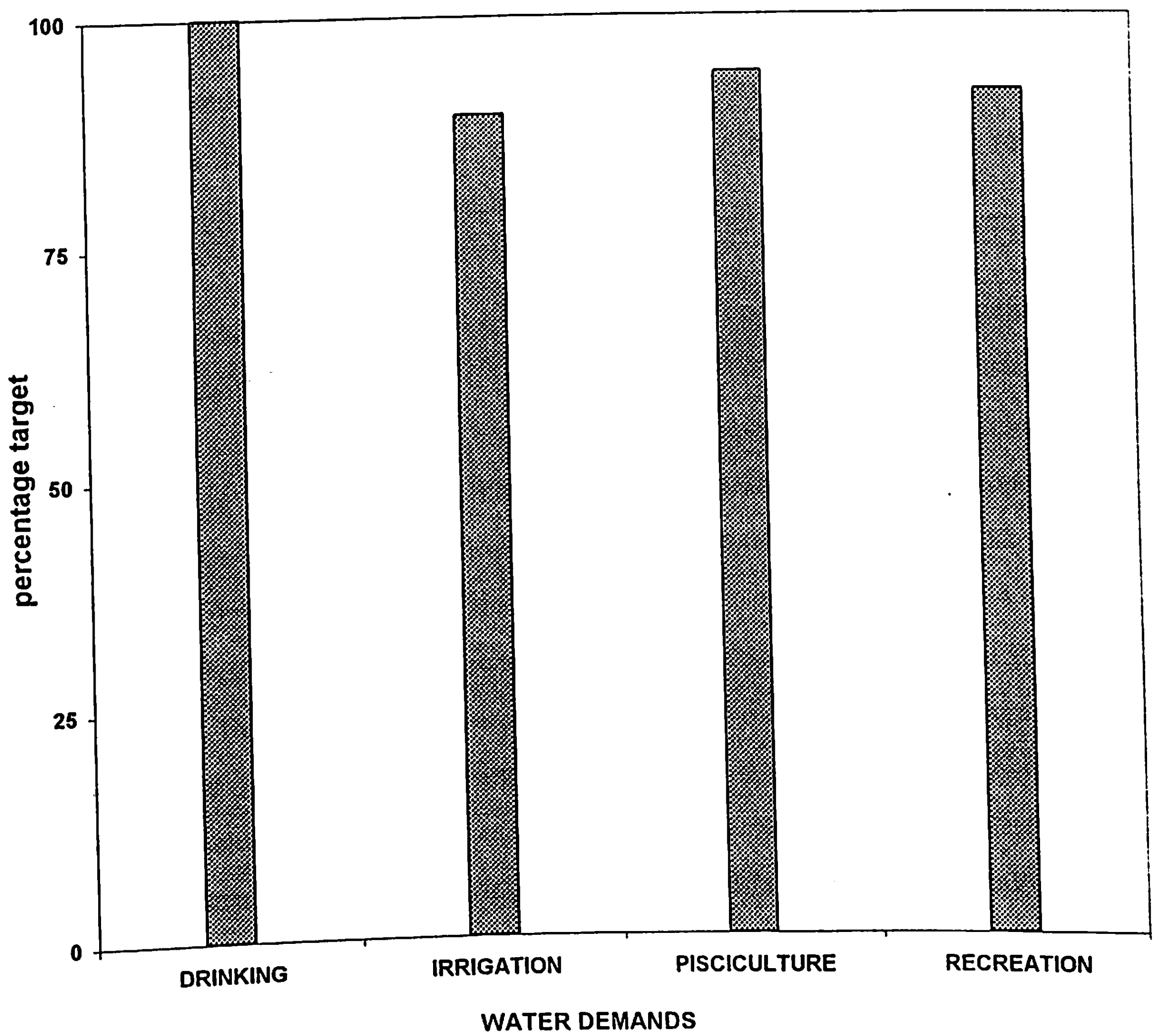


Fig. 14 Percentage target achieved for each purpose (1996-1997)

the total precipitation and inflow were 2445 mm and 128.55 Mm^3 respectively (Appendix- I & III). The simulated release for different purposes were 22.68 Mm^3, 98.795 Mm^3, 2.25 Mm^3 and 0.022 Mm^3 respectively (Table 6). Only in the month of April there was scarcity unlike the actual release where there was deficiency in most of the months. Drinking water demand was fully met by the simulation model. Water released for irrigation was not sufficient in the month of April as only 11.76 Mm^3 was released against a demand of 23.533 Mm^3, causing a deficit of 50 percent of the demand for the particular month. Similarly pisciculture and recreation experienced deficits only in the month of April.

Another set of releases that can be taken into consideration is where all the demands are satisfied to full extent. Taking the year 1997-1998 into consideration, Figures 15 (a), 15 (b), 15 (c) & 15(d) show the comparison of actual release and simulated release with respect to the demand for drinking, irrigation, pisciculture and recreation respectively. The demand for this year was recorded to be 22.68 Mm^3 for drinking, 110.56 Mm^3 for irrigation, 2.4 Mm^3 for pisciculture and 0.024 Mm^3 for recreation (Table5). The actual release was only 19.8 Mm^3 for drinking, 130.7 Mm^3 for irrigation, 1.3Mm^3 for pisciculture and 0.006 Mm^3 for recreation (Appendix-IV). Monthly release of 1.65 Mm^3 was only made when the demand was 1.89 Mm^3 for drinking. The actual irrigation releases were either in excess in most of the months or was not adequate, generally from February onwards till May. Pisciculture and recreation releases also showed scarcity in the summer months .

By simulation the targets set for drinking, irrigation, pisciculture and recreation were achieved to the full (Fig.16). This ideal situation was possible as there was enough rainfall of 3265 mm and a considerable amount of inflow of about 161.13 Mm^3 to the reservoir (Appendix I & III). The simulated releases were 22.68 Mm^3 for drinking, 110.56 Mm^3 for irrigation, 2.4 Mm^3 for pisciculture and 0.024 Mm^3 for recreation which matches with the demand.

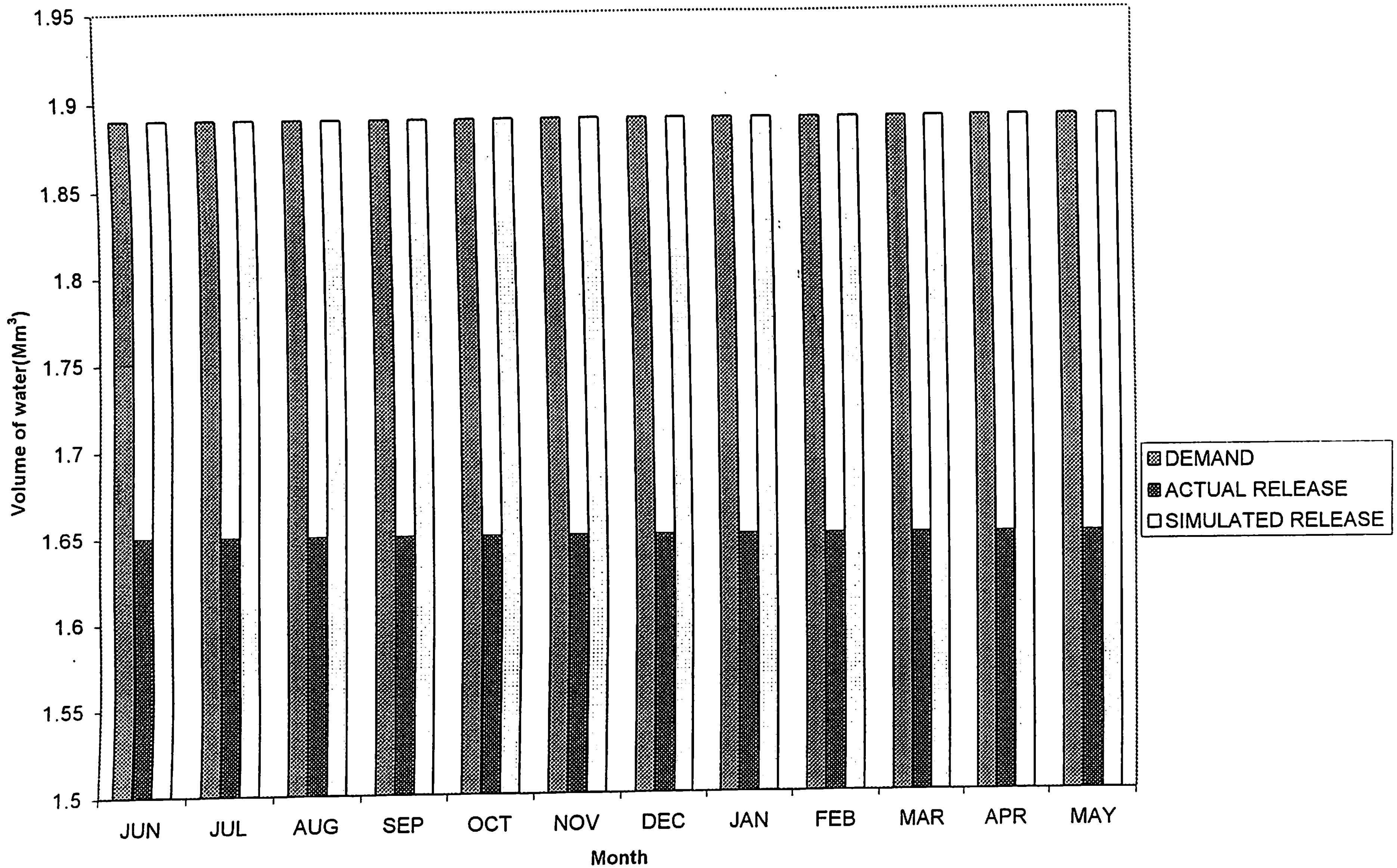


Fig. 15(a) Comparison between demand, actual release, and simulated release for drinking water (1997-1998)

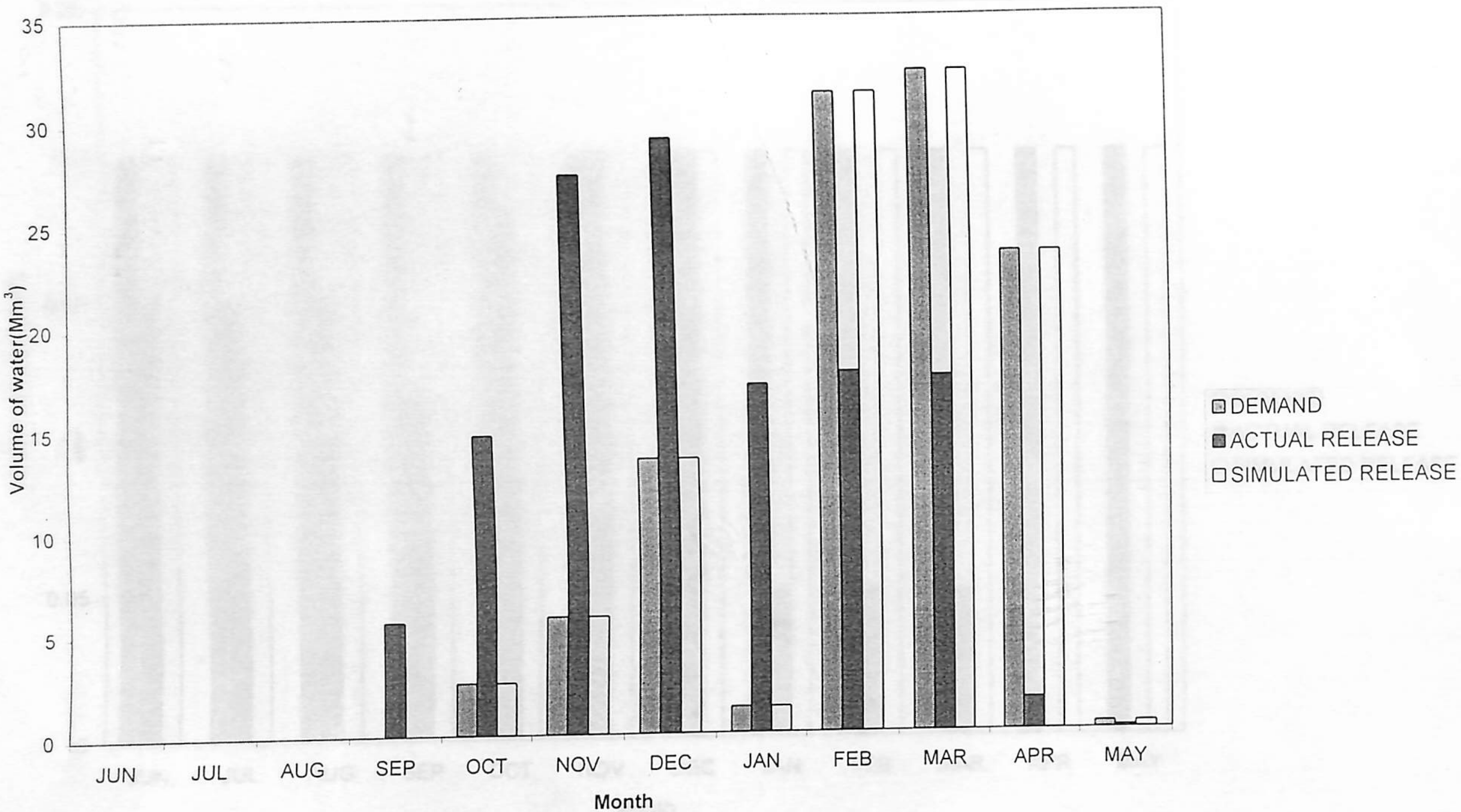


Fig.15 (b) Comparison between demand, actul release, and simulated release for irrigation(1997-1998)

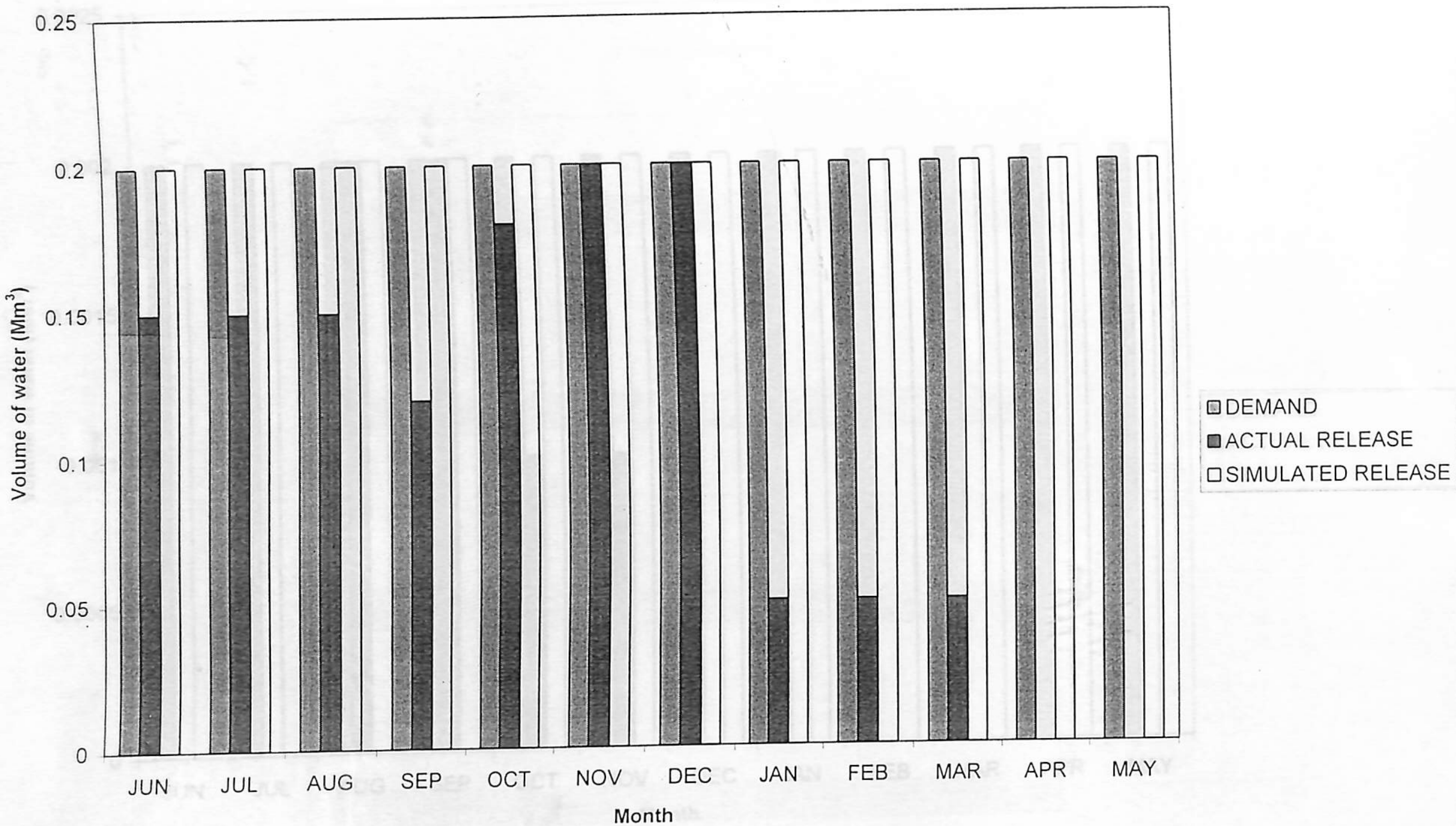


Fig.15 (c) Comparison betwen demand, actual release, and simulated release for pisciculture (1997-1998)

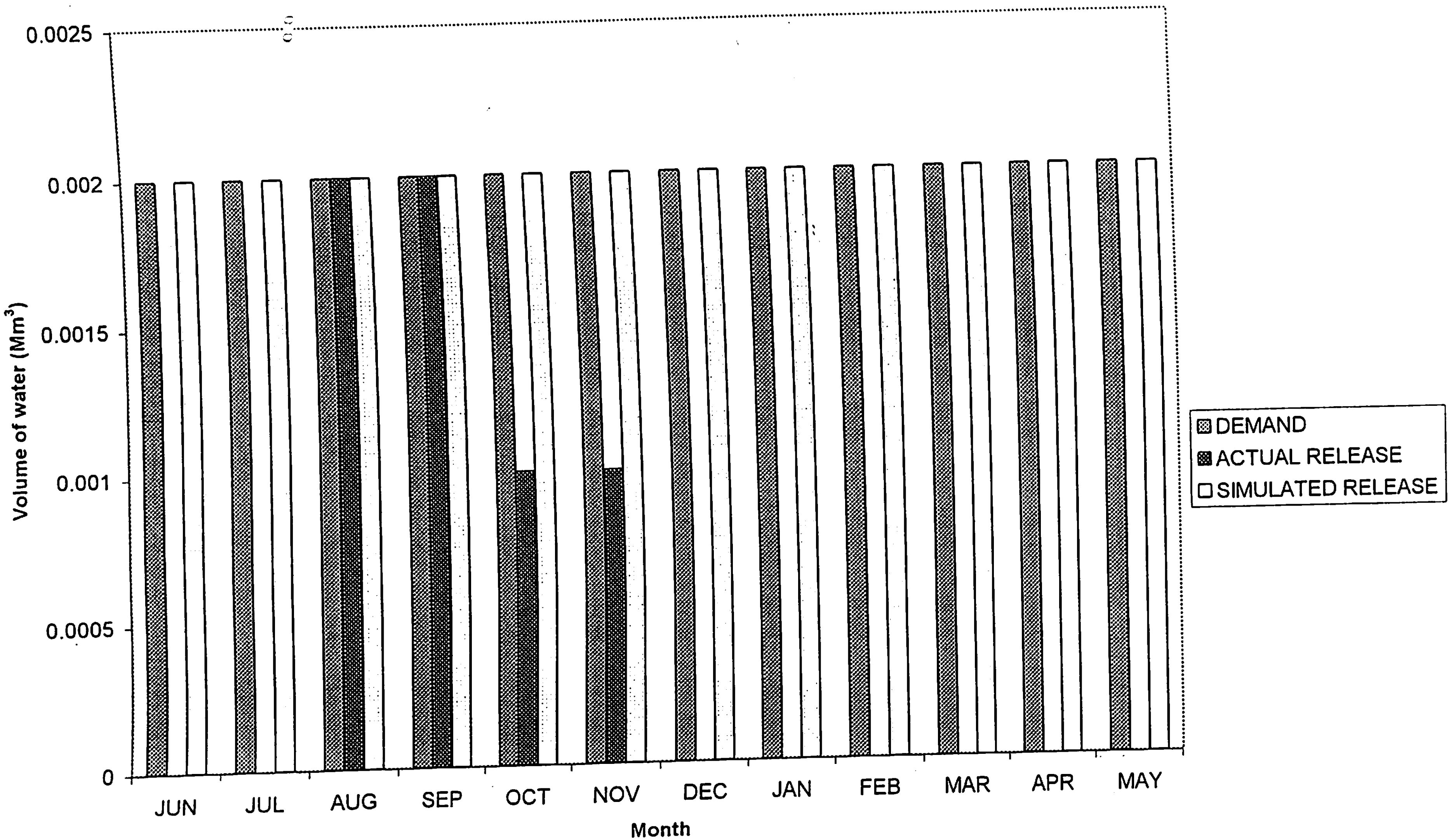


Fig. 15 (d) Comparison betwen demand, actual release, and simulated release for recreation (1997-1998)

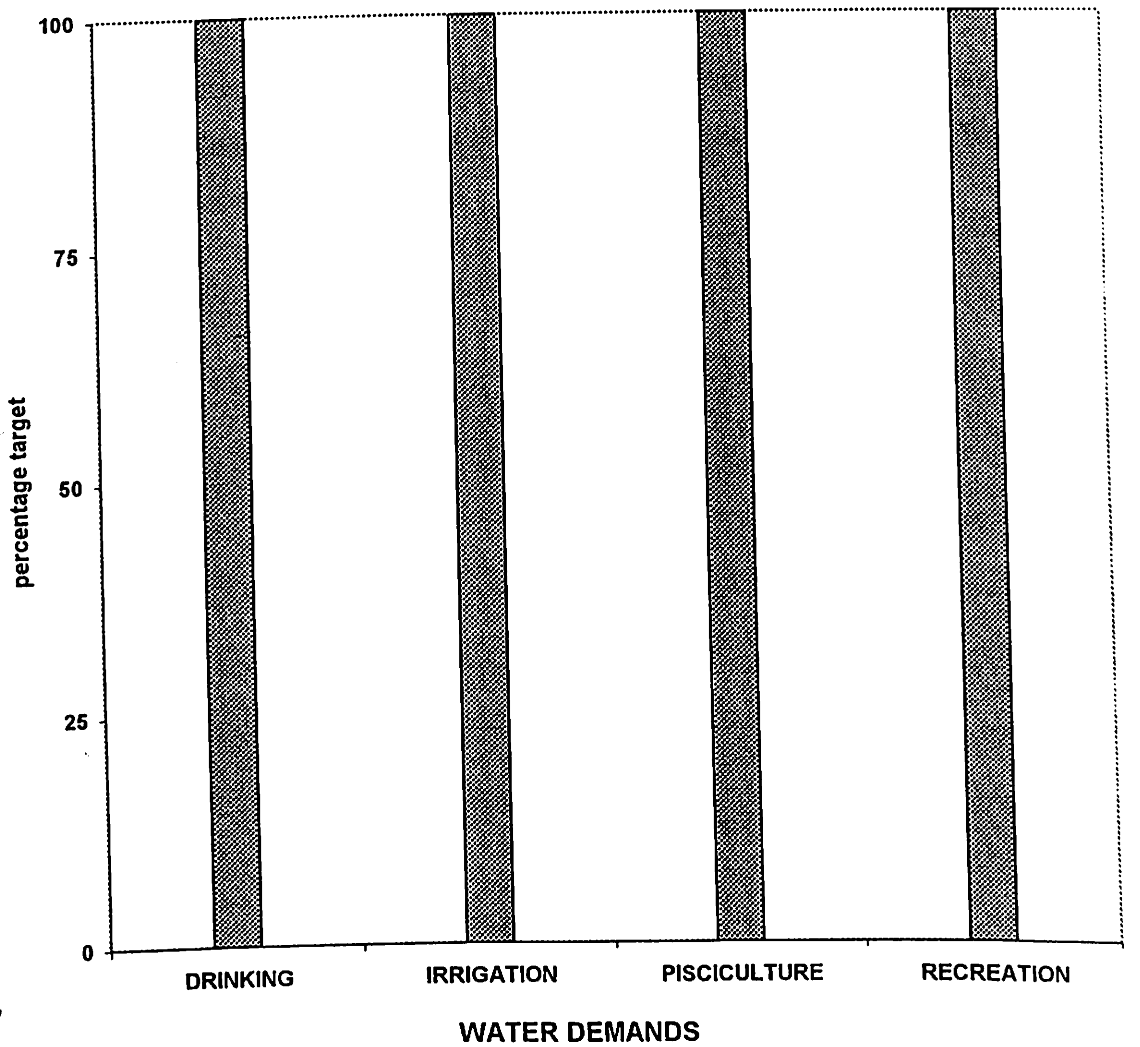


Fig. 16 Percentage target achieved for each purpose (1997-1998)

4.6 Limitations and suggestions

The results of the early years could not be taken for analysis as the value for various demands was assumed to be a constant over the years, due to lack of sufficient data. Hence the results are unrealistic in these years and can be viewed only as a test result of the simulation model.

The accuracy of the predictions can be increased by shortening the reservoir operation time. In the present study the operation period is one month while it can be 15 days or even shorter.

Summary & Conclusion

SUMMARY AND CONCLUSION

Planning and management of multipurpose reservoir systems have been and continue to be the subject of numerous research works. This attention is due to the essential benefits arising from scientific reservoir management. Since the adoption of modern techniques has become necessary for the management of water resources, an attempt has been carried out with the objective to develop a simulation model for a multipurpose reservoir. The reservoir management policy was evolved with a view to satisfy the water supply to Thrissur town, kole lands of Thrissur and to serve the facilities of pisciculture and recreation. The problem has been formulated as a monthly operation model based on historic stream flow. The operating horizon has been taken as twelve monthly periods from June to May.

The monthly water requirement for each purpose was considered as the target to be achieved i.e. the objective function was to minimize the deviations from the target release. For this the target was divided into four levels and the priorities were fixed. Since the targets were different for each of the objectives and in each month, the model accessed the highest value of target with highest priority. So there are sixteen releases made for different purposes in each month according to the priority assigned by the priority graph. The mathematical program was based on the continuity equation.

The inputs used for the algorithm developed were inflow, evaporation and water demands for different purposes. The algorithm developed was run with historical data of 35 years. The results gave the monthly releases and deficits of different demands. The conclusions derived from the present study can be summarised as follows.

1. Simulation approach to multiobjective reservoir shows the efficiency of the technique to handle complex water resource operation.

2. The flexibility of the model for changing the demands for allocation of water for different uses according to the changing needs of the region at any stage of the operation was brought out.
3. With the zoning of the target release an optimal allocation of water for all the purposes could be achieved to their priority levels.
4. It is seen that results obtained from the simulation model can be easily understood or even comprehended by non- technical decision-makers.
5. The versatility of the model is that it can incorporate changes and there in the model obtain the solution in the quickest time possible and is very user friendly.
6. The simulated model satisfied the drinking water demand for most of the years except a few years with deficiency in the months of April and May. This can be compensated by the fact that simulated release meets the specified demand in every other month, whereas the actual release is far below the demand.
7. In the case of irrigation there is no wastage of water in the months followed by rains or when there is no demand. Deficits are generally observed in the month of April and May, as the inflow is less.
8. There is enough water for pisciculture every month except for a few summer months. Harvesting is done in the dry months.
9. Recreation releases are not met by the model in the last 2,3 months of some years.

The present simulation study conducted for the previous years reveals that the reservoir operation policy adapted is adequate to meet all the different demands. The simulation approach suits very well for this system for the optimal releases.

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Appendices

APPENDIX I

RAINFALL DATA (mm)

MONTH	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	73-74	74-75
JUNE	456.4	825.2	256.6	727.5	643.2	938	544.2	964.8	779.7	895	561.8
JULY	788.3	774.3	809.9	274.8	674.5	303	631	903.1	318.46	586	107.93
AUG	448.2	516	266	664.9	688.5	255.2	646.2	350.4	546.7	534.2	564.6
SEP	501.1	134	153.7	72.1	302	231.7	174.3	254.9	461.8	342.6	445.6
OCT	223.3	107.2	540.7	97.7	86.3	199.9	193.4	246	219.4	189.3	105.2
NOV	119	82	236.8	51	10.5	134.9	35.3	28.2	137.9	89.36	62.5
DEC	23.3	78.45	56.5	419	0.9	50.8	0	29.1	0	0	0
JAN	0	0	0	0	0	0	1.6	0	0	0	0
FEB	0	0	0	61.5	0	0	7.9	0	0	1	0
MAR	0	51	12	149.5	0	0	0	0	1.6	2.3	52.2
APR	47.6	34.5	21.1	56.9	58.6	61.2	85.7	79.9	68.6	76.1	31.3
MAY	165.6	70.8	269.8	63.5	179.6	277.7	286.3	147.3	127.5	119.7	397.8
Total	2772.8	2673.45	2623.1	2638.4	2644.1	2452.4	2605.9	3003.7	2661.66	2835.56	2328.93

MONTH	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86
JUNE	932.6	247.3	480.8	780.3	611.4	978.4	968.4	784.9	467.92	490.5	907.4
JULY	657.6	891	656.2	795.5	997.8	624.3	558.2	605.1	774.75	763.4	786
AUG	365.6	400.1	262.5	828.8	502	582.8	629	620.9	710	700.33	583.1
SEP	465.8	194.4	283	68	201.6	124	412.5	83.6	389.1	75.63	113.63
OCT	308.2	175.1	319.6	123.6	108.2	432.3	75.5	194.2	100.65	390.5	149.7
NOV	275.8	241	299.8	291.1	249.3	207.8	106.7	84.54	59.25	31.13	37.2
DEC	1.1	1.2	0	70	0	5.8	0	7	8.1	62.78	22.05
JAN	0	0	0	0	0	0	0	0	0	0	0
FEB	0	0.2	21	29.9	0	0	0	1.4	0	0	0
MAR	15.4	12.1	69.5	25.8	0	12	14	25.1	35.55	0	0
APR	88.6	56.4	41.2	56.4	107.3	65.8	81.2	27.2	76.05	149.25	28.65
MAY	64.3	255.6	166.4	106.2	115.6	166.1	204.2	145.3	156.08	15.33	70.05
Total	3175	2474.4	2600	3175.6	2893.2	3199.3	3049.7	2579.24	2777.45	2678.85	2697.78

Contd. APPENDIX I

MONTH	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97
JUNE	176.9	401.2	968.3	814.05	717.2	960.7	900	402.5	853.1	954.3	668.1
JULY	748.73	345.05	934.5	608.06	887.5	988.6	792.1	100.3	1014.9	890.4	320
AUG	509.98	429	413.3	434.58	620.18	676.1	520.9	228	503.9	631.7	698.39
SEP	267.83	411	354.38	354.38	191.47	175.51	147.6	363	77.1	335	361.9
OCT	142.62	226.73	58.8	205.1	140.75	178.7	239.6	396	399.7	158.4	208.1
NOV	433.58	186.93	56.28	87.53	95.01	138.7	355.3	642	87.2	92.7	16.5
DEC	9.9	241	18.93	0	0	0	2	18.4	0	0	82
JAN	0	0	0	7.35	0	0	0	49.5	0	0	0
FEB	0	0	0	0	0	0	0	0.2	4.8	0	0
MAR	0	3	7.35	0	0	0	0.2	20.6	6.5	0	0
APR	0	95.54	43.2	10.8	9.26	24.5	58.5	163.7	47.2	78.7	0
MAY	118.27	96.35	73.27	125.7	28.4	121.1	160	86	380.4	29.7	90.5
Total	2407.81	2435.8	2928.31	2647.55	2689.77	3263.91	3176.2	2470.2	3374.8	3170.9	2445.49

MONTH	97-98	98-99	TOTAL	AVER
JUNE	756.8	637.3	24452.77	698.651
JULY	878.5	702	23491.78	671.194
AUG	728.5	519.5	18580.06	530.859
SEP	489.2	797	9810.43	280.298
OCT	113.6	79.2	7133.25	203.807
NOV	190.7	154	5407.51	154.5
DEC	11	26	1245.31	35.5803
JAN	0	0	58.45	1.67
FEB	0	0	127.9	3.65429
MAR	0	8.5	524.2	14.9771
APR	10.5	13.1	1954.55	55.8443
MAY	86.4	170	5136.85	146.767
Total	3265.2	3106.6	97923.06	2797.8

APPENDIX II

EVAPORATION DATA (Mm^3)

MONTH	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	73-74	74-75	75-76
JUN	0.234	0.1342	0.2746	0.3462	0.139	0.382	0.3645	0.356	0.232	0.163	0.146	0.136
JUL	0.042	0.3562	0.0136	0.164	0.2643	1.642	0.192	0.623	0.461	0.12	0.346	0.004
AUG	0.0264	0.9732	0.5632	0.246	0.5321	0.347	0.301	0.164	0.334	0.142	0.542	0.142
SEP	0.38	0.5621	0.634	0.563	0.6843	0.139	0.345	0.322	0.764	0.14	0.646	0.04
OCT	0.49	0.6731	0.782	0.542	0.733	0.953	0.643	0.742	0.546	0.746	0.613	0.33
NOV	0.5	0.7236	0.547	0.462	0.701	0.646	0.562	0.963	0.589	0.834	0.731	0.562
DEC	0.63	0.7834	0.5432	0.764	0.721	0.946	0.964	0.843	0.84	0.946	0.83	0.642
JAN	0.581	0.907	0.873	0.9463	0.934	1.47	0.843	1.06	0.94	0.98	0.96	0.691
FEB	0.732	0.8673	0.9231	0.846	1.362	0.846	1.462	1.09	0.98	0.97	0.92	0.731
MAR	0.846	1.632	1.463	0.372	1.433	1.002	1.5	1.846	1.36	1.4	0.94	0.798
APR	0.923	1.253	1.242	1.86	1.365	1.016	1.42	1.94	1.4	1.536	1.36	0.946
MAY	1.03	0.963	1.046	1.9	1.4	1	1.56	1.98	1.41	1.63	1.48	0.997
TOTAL	6.4144	9.8281	8.9047	9.0115	10.2687	10.389	10.1565	11.929	9.856	9.607	9.514	6.019

MONTH	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88
JUN	0.234	0.194	0.262	0.463	0.0264	0.016	0.113	0.634	0.342	0.341	0.246	0.326
JUL	0.146	0.246	0.132	0.141	0.562	0.12	0.28	0.162	0.162	0.14	0.212	0.121
AUG	0.341	0.382	0.244	0.36	0.16	0.24	0.214	0.004	0.243	0.361	0.132	0.112
SEP	0.375	0.364	0.46	0.34	0.15	0.26	0.213	0.172	0.421	0.432	0.562	0.467
OCT	0.264	0.521	0.441	0.573	0.242	0.42	0.464	0.593	0.251	0.416	0.229	0.264
NOV	0.316	0.673	0.52	0.641	0.241	0.41	0.321	0.742	0.643	0.642	0.28	0.646
DEC	0.3	0.722	0.49	0.721	0.346	0.52	0.642	0.79	0.621	0.531	0.68	0.734
JAN	0.542	0.84	0.637	0.846	0.746	0.63	0.732	0.834	0.742	0.831	0.731	0.842
FEB	0.831	0.96	0.66	0.946	0.891	0.72	0.842	0.801	0.831	0.821	0.714	0.723
MAR	0.88	0.98	0.74	0.952	0.942	0.84	0.921	0.816	0.921	0.816	0.846	0.71
APR	0.926	1.33	0.81	1.28	1.34	0.72	0.961	0.814	1.36	0.932	0.533	0.89
MAY	0.97	1.42	0.93	0.98	1.38	0.81	0.981	0.942	1.21	0.914	0.92	0.892
TOTAL	6.125	8.632	6.326	8.243	7.0264	5.706	6.684	7.304	7.747	7.177	6.085	6.727

Contd. APPENDIX II

MONTH	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	TOTAL	MEAN
JUN	0.321	0.162	0.362	0.341	0.263	0.462	0.264	0.462	0.643	0.632	0.364	10.3809	0.2965971
JUL	0.164	0.112	0.141	0.04	0.121	0.143	0.101	0.243	0.342	0.161	0.164	8.3841	0.2395457
AUG	0.021	0.131	0.236	0.166	0.192	0.231	0.193	0.394	0.531	0.234	0.012	9.4469	0.2699114
SEP	0.001	0.32	0.641	0.463	0.211	0.53	0.34	0.321	0.34	0.6	0.318	13.5204	0.3862971
OCT	0.315	0.121	0.39	0.32	0.2	0.34	0.48	0.101	0.31	0.43	0.26	15.7381	0.44966
NOV	0.53	0.635	0.35	0.43	0.216	0.563	0.56	0.493	0.53	0.41	0.64	19.2526	0.5500743
DEC	0.82	0.52	0.651	0.436	0.732	0.734	0.64	0.421	0.51	0.58	0.364	22.9576	0.6559314
JAN	0.56	0.804	0.732	0.846	0.849	0.834	0.62	0.643	0.64	0.52	0.946	28.1323	0.80378
FEB	0.51	0.831	0.641	0.321	0.79	0.721	0.534	0.531	0.72	0.734	0.76	28.5624	0.8160686
MAR	0.81	0.813	0.621	0.396	0.942	0.834	0.522	0.589	0.53	0.617	0.843	32.473	0.9278
APR	0.87	0.931	0.432	0.91	0.916	0.92	0.734	0.734	0.59	0.432	0.846	36.472	1.0420571
MAY	0.92	0.82	0.841	0.97	0.99	1.34	0.721	0.62	0.84	0.931	0.941	38.679	1.1051143
TOTAL	5.842	6.2	6.038	5.639	6.422	7.652	5.709	5.552	6.526	6.281	6.458	263.9993	7.5428371

APPENDIX III

INFLOW DATA (Mm^3)

MONTH	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	73-74	74-75	75-76	76-77
JUNE	21.436	17.849	24.356	19.257	48.321	24.369	19.354	17.789	33.32	30.364	32.256	26.354	14.329
JULY	50.83	50.567	55.675	56.258	23.354	38.364	37.64	75.456	34.453	39.25	39.247	74.25	26.216
AUG	28.36	20.354	20.1867	37.458	23.78	34.36	36,241	37.248	21.453	25.147	15.14	18.365	25
SEP	21.423	20.419	14.25	12.354	15.897	16.38	13.147	25.247	5.324	22.14	9.247	14.258	8.219
OCT	11.64	9.954	19.56	10.258	13.56	9.365	8.365	14.354	16.238	20.147	5.458	25.369	12.45
NOV	10.46	18.352	8.584	5.241	10.78	14.255	12.874	8.964	13.458	11.147	8.254	24.16	3.354
DEC	4.32	3.984	6.697	6.2547	18.1	8.241	3.412	6.147	7.786	10.258	6.369	27.15	2.385
JAN	5.68	3.654	4.786	4.257	1.987	5.541	6.247	3.148	9.258	4.124	4.54	2.147	4.215
FEB	5.41	1.352	2.435	2.3147	1.5471	6.368	3.014	4.251	4.546	6.214	5.425	1.385	5.145
MAR	2.36	0.0265	1.34	0.2367	2.254	2.254	1.47	1.024	1.232	1.3654	1.347	0.0125	4.15
APR	1.42	1.698	0.2547	0.645	1.35	0.4102	0.314	0.3657	0.154	0.258	0.8741	0.0127	0.0115
MAY	1.87	1.542	0.2147	1.47	1.687	0.1768	0.147	0.168	0.152	0.0014	0.625	0.005	0.102
Total	165.209	149.7515	158.3391	156.0041	162.6171	160.084	142.225	194.1617	147.374	170.4158	128.7821	213.4682	105.5765

MONTH	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
JUNE	36.214	55	38.321	49.0514	58.0185	28.02	15.462	16.302	35.24	12.7542	10.10622	30.661	29.16
JULY	22.354	51.257	41.3256	19.7737	44.6827	42.043	35.777	51.337	41.4112	20.616	18.2007	27.859	31.363
AUG	12.146	46.147	23.14	29.5963	39.3337	11.672	55.615	25.848	30.791	28.4695	19.887	39.752	21.326
SEP	14.158	15.147	24.214	15.5218	38.2317	14.032	31.144	14.622	12.705	7.829	9.955	41.3803	11.754
OCT	13.564	18.124	15.147	28.686	13.3743	11.362	6.617	23.201	13.311	17.864	13.335	13.1847	17.731
NOV	12.147	8.365	12.354	27.22	14.4485	11.629	9.883	7.328	5.384	12.5664	9.214	8.703	7.109
DEC	12.45	13.147	10.125	27.06	3.7321	7.462	4.062	7.005	7.438	4.9994	7.251	2.192	5.468
JAN	4.369	5.145	2.0936	2.8117	2.9346	4.75384	1.748	3.317	1.006	2.798	3.416	2.347	2.347
FEB	2.147	4.258	0.3861	1.3478	1.623	2.595	2.668	4.5051	2.625	5.914	8.179	1.646	1.231
MAR	1.64	1.36	0.2895	0.0676	0.4672	6.956	2.133	1.262	2.4564	4.364	9.707	7.61	2.581
APR	0.6472	0.235	1.0691	0.8006	0.9823	0.3908	0.742	0.23	0.6464	6.8912	6.627	0.287	0.252
MAY	0.3147	0.684	1.3146	0.6898	0.7645	0.8698	0.196	0.623	0.76	0.235	0.93	0.545	2.925
Total	132.151	218.869	169.7795	202.6267	218.5931	141.7854	166.047	155.5801	153.774	125.3007	116.8079	176.167	133.247

contd. APPENDIX- III

MONTH	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	TOTAL	MEAN
JUNE	17.491	18.989	13.1748	9.389	25.112	11.565	4.5816	4.6307	13.13827	861.7357	24.62102
JULY	58.834	74.695	66.204	39.314	72.879	41.3266	23.035	52.15066	40.2556	1518.254	43.37868
AUG	29.724	52.594	41.586	28.952	32.6507	26.5495	19.44	46.6018	57.4543	1062.369	30.35339
SEP	3.515	7.625	15.355	6.341	21.9324	26.328	27.715	3.98	27.2913	589.0815	16.8309
OCT	11.885	11.6095	20.356	19.355	12.4	68.3664	23.177	10.2635	35.7219	595.3533	17.01009
NOV	11.73	8.907	18.8122	8.957	9.8667	7.4385	4.8263	13.7748	10.075	390.6214	11.16061
DEC	3.237	8.954	8.69	4.186	4.8159	10.4801	6.118	7.1786	13.542	290.6968	8.305623
JAN	2.836	3.19	2.104	3.104	4.067	3.51	4.504	6.75384	0.2669	129.0065	3.685899
FEB	3.162	3.12	4.358	2.584	3.502	7.35	3.55	2.59562	10.9648	129.7182	3.706235
MAR	3.763	5.977	2.764	3.239	4.691	5.05	5.931	6.956	5.5548	103.8916	2.968331
APR	1.608	0.5	2.165	2.11	2.317	1.215	4.8963	5.3906	5.236	53.0064	1.514469
MAY	0.463	0.4942	2.6048	0.9852	3.544	4.4712	0.7789	0.85698	4.251	37.46158	1.070331
Total	148.248	196.6547	198.1738	128.5162	197.7777	213.6503	128.5531	161.1331	223.7519	5761.195	164.6056

APPENDIX IV

ACTUAL RELEASE (IRRIGATION, Mm^3)

MONTH	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	73-74
JUN	0	0	0	0	0	0	0	0	0	0
JUL	0	0	0	1.1	0	0	0	0.5	0	0
AUG	0	0	0	1.29	6.06	4.22	0	0.101	1.302	12.21
SEP	22.13	16.402	17.432	2.3	18.43	24.32	0	22.36	18.46	26.42
OCT	27.41	21.64	27.64	25.62	19.18	21.12	15.36	27.64	25.32	18.19
NOV	27.48	28.94	23.32	24.29	26.41	25.31	27.16	26.32	22.61	22.31
DEC	28.64	25.93	25.6	27.31	22.32	21.42	25.43	28.16	22.21	20.17
JAN	3.26	6.41	9.32	15.26	4.61	1.27	5.21	15.92	3.01	5.21
FEB	18.41	8.26	9.41	18.11	16.22	18.31	27.31	15.21	16.32	14.36
MAR	12.31	16.49	18.36	16.21	20.19	15.26	15.26	27.61	12.19	22.21
APR	3.04	0	1.4	2.6	3.21	0	1.09	2.11	0	3.11
MAY	0	0	0	0	0	0	0	0	0	0
Total	142.68	124.072	132.482	134.09	136.63	131.23	116.82	165.931	121.422	144.19

MONTH	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84
JUN	0	0	0	0	0	0	0	0	0	0
JUL	0	0	0	0	0	0	0	0.228	0	0
AUG	0	26.353	0	0	61.898	13.971	14.614	40.595	0	0
SEP	14.61	37.252	11.056	13.3	17.508	21.994	36.379	38.082	17.262	18.89
OCT	25.104	27.9145	15.96	17.096	28.838	25.297	23.772	26.571	27.088	30.118
NOV	26.32	23.959	14.83	11.498	20.646	21.271	21.913	24.288	24.466	28.38
DEC	4.212	28.079	12.55	25.33	22.276	20.335	27.285	27.559	20.406	28.38
JAN	3.939	6.096	2.789	5.621	7.308	5.496	8.88	5.909	0	3.84
FEB	11.69	16.42	2.448	10.369	4.736	12.568	21.906	15.406	18.167	19.185
MAR	14.954	22.657	19.137	17.976	23.671	21.463	20.827	20.688	11.829	13.376
APR	2.477	3.045	3.914	5.084	9.383	3.22	3.711	2.285	0	0
MAY	0	0	0	0	0	0	0	0	0	0
Total	103.306	191.7755	82.684	106.274	196.264	145.615	179.287	201.611	119.218	142.169

Contd. APPENDIX IV

Contd. ACTUAL RELEASE (IRRIGATION, Mm^3)

MONTH	84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
JUN	0	0	0	2.94	0	0	0	0	0	0
JUL	0	0	0	0	3.038	0	0	0	0	0
AUG	0	5.3368	0	0	3.038	0	2.608	33.856	14.562	0.53
SEP	18.476	21.915	2.383	0	10.928	0	3.693	20.553	15.937	2.954
OCT	24.501	22.015	10.872	9.524	21.787	11.58	22.874	21.819	23.049	11.044
NOV	27.38	26.58	8.861	3.184	28.74	20.735	18.481	23.745	22.696	23.265
DEC	24.08	22.386	25.326	11.163	22.089	23.421	20.004	22.71	27.397	24.137
JAN	8.446	1.21	5.843	5.246	15.21	6.462	8.099	12.737	12.495	9.425
FEB	11.341	13.995	18.934	26.033	17.812	26.838	25.345	15.337	26.975	14.067
MAR	17.892	16.001	26.431	22.36	18.601	16.771	18.021	19.035	17.843	16.073
APR	0	0	5.167	12.176	9.689	1.26	3.559	1.276	12.03	0
MAY	0	0	0	0	0	0	0	0	0	0
Total	132.116	129.4388	103.817	92.626	150.932	107.067	122.684	171.068	172.984	101.495

MONTH	94-95	95-96	96-97	97-98	98-99	TOTAL
JUN	0	0	0	0	0	2.94
JUL	0.042	0.1	0.1	0	0.1	5.208
AUG	6.78	18.02	0	0	0.1	267.4448
SEP	20.34	17.56	0	5.587	29.16	564.073
OCT	24.94	26.192	5.703	14.7488	13.4065	740.9338
NOV	23.66	26.474	22.32	27.383	37.16	812.385
DEC	28.861	28.861	24.24	29.13	40.07	837.477
JAN	20.04	15.494	15.131	17.096	26.42	298.712
FEB	16.656	17.531	12.89	17.673	3.184	559.426
MAR	17.98	17.332	12.316	17.459	23.243	640.026
APR	3.683	3.092	5.15	1.53	6.45	114.741
MAY	5	13.8	0.1	0.1	13.508	32.508
Total	167.982	184.456	97.95	130.7068	192.8015	4875.8746

Contd. APPENDIX - IV

ACTUAL RELEASE

DRINKING (Mm^3)

MONTH	64-87	87-94	94-99
JUN	0.93	1.26	1.65
JUL	0.93	1.26	1.65
AUG	0.93	1.26	1.65
SEP	0.93	1.26	1.65
OCT	0.93	1.26	1.65
NOV	0.93	1.26	1.65
DEC	0.93	1.26	1.65
JAN	0.93	1.26	1.65
FEB	0.93	1.26	1.65
MAR	0.93	1.26	1.65
APR	0.93	1.26	1.65
MAY	0.93	1.26	1.65
Total	11.16	15.12	19.8

PISCICULTURE (Mm^3)

MONTH	64-99
JUN	0.15
JUL	0.15
AUG	0.15
SEP	0.12
OCT	0.18
NOV	0.2
DEC	0.2
JAN	0.05
FEB	0.05
MAR	0.05
APR	0
MAY	0
Total	1.3

RECREATION (Mm^3)

MONTH	64-99
JUN	0
JUL	0
AUG	0.002
SEP	0.002
OCT	0.001
NOV	0.001
DEC	0
JAN	0
FEB	0
MAR	0
APR	0
MAY	0
Total	0.006

PROGRAMMING VARIABLES

CPW(i,j)	:	Crop water requirement
Ddo	:	Drinking water demand
Dso	:	Dead storage
EVP (i,j)	:	Evaporation
FDo	:	Pisciculture demand
INF (i,j)	:	Inflow
MC	:	Maximum capacity for opening of shutters
PM (i,j)	:	Previous month's storage
Rdo	:	Recreation demand
REL	:	Release
RSTOR	:	Remaining storage
Seep	:	Seepage and other losses
SPD (i,j)	:	Spillway discharge
STORCM (i,j)	:	Initial storage .
TODRIWAT(i,j)	:	Total water for drinking
TOFISWAT (i,j)	:	Total water for pisciculture
TOIRRWAR(ij)	:	Total water for irrigation
TORECWAT(i,j)	:	Total water for recreation
YR1 (i,j)	:	Water year 1
YR2 (i,j)	:	Water year 2

APPENDIX –V

PROGRAM FOR RESERVOIR SIMULATION MODEL (VB-6.0)

WELCOME FORM:

NEXT button:

```
Private Sub Command1_Click()
Load RESERVOIRSIM
RESERVOIRSIM. Show
End Sub

Private Sub Form_Load()
Module1.FNAME
End Sub

Private Sub Command2_Click()
Unload Me
End Sub
```

INPUT FILE FORM:

ADD button:

```
Private Sub Command1_Click()
Module1.Add
End Sub

Private Sub Command2_Click()
txtIN. Text = " "
txtEVP. Text = " "
txtCW. Text = " "
End Sub
```

RESULT button:

```
Public Sub Command5_Click()
Module1.RESULT
End Sub
```

EXIT button:

```
Private Sub Command3_Click()
Unload Me
End Sub
```

OUT PUT FORM:

```
Private Sub Command1_Click()
Module1.prev
End Sub
Private Sub Command2_Click()
```

```
Module1.nxt
End Sub

Private Sub Command3_Click()
Unload Me
End Sub
```

MODULE1 :

```
Public FILNAME, MON(60, 13) As String
Public RecNo, COUNT, YR1(60, 13), YR2(60, 13), y As Integer
Public TODRIWAT(60, 13), TOIRRWAT(60, 13), TOFISWAT(60, 13), TORECWAT(60, 13),
PM(60, 13), STORCM(60, 13) As Double
Public INF(60, 13), EVP(60, 13), SPD(60, 13) As Double
Public CRecNo As Integer

Public Sub FNAME()
FILNAME = InputBox("ENTER A FILE NAME FOR STORING THE RESERVOIR DATA ( C:\......)")
End Sub
```

ADD subroutine:

```
Public Sub Add()
Dim Y1, Y2 As Integer
Dim i, EV, CW As Single
Dim M As String
RecNo = RecNo + 1
Open FILNAME For Append As #1
Y1 = RESERVOIRSIM.txtY1.Text
Y2 = RESERVOIRSIM.txtY2.Text
M = RESERVOIRSIM.txtM.Text
i = RESERVOIRSIM.txtIN.Text
EV = RESERVOIRSIM.txtEVP.Text
CW = RESERVOIRSIM.txtCW.Text
Write #1, Y1, Y2, M, i, EV, CW
Close #1
If (RecNo < 12 * (COUNT + 1)) Then
RESERVOIRSIM.txtY1.Text = Y1
RESERVOIRSIM.txtY2.Text = Y2
Else
RESERVOIRSIM.txtY1.Text = RESERVOIRSIM.txtY1.Text + 1
RESERVOIRSIM.txtY2.Text = RESERVOIRSIM.txtY2.Text + 1
COUNT = COUNT + 1
End If
If RESERVOIRSIM.txtM.Text = "JUN" Then RESERVOIRSIM.txtM.Text = "JUL": GoTo 10
If RESERVOIRSIM.txtM.Text = "JUL" Then RESERVOIRSIM.txtM.Text = "AUG": GoTo 10
If RESERVOIRSIM.txtM.Text = "AUG" Then RESERVOIRSIM.txtM.Text = "SEP": GoTo 10
If RESERVOIRSIM.txtM.Text = "SEP" Then RESERVOIRSIM.txtM.Text = "OCT": GoTo 10
If RESERVOIRSIM.txtM.Text = "OCT" Then RESERVOIRSIM.txtM.Text ="NOV": GoTo 10
If RESERVOIRSIM.txtM.Text = "NOV" Then RESERVOIRSIM.txtM.Text ="DEC": GoTo 10
If RESERVOIRSIM.txtM.Text = "DEC" Then RESERVOIRSIM.txtM.Text = "JAN": GoTo 10
If RESERVOIRSIM.txtM.Text = "JAN" Then RESERVOIRSIM.txtM.Text = "FEB": GoTo 10
If RESERVOIRSIM.txtM.Text = "FEB" Then RESERVOIRSIM.txtM.Text ="MAR": GoTo 10
If RESERVOIRSIM.txtM.Text = "MAR" Then RESERVOIRSIM.txtM.Text="APR": GoTo 10
If RESERVOIRSIM.txtM.Text = "APR" Then RESERVOIRSIM.txtM.Text="MAY": GoTo 10
If RESERVOIRSIM.txtM.Text = "MAY" Then RESERVOIRSIM.txtM.Text = "JUN"
```

```
10 RESERVOIRSIM.txtIN.Text = ""
RESERVOIRSIM.txtEVP.Text = ""
RESERVOIRSIM.txtCW.Text = ""
End Sub
```

RESULT subroutine :

```
Public Sub RESULT()
Dim i, j, k, l, DamCount As Integer
Dim CPW(60, 13), IST(60, 13), DD(60, 13), ID(60, 13), FD(60, 13), RD(60, 13), RS(60, 13) As Double
Dim DSo, DDo, FDo, RDo, seep As Single
Dim REL1, REL2, REL3, REL4, REL5, REL6, REL7, REL8, REL9, REL10, REL11, REL12, REL13,
REL14, REL15, REL16, MC As Double
Dim RSTOR1, RSTOR2, RSTOR3, RSTOR4, RSTOR5, RSTOR6, RSTOR7, RSTOR8, RSTOR9,
RSTOR10 As Double
Dim RSTOR11, RSTOR12, RSTOR13, RSTOR14, RSTOR15, RSTOR16 As Double
Dim A, B As Double
DamCount = 0
CRecNo = 0
y = 1
DSo = 0.63: FDo = 0.2: RDo = 0.002: DDo = 1.89
seep = 0.35
PM(1, 1) = 0.63 'Val(InputBox("PREVIOUS MONTH STORAGE OF THE RESORVOIR"))
MC = 106 'Val(InputBox("MAXIMUM CAPACITY OF RESERVOIR"))


Debug.Print Tab(30); "RESULTS OF RESERVOIR SIMULATION MODEL"
Debug.Print Tab(30); "-----------------------------------------------------------------------"
Debug.Print
Debug.Print "INPUT CONSTANTS:"
Debug.Print
Debug.Print "Dead storage                                        :"; DSo
Debug.Print "Drinking water demand                               :"; DDo
Debug.Print "Pisciculture demand                                 :"; FDo
Debug.Print "Recreation demand                                   :"; RDo
Debug.Print "Seepage and other losses                            :"; seep
Debug.Print "Previous month storage                              :"; PM(1, 1)
Debug.Print "Maximum capacity for the opening of shutters        :"; MC
Debug.Print

On Error GoTo 120
Open FILNAME For Input As #1
Do While Not EOF(1)  ' Check for end of file.
DamCount = DamCount + 1
If (DamCount > 12) Then y = y + 1: DamCount = 1
Input #1, YR1(y, DamCount), YR2(y, DamCount), MON(y, DamCount), INF(y, DamCount), EVP(y,
DamCount), CPW(y, DamCount)
Loop
Close #1

Open "c:\result.out" For Output As #1
Print #1, Tab(30); "RESERVOIR SIMULATION MODEL RESULTS"
Print #1, Tab(30); "-----------------------------------------------------------------------"
Print #1, "INPUT CONSTANTS:"
```

```
Print #1, "Dead storage                                    :"; DSo
Print #1, "Drinking water demand                           :"; DDo
Print #1, "Pisciculture demand                             :"; FDo
Print #1, "Recreation demand                               :"; RDo
Print #1, "Seepage and other losses                        :"; seep
Print #1, "Previous month storage                          :"; PM(1, 1)
Print #1, "Maximum capacity for the opening of shutters   :"; MC

l = 0
For i = 1 To y
Debug.Print "YEAR:"; YR1(i, i - 12 * l); "-"; YR2(i, i - 12 * l)
Debug.Print
Debug.Print Tab(2); "------------------------------------------------------------------------------------------------------------------------------------"
Debug.Print Tab(2); "MONTH"; Tab(15); "INFL"; Tab(20); "EVP"; Tab(30); "SPILL"; Tab(40); "INIST";
Tab(50); "DRINK"; Tab(60); "IRRIG"; Tab(70); "PISCI"; Tab(80); "REC"; Tab(90); "REMST"
Debug.Print Tab(2); "------------------------------------------------------------------------------------------------------------------------------------"

Print #1, "YEAR:"; YR1(i, i - 12 * l); "-"; YR2(i, i - 12 * l)
Print #1, Tab(2); "------------------------------------------------------------------------------------------------------------------------------------"
Print #1, Tab(2); "MONTH"; Tab(15); "INFL"; Tab(20); "EVP"; Tab(30); "SPILL"; Tab(40); "INIST";
Tab(50); "DRINK"; Tab(60); "IRRIG"; Tab(70); "PISCI"; Tab(80); "REC"; Tab(90); "REMST"
Print #1, Tab(2); "------------------------------------------------------------------------------------------------------------------------------------"

For j = 1 To 12
SPD(i, j) = 0: STORCM(i, j) = 0
REL1 = 0: REL2 = 0: REL3 = 0: REL4 = 0: REL5 = 0: REL6 = 0
REL7 = 0: REL8 = 0: REL9 = 0: REL10 = 0: REL11 = 0: REL12 = 0
REL13 = 0: REL14 = 0: REL15 = 0: REL16 = 0

If PM(i, j) - Val(EVP(i, j)) < 0 Then PM(i, j) = 0
  STORCM(i, j) = Val(INF(i, j)) + PM(i, j) - Val(EVP(i, j)) - seep
If STORCM(i, j) < 0 Then STORCM(i, j) = 0: GoTo 100
If STORCM(i, j) < MC Then GoTo 40
  SPD(i, j) = STORCM(i, j) - MC
  STORCM(i, j) = MC
40 If STORCM(i, j) - (DSo + 0.25 * DDo) < 0.25 * DDo Then GoTo 50
  REL1 = 0.25 * DDo
  RSTOR1 = STORCM(i, j) - REL1
  CPW(i, j) = CPW(i, j) / 0.7
If RSTOR1 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j < 12 Then PM(i, j + 1) = RSTOR1: GoTo 30
If RSTOR1 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j = 12 Then PM(i + 1, 1) = RSTOR1: GoTo 30
   REL2 = 0.25 * CPW(i, j)
   RSTOR2 = RSTOR1 - REL2
 If RSTOR2 - (DSo + 0.25 * DDo) < 0.25 * DDo Then GoTo 60
   REL3 = 0.25 * DDo
   RSTOR3 = RSTOR2 - REL3
 If RSTOR3 - (DSo + 0.25 * DDo) < 0.25 * FDo And j < 12 Then PM(i, j + 1) = RSTOR3: GoTo 20
 If RSTOR3 - (DSo + 0.25 * DDo) < 0.25 * FDo And j = 12 Then PM(i + 1, 1) = RSTOR3: GoTo 20
   REL4 = 0.25 * FDo
   RSTOR4 = RSTOR3 - REL4
```

```
If RSTOR4 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j < 12 Then PM(i, j + 1) = RSTOR4: GoTo 10
If RSTOR4 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j = 12 Then PM(i + 1, 1) = RSTOR4: GoTo 10
  REL5 = 0.25 * CPW(i, j)
  RSTOR5 = RSTOR4 - REL5
If RSTOR5 - (DSo + 0.25 * DDo) < 0.25 * DDo Then GoTo 70
  REL6 = 0.25 * DDo
  RSTOR6 = RSTOR5 - REL6
If RSTOR6 - (DSo + 0.25 * DDo) < 0.25 * DDo Then GoTo 80
  REL7 = 0.25 * DDo
  RSTOR7 = RSTOR6 - REL7
If RSTOR7 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j < 12 Then PM(i, j + 1) = RSTOR7: GoTo 100
If RSTOR7 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j = 12 Then PM(i + 1, 1) = RSTOR7: GoTo 100
  REL8 = 0.25 * CPW(i, j)
  RSTOR8 = RSTOR7 - REL8
If RSTOR8 - (DSo + 0.25 * DDo) < 0.25 * FDo And j < 12 Then PM(i, j + 1) = RSTOR8: GoTo 100
If RSTOR8 - (DSo + 0.25 * DDo) < 0.25 * FDo And j = 12 Then PM(i + 1, 1) = RSTOR8: GoTo 100
  REL9 = 0.25 * FDo
  RSTOR9 = RSTOR8 - REL9
If RSTOR9 - (DSo + 0.25 * DDo) < 0.25 * RDo And j < 12 Then PM(i, j + 1) = RSTOR9: GoTo 100
If RSTOR9 - (DSo + 0.25 * DDo) < 0.25 * RDo And j = 12 Then PM(i + 1, 1) = RSTOR9: GoTo 100
  REL10 = 0.25 * RDo
  RSTOR10 = RSTOR9 - REL10
If RSTOR10 - (DSo + 0.25 * DDo) < 0.25 * CPW(i, j) And j < 12 Then PM(i, j + 1) = RSTOR10: GoTo 100
If RSTOR10 - (DSo + 0.25 * DDo) < 0.25 *CPW(i, j) And j = 12 Then PM(i + 1, 1) = RSTOR10: GoTo 100
  REL11 = 0.25 * CPW(i, j)
  RSTOR11 = RSTOR10 - REL11
If RSTOR11 - (DSo + 0.25 * DDo) < 0.25 * FDo And j < 12 Then PM(i, j + 1) = RSTOR11: GoTo 100
If RSTOR11 - (DSo + 0.25 * DDo) < 0.25 * FDo And j = 12 Then PM(i + 1, 1) = RSTOR11: GoTo 100
  REL12 = 0.25 * FDo
  RSTOR12 = RSTOR11 - REL12
If RSTOR12 - (DSo + 0.25 * DDo) < 0.25 * FDo And j < 12 Then PM(i, j + 1) = RSTOR12: GoTo 100
If RSTOR12 - (DSo + 0.25 * DDo) < 0.25 * FDo And j = 12 Then PM(i + 1, 1) = RSTOR12: GoTo 100
  REL13 = 0.25 * FDo
  RSTOR13 = RSTOR12 - REL13
If RSTOR13 - (DSo + 0.25 * DDo) < 0.25 * RDo And j < 12 Then PM(i, j + 1) = RSTOR13: GoTo 100
If RSTOR13 - (DSo + 0.25 * DDo) < 0.25 * RDo And j = 12 Then PM(i + 1, 1) = RSTOR13: GoTo 100
  REL14 = 0.25 * RDo
  RSTOR14 = RSTOR13 - REL14
If RSTOR14 - (DSo + 0.25 * DDo) < 0.25 * RDo And j < 12 Then PM(i, j + 1) = RSTOR14: GoTo 100
If RSTOR14 - (DSo + 0.25 * DDo) < 0.25 * RDo And j = 12 Then PM(i + 1, 1) = RSTOR14: GoTo 100
  REL15 = 0.25 * RDo
  RSTOR15 = RSTOR14 - REL15
If RSTOR15 - (DSo + 0.25 * DDo) < 0.25 * RDo And j < 12 Then PM(i, j + 1) = RSTOR15: GoTo 100
If RSTOR15 - (DSo + 0.25 * DDo) < 0.25 * RDo And j = 12 Then PM(i + 1, 1) = RSTOR15: GoTo 100
  REL16 = 0.25 * RDo
  RSTOR16 = RSTOR15 - REL16
  If j < 12 Then PM(i, j + 1) = RSTOR16
  If j = 12 Then PM(i + 1, 1) = RSTOR16
  GoTo 100
50 If STORCM(i, j) - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = STORCM(i, j): GoTo 100
  If STORCM(i, j) - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = STORCM(i, j): GoTo 100
  REL1 = 0.25 * DDo
  RSTOR1 = STORCM(i, j) - REL1
  If j < 12 Then PM(i, j + 1) = RSTOR1
  If j = 12 Then PM(i + 1, 1) = RSTOR1
  GoTo 100
```

```
60  If RSTOR2 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR2: GoTo 100
    If RSTOR2 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR2: GoTo 100
    REL3 = 0.25 * DDo
    RSTOR3 = RSTOR2 - REL3
    If j < 12 Then PM(i, j + 1) = RSTOR3
    If j = 12 Then PM(i + 1, 1) = RSTOR3
    GoTo 100
70  If RSTOR5 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR5: GoTo 100
    If RSTOR5 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR5: GoTo 100
    REL6 = 0.25 * DDo
    RSTOR6 = RSTOR5 - REL6
    If j < 12 Then PM(i, j + 1) = RSTOR6
    If j = 12 Then PM(i + 1, 1) = RSTOR6
    GoTo 100
80  If RSTOR6 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR6: GoTo 100
    If RSTOR6 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR6: GoTo 100
    REL7 = 0.25 * DDo
    RSTOR7 = RSTOR6 - REL7
    If j < 12 Then PM(i, j + 1) = RSTOR7
    If j = 12 Then PM(i + 1, 1) = RSTOR7
    GoTo 100

30  If RSTOR1 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR1: GoTo 100
    If RSTOR1 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR1: GoTo 100
    REL3 = 0.25 * DDo
    RSTOR3 = RSTOR1 - REL3
    If j < 12 Then PM(i, j + 1) = RSTOR3
    If j = 12 Then PM(i + 1, 1) = RSTOR3

GoTo 100

20  If RSTOR3 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR3: GoTo 100
    If RSTOR3 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR3: GoTo 100
    REL6 = 0.25 * DDo
    RSTOR6 = RSTOR3 - REL6
    If j < 12 Then PM(i, j + 1) = RSTOR6
    If j = 12 Then PM(i + 1, 1) = RSTOR6

GoTo 100

10 If RSTOR4 - DSo < 0.25 * DDo And j < 12 Then PM(i, j + 1) = RSTOR4: GoTo 100
    If RSTOR4 - DSo < 0.25 * DDo And j = 12 Then PM(i + 1, 1) = RSTOR4: GoTo 100
    REL6 = 0.25 * DDo
    RSTOR6 = RSTOR4 - REL6
    If j < 12 Then PM(i, j + 1) = RSTOR6
    If j = 12 Then PM(i + 1, 1) = RSTOR6

100 If j < 12 And PM(i, j + 1) < 0 Then PM(i, j + 1) = 0
    If j = 12 And PM(i, j) <= 0 Then PM(i + 1, 1) = 0
    TODRIWAT(i, j) = REL1 + REL3 + REL6 + REL7
    TOIRRWAT(i, j) = REL2 + REL5 + REL8 + REL11
    TOFISWAT(i, j) = REL4 + REL9 + REL12 + REL13
    TORECWAT(i, j) = REL10 + REL14 + REL15 + REL16
```

```
If j < 12 Then Print #1, Tab(2); MON(i, j); Tab(10); Format$(INF(i, j), "#####.####"); Tab(20); Format$(EVP(i, j), "##.####"); Tab(30); Format$(SPD(i, j), "#####.####"); Tab(40); Format$(STORCM(i, j), "#####.####"); Tab(50); Format$(TODRIWAT(i, j), "#####.####"); Tab(60); Format$(TOIRRWAT(i, j), "#####.####"); Tab(70); Format$(TOFISWAT(i, j), "#####.####"); Tab(80); Format$(TORECWAT(i, j), "#####.####"); Tab(90); Format$(PM(i, j + 1), "#####.####")
If j = 12 Then Print #1, Tab(2); MON(i, j); Tab(10); Format$(INF(i, j), "#####.####"); Tab(20); Format$(EVP(i, j), "##.####"); Tab(30); Format$(SPD(i, j), "#####.####"); Tab(40); Format$(STORCM(i, j), "#####.####"); Tab(50); Format$(TODRIWAT(i, j), "#####.####"); Tab(60); Format$(TOIRRWAT(i, j), "#####.####"); Tab(70); Format$(TOFISWAT(i, j), "#####.####"); Tab(80); Format$(TORECWAT(i, j), "#####.####"); Tab(90); Format$(PM(i + 1, 1), "#####.####")

Next j
Debug.Print Tab(2); "--------------------------------------------------------------------------------------------------------------------------------------------------------"
Print #1, Tab(2); "-------------------------------------------------------------------------------------------------------------------------------------------------------"
If i / 12 = 1 Then l = l + 1
If i / 12 = 2 Then l = l + 1
If i / 12 = 3 Then l = l + 1
If i / 12 = 4 Then l = l + 1
If i / 12 = 5 Then l = l + 1
Next i
Close #1

Load RESOUT
RESOUT.Show
For i = 1 To l
For k = 1 To 12
RESOUT.lblY1.Caption = YR1(i, k)
RESOUT.lblY2.Caption = YR2(i, k)
RESOUT.lblM(k - 1).Caption = MON(i, k)
RESOUT.lblINF(k - 1).Caption = Format$(INF(i, k), "#####.####")
RESOUT.lblEVP(k - 1).Caption = Format$(EVP(i, k), "#####.####")
RESOUT.lblSD(k - 1).Caption = Format$(SPD(i, k), "#####.####")
RESOUT.lblIPS(k - 1).Caption = Format$(STORCM(i, k), "#####.####")
RESOUT.lblDW(k - 1).Caption = Format$(TODRIWAT(i, k), "#####.####")
RESOUT.lblIRR(k - 1).Caption = Format$(TOIRRWAT(i, k), "#####.####")
RESOUT.lblFD(k - 1).Caption = Format$(TOFISWAT(i, k), "#####.####")
RESOUT.lblREC(k - 1).Caption = Format$(TORECWAT(i, k), "#####.####")
If k < 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(i, k + 1), "#####.####")
If k = 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(i + 1, 1), "#####.####")
Next k
Next i
CRecNo = CRecNo + 1
120 End Sub
```

PREVIOUS button:

```
Public Sub prev()
Dim k As Integer
RESOUT.Show
CRecNo = CRecNo - 1
If CRecNo < 1 Then CRecNo = y
For k = 1 To 12
```

```
RESOUT.lblY1.Caption = YR1(CRecNo, k)
RESOUT.lblY2.Caption = YR2(CRecNo, k)
RESOUT.lblM(k - 1).Caption = MON(CRecNo, k)
RESOUT.lblINF(k - 1).Caption = Format$(INF(CRecNo, k), "#####.####")
RESOUT.lblEVP(k - 1).Caption = Format$(EVP(CRecNo, k), "#####.####")
RESOUT.lblSD(k - 1).Caption = Format$(SPD(CRecNo, k), "#####.####")
RESOUT.lblIPS(k - 1).Caption = Format$(STORCM(CRecNo, k), "#####.####")
RESOUT.lblDW(k - 1).Caption = Format$(TODRIWAT(CRecNo, k), "#####.####")
RESOUT.lblIRR(k - 1).Caption = Format$(TOIRRWAT(CRecNo, k), "#####.####")
RESOUT.lblFD(k - 1).Caption = Format$(TOFISWAT(CRecNo, k), "#####.####")
RESOUT.lblREC(k - 1).Caption = Format$(TORECWAT(CRecNo, k), "#####.####")
If k < 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(CRecNo, k + 1), "#####.####")
If k = 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(CRecNo + 1, 1), "#####.####")
Next k
End Sub
```

NEXT button:

```
Public Sub nxt()
Dim k As Integer
RESOUT.Show
CRecNo = CRecNo + 1
If CRecNo > y Then CRecNo = 1
For k = 1 To 12
RESOUT.lblY1.Caption = YR1(CRecNo, k)
RESOUT.lblY2.Caption = YR2(CRecNo, k)
RESOUT.lblM(k - 1).Caption = MON(CRecNo, k)
RESOUT.lblINF(k - 1).Caption = Format$(INF(CRecNo, k), "#####.####")
RESOUT.lblEVP(k - 1).Caption = Format$(EVP(CRecNo, k), "#####.####")
RESOUT.lblSD(k - 1).Caption = Format$(SPD(CRecNo, k), "#####.####")
RESOUT.lblIPS(k - 1).Caption = Format$(STORCM(CRecNo, k), "#####.####")
RESOUT.lblDW(k - 1).Caption = Format$(TODRIWAT(CRecNo, k), "#####.####")
RESOUT.lblIRR(k - 1).Caption = Format$(TOIRRWAT(CRecNo, k), "#####.####")
RESOUT.lblFD(k - 1).Caption = Format$(TOFISWAT(CRecNo, k), "#####.####")
RESOUT.lblREC(k - 1).Caption = Format$(TORECWAT(CRecNo, k), "#####.####")
If k < 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(CRecNo, k + 1), "#####.####")
If k = 12 Then RESOUT.lblREM(k - 1).Caption = Format$(PM(CRecNo + 1, 1), "#####.####")
Next k
End Sub
```

SIMULATION OF A RESERVOIR SYSTEM WITH MULTIPLE OBJECTIVES

By

LEENA DIVAKAR

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Irrigation and Drainage Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2001

ABSTRACT

During the past three decades, the application of the systems approach to reservoir management application has been established as one of the most important advances made in the field of water resources engineering. Water resources planning has become exceedingly complex and is bound to become even more complex in the future considering the various demands. Application of sophisticated techniques for scientific planning and utilisation of the limited available water resources has become highly necessary to meet the growing demands of various types of consumptive and non-consumptive needs.

Though India has been endowed with plenty of rainfall, the distribution is uneven both in time and space. A reservoir system simulation model reproduces the hydrologic and in some cases economic performance of a reservoir system for given inflow and operating rules.

A computer simulation model for a multipurpose reservoir system was developed and tested for Peechi reservoir of Kerala state in south India. The model was designed for monthly operation with historic inflow of 35 years. The model obtains the monthly releases for various uses. The monthly water requirements for different purposes like drinking, irrigation, pisciculture and recreation are taken as the target to be achieved by the model. Out of the different uses only irrigation demand had monthly variation and the rest were taken as constants along with the dead storage and the maximum capacity for opening of the shutters. The objective of the model is to minimise the deviations of the release from the targets for each demand.

The model has been formulated with appropriate priorities, which satisfy the continuity and physical conditions of the system. The priorities of different water demands can be altered at any stage of the operation according to the changing needs of the region. The program is written in Visual Basic-6.0 and the results gave

the monthly releases and deficits of different demands. One advantage of the model is that even non technical decision makers can comprehend the results obtained from this. The efficiency of the model is such that the solution can be obtained in the quickest time possible and is very user friendly.