RESERVOIR SIMULATION FOR WATER CONSERVATION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which has been presented in this dissertation entitled, "**RESERVOIR SIMULATION FOR WATER CONSERVATION**", submitted in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in "**Conservation Of Rivers and Lakes**" submitted in Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period from July 2011 to June 2012 under the supervision and guidance of **Dr. D.K. Srivastava,** Professor, Department Of Hydrology, Indian Institute of Technology Roorkee.

I also declare that the matter contained herein has not been submitted by me for the award of any other degree or diploma elsewhere.

Date: June 12th, 2012

Place: Roorkee

(Siva Rama Krishna Madeti)

CERTIFICATE

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

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ABSTRACT

The comprehensive planning of irrigation projects considering the various aspects related to them is of primary concern for an overall increase in the efficiencies of these projects which have been subjected to much criticism. Planning and management of the water resources and then efficient distribution of the available water in the fields for an increased agricultural production are the two major objectives which should be met to make an irrigation project successful.

A number of simulation and optimization models have been developed and applied to derive planning and operating strategies for large irrigation reservoir projects over longer intervals of time (generally monthly). Application of optimization techniques to reservoir operation has become a major focus of water resources planning and management. Traditionally, reservoir operation is based on heuristic procedures, embracing rule curves and, to a certain extent, subjective judgments by the operator. Water use involves a large number of stakeholders with different objectives, and optimization techniques are expected to provide balanced solutions between often conflicting objectives. The thesis proposes an avenue for changing traditional reservoir operation into optimized strategies, taking advantage of the rapid development in computational techniques.

The main contribution of the thesis is the development of a framework in which a simulation model is coupled with a numerical search method for optimizing decision variables specifically defined for operation of the reservoir. The MATLAB program is adopted for simulating the various components of the reservoir to obtain the near optimum values of the design variables. The systematic search would be used for sampling the set of data.

The framework is tested on the Harbhangi Irrigation Project is an inter-basin irrigation project in Orissa state, constructed across river Harbhangi considering irrigation water supplied to the farms on rotational basis. The results show that simulation models have proved extremely useful in achieving the optimal design in reservoir planning. To further improve the operation, real-time optimization is performed taking real-time and forecast information about reservoir levels, reservoir inflows and water demands into account. The analysis demonstrates that the real-time optimization procedure improves the performance and enhances the flexibility of the reservoir operation in comparison to a strict application of the optimized regulation.

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NOMENCLATURE

A. LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
B	Present value of net benefits in Rs.
Y	Reservoir Capacity
I_r	Irrigation Demand
S_{t_1}	Reservoir storage at the beginning of time t
I_t	Inflow into reservoir during time t
I'_t	Local inflow to the reservoir from the surrounding area in time t
P_t	Precipitation in the reservoir in time t
E_{lt}	Evaporation losses from the reservoir in time t
O_t	Total outflow (release) from the reservoir in time t
O'_t	Release to natural channel from reservoir in time t
S_t	Reservoir storage at the end of time t
$O_r{}'_t$	Actual release for water supply from reservoir in time t
$O_a{}''_t$	Additional release from reservoir to fulfil energy demand in time t
$O_r{}'_t$	Actual irrigation release from reservoir in time t
S_{pt}	Reservoir spill in time t

CHAPTER 1

INTRODUCTION

1.1. GENERAL:

Among many natural resources on earth the water is such a vital and important resource that the less said about it, the better. Its importance is so much felt by people living in arid environments and drought affected areas. They cry for water throughout the year. Only after such a basic need is satisfied, they look for any-thing else — food, job and shelter, etc. How such a rare and vital resource can best be utilized for human use and how efficiently this can be managed are the burning questions raised all over the world today in greater intensity than ever before.

There are no wanting proofs that ever since the dawn of civilization, the intelligent and perseverant man has ever tried to divert the available surface water and use it for his agricultural and other allied purposes. But to his great misfortunes the nature has always behaved in a strange way. Very often he is victimized by the nature's most cruel act — erratic or no rain. This results into severe droughts— very poor or no agricultural outputs and finally the outcome of a famine in the most disastrous form. His long built civilization and material progress are stopped and even disappear altogether.

Now coming to real problem of India, One sees that about 60% of its population mainly depends on agriculture. Under the present situations of its rapid population growth, there is always a heavy pressure for exploitation of available water resource in the best possible manner, to meet the increasing demand for food. There is ever increasing need for irrigation for better agricultural outputs and fight against hunger, diseases and other wants.

Under the circumstances, it comes to mind automatically to realize the great importance of water resource management schemes and the vital roles to be played by the concerned water resource engineers or hydrologists. These useful technocrats have desired and hoped that they should find out better operating policies of storage reservoirs, contribute better know—hows for transfer of water in the judicious ways and for the economic use of available water supply and devise similar other policies. They are entrusted with the task of constructing reservoirs, to manage them more efficiently and help in building a sound economy to the nation and the people.

There are rays of hope now that much emphasis is placed countrywide for the development and management of water resources, in spite the limitations that there are political and legal problems. All efforts are being made in the national level with directives to the concerned organization to upgrade the socio-economic condition of the poor people through rational planning of water resources projects and following improved operational policies. It may be appropriate to mention here that no water resource system is free from problems. It may be due to the fact that water is often available at times; the amount of water available is not upto the demand besides there is a maldistribution of water in space and time.

On the whole the water resource system is developed on a huge cost. It should not be allowed to fail to serve its purpose. Although it may be admitted that a reservoir project may yield benefits in long terms, but its failure to supply water at the time of acute need cannot be ignored. This may be due to adopting a very poor operating policy and management. From the foregoing discussion it is now clear that a water resource project with efficient management and improved operational policy can establish real hopes for the aspirants and build a strong edifice for overall progress [1].

1.2 REVIEW OF SIMULATION:

Many advanced theories and methods are contributed by several research workers in the field of water resource system. Either they are aimed at finding out criteria for the optimal design of system elements such as dam, reservoirs etc., or target outputs for irrigation water or in optimal operating policy i.e. a schedule indicating volumes of water to be kept in storage or released from a storage facilities at given points in time.

Due to advent of high speed computers along with the new knowledge on system analysis, these fields of water resources planning management open out with new methodology. This methodology, rather the tool of the discipline, aims in integrating all possible functions of the reservoirs. Certain patterns of reservoir behavior in future remain apparently clear and also a statement of future risk is explained. It is now worthwhile to review a few such works which are based on simulation techniques, etc.

SIMULATION:

"Simulation is defined as a process duplicating the essence of a system or activity without attaining reality itself". It is essentially a search technique which resembles the trial and error approach used in traditional operation studies. In simulation less flexibility is there for the operating procedure, which is once fixed in the program.

Many situations encountered in planning and designing water resource system involve rigorous mathematical methods difficult to solve. Simulation helps to avoid such difficulty. It incorporates quantitative relationships among the variables and describes the outcome or response of the operating system under a given sets of inputs and operating conditions [2].

1.3 IMPORTANCE OF THE STUDY:

The Central Water Commission, the main authority to accord technical sanctions to water resources projects in India, has recommended for adopting the optimization methods for project planning. A number of simulation and optimization models have been developed and applied to derive planning and operating strategies for large irrigation reservoir projects over longer intervals of time (generally monthly). However less attention has been paid to develop demand based water releasing strategies for shorter intervals of time (weekly, bi-weekly, ten-daily periods) for which the canals are operated. In most of the irrigation projects it is a common experience that the area actually irrigated is far less than the planned and also there are wide gaps between irrigation water supplies and demands over shorter intervals of time. These gaps are due to inadequate attention paid to the proper planning of water resources and non-matching of canal water releases with the crop water requirement and the local rainfall. Therefore it is immensely important to derive planning and operating strategies for reservoir release for shorter time intervals based upon the actual water requirements in the field.

At present the operation and management of the irrigation systems in the country are subjected to much criticism. Problems of low water use efficiencies and inequitable distribution of water among the beneficiaries are common. In most of the irrigation projects, the present status indicates that there is considerable scope for improving efficiencies in the realm of water management. Studies regarding the assessment of water deliveries in irrigation systems reveal that there is non-uniform and inadequate distribution of irrigation water to the farms (Clemmens and Molden 2007) leading to low productivity of irrigation projects. The root cause of the poor performance of our irrigation systems is the lack of scientific approach to their management. On most command areas served by a canal, water is poorly distributed over area and time. A common shortcoming is that tail-end users are not getting water or are getting insufficient and unreliable water. Conversely, head-end users often get too much water, either because they have no choice or deliberately, taking water when they can and often more than needed. The on-farm irrigation practices prevailing in the country also results in wastage leading to low irrigation efficiency. Most farmers still irrigate the way their forefathers did thousands of years ago by flooding or channeling water through parallel furrows.

Thus keeping in view the above shortcomings in realm of water resources planning and management it becomes clear that a study needs to be carried out which should cover the aspect of optimal planning of water resources for irrigation as well as management of that irrigation systems.

1.4. ORGANIZATION OF THE THESIS:

Chapter-2

This chapter details about a critical review of academic literature pertaining to this study are presented in this chapter. The review related to the topics of application of system analysis in water resources planning, planning and operation of reservoirs, reservoir simulation. Under the topic of irrigation water management the review regarding assessment of irrigation systems using irrigation performance indicators, scheduling procedures for canal water distribution, irrigation scheduling, MATLAB programs for irrigation scheduling and spreadsheet softwares developed.

Chapter-3

In this Chapter, deals with various definitions given in the latest code IS: 7323-1994 (BIS code on Operation of Reservoirs-Guidelines) e.g. types of reservoirs, various kind of water uses and their interdependencies, conflicts in reservoir operation, forecasts, and rule curve.

Chapter-4

Description of the study area (existing Harabhangi irrigation project) has been presented in this chapter along with the configuration and basic information regarding the project in the context of present study.

Chapter-5

In this chapter, touches the importance of System Engineering techniques in water resources system planning and management. It also deals with various techniques available e.g. simulation and optimization techniques in this area. A brief comparison has also been made between simulation and optimisation methodologies.

Chapter-6

The theory adopted here to formulate the monthly operating policies and the different criteria of analysis for the reservoir operation are incorporated. Reservoir operation is carried out in through MATLAB programs for 42 years of available flow data as well as Irrigation demand. The reservoir operation carried though MS-Excel and computer programs by not using the adapted operation policy in first case and using the monthly operation policy in the second, gave valuable information regarding the effectiveness of the newly adapted monthly operation policy.

Chapter-7

A concluding remark is given at the end in Chapter 7. Possible suggestions are also incorporated after a good deal of discussions on the work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION:

The ever increasing water demands in the irrigation sector and the inefficiencies in the water distribution patterns has lead to a poor state of affairs of the irrigation projects in the country. There is an immense need of evaluation of these projects on the whole by studying the various aspects related to them. These include planning reservoir releases using long term historic data of inflows which may need to be generated and then distributing the released water efficiently to the distribution systems. Scheduling of water deliveries for the equitable and adequate distribution of irrigation water in the complex network of distributaries is a cumbersome task in itself and poses many challenges.

For studying the overall optimal utilization of water and management of irrigation system suitable techniques relating to each aspect have been used for the present study. As such, it is essential to review the literature to identify the research needs in the context of present study. The review is organized in accordance with the steps required to be followed for the comprehensive planning of the irrigation projects using the techniques of long term hydrological simulation for generating inflows, the reservoir yield models, reservoir simulation studies, studies regarding assessment of irrigation systems, canal water distribution procedures.

Before that it is very important to review the application of system analysis in planning of water resources and the studies on planning and operation of reservoirs. Application of the systems approach and use of systems analysis techniques and models to the real life systems have improved our understanding of such systems, and contributed to continuous process of developing the methodologies for improving the system planning, management, and operation.

2.2. STUDIES ON PLANNING AND OPERATION OF A RESERVOIR:

William W-G. Yeh et al. (1974) [3] addresses a typical requirement of real time multiple-reservoir operation for the analysis of Shasta and Trinity sub-systems of the California Central Valle. In methodology they utilizing a form of dynamic programming (DP) for the selection of an optimal reservoir storage policy path through a specified number of policy periods, and a linear programming (LP) routine is used for period by period optimization. The method is of considerable value for the determination of release policies in real time operation of an existing system.

Vedula et al. (1981) [4] developed a mathematical planning model to find optimum cropping patterns in irrigation in the context of river basin development. A multi objective deterministic LP model was applied to a system of four reservoirs in India to maximize the net economic benefit and the irrigated cropped area. The problem is solved by using the constraint method and the tradeoffs were discussed.

Hashimoto et al. (1982) [5] discussed three criteria for evaluating the possible performance of water resource systems. These measures describe how likely a system is to fail (reliability), how quickly it recovers from failure (resiliency), and how severe the consequences of failure may be (vulnerability). These criteria can be used to assist in evaluation and selection of alternative design and operating policies for a wide variety of water resource projects.

Srivastava and Sunder (1985) [6] showed the importance of simulation in reservoir planning by studying an existing irrigation reservoir. The study showed that the existing reservoir capacity is larger than required to serve the useful purposes.

Yeh (1985) [7] reviewed the state-of-art of mathematical models development for reservoir operations, including simulation. Algorithms and methods surveyed include LP, DP, non-linear programming (NLP), and simulation.

Simonovic and Burn (1989) [8] presented an original modeling procedure which explicitly utilizes the trade-off between forecast reliability and the penalties associated with deviations from the target values for the reservoir operation.

Vedula and Mohan (1990) [9] developed a real-time operational methodology for multipurpose reservoir operation for irrigation and hydropower generation with application to the Bhadra reservoir system in the state of Karnataka, India. The methodology consists of three phases of computer modelling. In the first phase, the optimal release policy for a given initial storage and inflow is determined using a stochastic dynamic programming (SDP) model. Streamflow forecasting using an adaptive AutoRegressive Integrated Moving Average (ARIMA) model constitutes the second phase. A real-time simulation model is developed in the third phase using the forecast inflows of phase 2 and the operating policy of phase 1.

Garudkar (1991) [10] studied an existing reservoir with water supply and multi irrigation demands and showed the feasibility of simulation for reservoir planning. The LP and simulation technique (Nadkarni 1986; and Kar 1991) for irrigation reservoir and for multipurpose reservoir were used (Sadeghian 1991) for planning purposes to test the project provisions.

Srivastava and Patel (1992) [11] used optimization (LP and DP) simulation models for the systems analysis of the Karjan irrigation reservoir project in India. They reported that, the linear programming model is most suitable for finding reservoir capacity. Dynamic programming may be used for further refining the output targets and finding the possible reservoir carry-over capacity. The simulation should then be used to obtain the near optimum values of the design variables.

Loucks (1992) [12] discussed the role of water resource system models in planning. The major challenges facing water resource system planners and managers, the information they need to meet these challenges, and the role analysts have in helping to provide this information have been discussed.

Vedula and Nagesh Kumar (1996) [13] derived a steady state reservoir operating policy used a stochastic dynamic programming (SDP). The objective of the SDP was to maximize the expected sum of relative yields of all crops in a year. First module was an intra-seasonal allocation model to maximize the sum of relative yields of all crops for a given state of the system.

P. P. Mujumdar et al. (1997) [14] developed a model for irrigation of multiple crops at Malaprabha irrigation reservoir in Karnataka, India. They reported that operating policy model, which optimizes reservoir releases across time periods in a year, and an allocation model, which optimizes irrigation allocations across crops within a time period. Simulation with steady state and the short-term real-time operation model showed that for shorter operating horizons, the real-time adaptive policy performs better in case of critical low-flow years.

Ehsanolah Malek-Mohammadi (1998) [15] integrates an optimization model is developed for planning irrigation systems. In this work, surface reservoir capacity, ground-water and spring withdrawal, delivery system capacities (including canals, pumping stations, and tunnels), hectares of land to be developed for irrigation, and cropping pattern are considered as interacting parts of the system. The system is optimized by means of a chance-constraint optimization model.

The model uses mixed integer linear programming to maximize the net benefit associated with the development. To linearize a collection of interrelated nonlinear cost functions, a new generalized technique is developed. This technique reduces the size of the models and excludes possible infeasibility that may occur in the model. the application of the model is not limited to agriculture development, for it can also be applied to other fields.

Rangarajan et al. (1999) [16] proposed a reliability programming model, which incorporates a four-step simulation algorithm to derive the loss function, which is a relationship between the reliability and its associated economic losses. The performance of the model was demonstrated through a case study.

Srinivasa Raju and Pillai (1999) [17] selected the best reservoir configuration for the case study of Chaliyar river basin, Kerala, India by employing various Multicriterion Decision Making (MCDM) methods, namely, ELECTRE-2, PROMETHEE-2, Analytic Hierarchy Process (AHP), Compromise Programming (CP) and EXPROM-2. Although, these methods follow different approaches, the analysis has shown that the same preference strategy is reached by all the methods. Comparative evaluation of MCDM methods revealed that Compromise Programming is best suited for their case study.

Peng and Buras (2000) [18] presented a series of computational procedures to estimate inflows into a multiple reservoir system where storage levels and gauged releases are available at regular intervals. The inflows are estimated by water budget computations.

Deepti Rani (2004) [19] carried out an integrated study for planning and operation for the proposed Pampa-Achankovil-Vaippar link diversion system (PAV system), which includes three reservoirs located in southern part of India. The author used system analysis techniques to do multi level planning and operation for the system.

Mazhar Hussain (2005) [20] proposed that Hydraulic numerical models of irrigation canals are valuable tools to simulate actual behavior and check its design and operational practices under different scenarios. He identifies current application and limitations of these models and the needs for improvements.

He simulated the two irrigation systems using hydrodynamic computer models i.e., SIC and CanalMan. The simulation results show stable patterns both for steady and unsteady conditions. While using the computer models, setting up of models needed some adjustments to match the requirements of local conditions. Both SIC and CanalMan have certain difficulties in modeling CRBC and PHLC. In fact, all the available simulation models have limitations and do not address the full spectrum of modeling of Canal Irrigation System.

Ahmed and Sarma (2005) [21] presented a GA model for finding the optimal operating policy of a multi-purpose reservoir, located on the river Pagladia, a major tributary of the river Brahmaputra. The operating policy derived from a synthetic monthly streamflow series of 100 years is compared with that of the SDP model on the basis of their performance in reservoir simulation.

Ravi Kumar and Khosa (2005) [22] adopted a sequentially implemented multi-criteria approach to the problem of allocating Cauvery water among the co-basin states of Karnataka, Tamilnadu and Kerala.

Nagesh Kumar et al. (2006) [23] presented a genetic algorithm (GA) model for obtaining an optimal operating policy and optimal crop water allocations from an irrigation reservoir. The model was applied to the Malaprabha single-purpose irrigation reservoir in Karnataka State, India. The optimal operating policy obtained using the GA is similar to that obtained by linear programming. This model can be used for optimal utilization of the available water resources of any reservoir system to obtain maximum benefits.

Mahnosh Moghaddasi. (2010) [24] illustrates certain benefits of using variable demands for long-term reservoir operation to help manage water resources system. A regional optimal allocation of water among different crops and irrigation units is developed. The optimal allocation model is coupled with a reservoir operating model. This coupled model is able to activate restrictions on allocating water to agricultural demands considering variation of inflow to the reservoir, variation of demands, and the economic value of allocating water among different crops and irrigation units.

2.3 GAPS IDENTIFIED:

1. On the basis of the available information, the following gaps are identified for the Harabhangi Reservoir:
2. As per Literature review, I observed that simulation study on Harabhangi reservoir is not carried out.
3. Orissa state is very rich in natural resources, especially water resource but economically poorer in comparison with other state due to inability for proper management of these resources.
4. Due to siltation life of reservoir gets reduced over the years.
5. The situation of too much water in the rainy season and too little water in the dry season causes many difficulties in reservoir operation.

2.4 OBJECTIVES OF THE STUDY:

The domain of the study has been limited to the existing Harabhangi irrigation reservoir system. The water released from the reservoir is being used to irrigate a command area of 9150 ha on the basis of an operational plan for canal operation issued by the authorities. The water is to be supplied to the crops on a rotational basis. The study has been carried out on the following aspects:

1. Evaluation of reservoir yield for the earlier scenario of water use for irrigation.
2. Evaluation of reservoir yield for the current scenario of water use for irrigation.
3. Using operation procedure develops a MATLAB program to carry out the operation of the reservoir.
4. Simulate the reservoir by sampling data pertaining to design variables to obtain the nearer optimal value.
5. Carrying out simulations for further refining the modeled reservoir releases
6. Development of user-friendly spreadsheet software for canal scheduling for rotational irrigation.
7. Identify how best and how much to provide further irrigation facilities.

CHAPTER 3

RESERVOIR OPERATION

Reservoir is the most important component of a water resources development scheme. Reservoirs serve to regulate natural stream-flow thereby modifying the temporal and spatial availability of water according to human needs. The water stored can be used for irrigation, domestic and industrial needs, hydroelectric power generation etc. The empty space in a reservoir also enables storage of flood water temporarily, thereby moderating inflow peaks and protection of downstream areas from flood damages. Reservoirs also provide pool for navigation, habitat for aquatic life and facilities for recreation and sports[25].

3.1 CLASSIFICATION OF RESERVOIRS:

Reservoirs can be classified in several ways. From the point of view of reservoir operation, it is appropriate to classify the reservoirs according to the purposes they serve, i.e. single purpose reservoir or multipurpose reservoirs.

3.1.1 Single Purpose Reservoirs:

These reservoirs are developed to serve only one purpose, which may be flood control or any of the conservation uses such as irrigation, power generation, navigation, industrial use, municipal water supply etc.

3.1.2 Multi-Purpose Reservoirs:

These reservoirs are developed to serve more than one purpose which may be a combination of any of the conservation uses with or without flood control.

3.1.3 Pondage Reservoirs:

Pondage reservoirs are projects involving larger storage element than the diversion projects with pondage. The storage, however, would not be so large so as to confidently decide a season of increasing or decreasing storage. Such a project may spill even during the low flow season, if the flows are rather good. Similarly, it may fail even during high flow season, if for some period during the season the flows are rather low.

In general, simulation of such projects would have to be carried out either on 10-daily or monthly basis for assessing the project performance. It should, however, be remembered that classification of such projects may change from season to season. For example, certain projects in Bihar cater to a very large Kharif (high flow season) irrigation and a small Rabi (post high flow season) irrigation. During Kharif period, the projects supplement the fluctuating command area rainfall, which may be quite substantial. Thus when the rains fail, the water requirements for large irrigation area would be so heavy that the reservoir would be substantially depleted right during the monsoon. The project will thus act as a pondage reservoir requiring 10-daily working during Kharif season. However, the non-monsoon flows are too small compared to the storage and the full monsoon non-monsoon or Rabi irrigation season is storage depletion period without any chance of spills. During this period, the project would act as a "within the year" or "over the year" storage projects.

3.1.4 Within the Year Storage Reservoirs:

Within the year storage reservoirs are so designed that in normal circumstances they completely fill up and even spill during the flood season and are almost completed depleted in the low flow season. For such reservoirs, the storage accumulation and storage depletion period can be defined rather accurately. For example, the reservoirs in Indian peninsula, in which Kharif irrigation is not very prominent, July to September would be a season, where storage would increase and storage would almost always decrease from November to May. For such projects, it would be sufficient to divide the year in four parts i.e. June, July-September, October, November-May for performance testing.

3.1.5 Carryover Storage Reservoirs

These reservoirs are also called as over the year reservoirs. They have an active storage element larger than the normal inflows and requirements, so that they do not spill every year. Small changes, in the distribution of flows within the year, would not normally affect their performance, which would be governed more by the sequence of annual flows. The working tables for such projects can be prepared with sufficient accuracy on annual or bi-seasonal basis.

3.1.6 System of Reservoirs

These consist of a group of single / multiple purpose reservoirs, which may be operated in an integrated manner for optimum utilization of the water resources of the river system.

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3.2 WATER USES:

The purpose a reservoir serves may be conservational uses or flood moderation. The uses which are met from water stored or conserved in a reservoir during the monsoon season are termed as conservational or conservation uses. These include irrigation, power, generation, Municipal & Industrial, navigation, recreation, water quality control, etc. The compatibility, of purposes a reservoir serves, is very significant in its operation. The degree of compatibility of each water use depends on the characteristics of the river system, water use requirements, and ability to forecast runoff. In case the purposes are relatively compatible, reservoir operation becomes easier and on the other hand, if the purposes are not compatible, operation becomes rather complex. It is thus relevant to understand the purposes or water uses a reservoir serves and their relative compatibility.

3.2.1 Irrigation:

The irrigation requirements are seasonal in nature and the variation largely depends upon the cropping pattern in the command area. The irrigation demands are consumptive in nature. However, a small fraction of the water supplied for irrigation, joins back the system as return flow. The irrigation requirements have a direct correlation with the rainfall in the command area; high rainfall leads to low demand.

The general mode of regulation of reservoirs to meet the irrigation demands is to store all runoff in excess of minimum flow / domestic demands during the monsoon season. This filling season in India is generally between June-October (when demand is usually less than inflows), and the depletion period is November-May (when demand is usually more than inflows).

3.2.2 Hydroelectric Power:

The hydroelectric power demands usually vary seasonally and to a lesser extent daily and hourly. The degree of fluctuation depends upon the type of loads being served, viz. industrial, municipal, and agricultural. Hydroelectric power demand comes under the non-consumptive use, because water passing through the turbines can be used for consumptive uses downstream. Reservoirs which incorporate hydropower generally fall under two distinct categories: (a) storage reservoirs which have a sufficient capacity to regulate stream flows on seasonal basis; and (b) run-off-the-river projects, where storage capacity is minor relative to the volume of flow. Hydropower plants are generally operated as "Base Load Stations" or as "Peaking Stations". Base load stations are operated to meet a predefined pattern of power demands of the system. The power generation in peaking stations tends to be random and without a set pattern. Such power stations are operated to meet the peak demands of the system and also to meet grid shortages or failures in the system. It is also usual to develop "pumped storage" plants to utilize off-peak electrical energy, which is less costly, for pumping water back to a storage reservoir and release water from storage to meet peak system power demands.

3.2.3 Municipal and Industrial

Generally, the average water requirements for Municipal and Industrial (M&I) purposes are quite constant throughout the year, as compared to the water requirements for irrigation or hydropower. The water requirements may increase from year to year due to growth in population and / or expansion of industries. The seasonal demand peak is observed in summer. Supply of water for M&I purpose has to be made at high level of reliability of 100%.

3.2.4 Navigation

Many times storage reservoirs are designed to make the stretch of river downstream of the reservoir navigable by maintaining sufficient flow in the channel. The water requirements for navigation show a marked seasonal variation. The demand during any period also depends upon the type and volume of traffic in the navigable waterways.

3.2.5 Recreation

The general public could use reservoirs for water related recreational activities. Also, the river system below the dams are frequently used for recreational boating, swimming, fishing, and other water related activities. These recreational benefits are usually incidental to the other uses and rarely a reservoir is operated for recreational purpose alone. The recreational activities can be sustained at best by keeping the reservoir at levels suitable for such activities during the season. Large and rapid fluctuations in water level of reservoirs or fluctuations in downstream releases are usually deterrent to recreation.

3.2.6 Water Quality Control

Water quality encompasses the physical, chemical, and biological characteristics of water and the biotic and abiotic relationships. The quality of water and the aquatic environment is significantly affected when flow in the river system gets reduced due to construction of a dam. Thus maintenance of adequate flows in the downstream rover channel is one of the purpose to be served by the reservoirs.

3.2.7 Flood Moderation

Flood moderation is one of the important functions of a reservoir. Operation of a flood moderation reservoir aims to moderate the flood flows, by temporarily retaining the flood water and making controlled releases within the safe carrying capacity of the downstream channels, in order to minimize flood damages. Flood moderation storage in a reservoir is seldom provided for complete protection against extremely large floods, such as the Standard Project Flood. However, storage capacity is usually sufficient to reduce flood levels resulting from such an event to moderate levels and to prevent any major flood disasters. Flood storage is usually sufficient for storing the entire runoff from minor and moderate flood events. Reservoirs are usually not constructed solely for flood moderation purpose alone. Often flood moderation is combined with conservational purposes. In such case, either a fixed amount of storage space on the top of the reservoir is reserved for flood moderation purpose and storage below is used for conservational purposes or storage capacity available is shared for both conservational and flood control purposes. When sharing of storage is contemplated, flood storage zone capacity varies with time in year, instead of being fixed. In case of reservoirs with variable flood moderation storage, the reservoir could be either at full conservation storage level or below that level when flood wave strikes it. In the situation when it is at the top of conservation level, the flood cushion can be created by making additional releases from the reservoir in anticipation of flood, before the flood actually strikes. Such a release is called pre-release or reservoir evacuation. Pre-release makes storage space available in the reservoir to absorb part or whole volume of incoming flood. Pre-release can be effective even if the reservoir is at levels lower than the full conservation level, when the flood impinges the reservoir. In such a situation the storage space created due to pre-release is in addition to the storage space available between Maximum Water Level and the current reservoir level. Forecast of inflows into the reservoir plays a vital role in these operational decisions and for increasing the flood moderation efficiency without reducing conservational benefits. It is however, very important to determine the correct amount of pre-release to be made at any instant of time. Incorrect release decisions may lead to inefficient flood moderation and chances of reservoir remaining unfilled upto the conservation level by the end of monsoon. The pre-release decision will depend upon the forecast values of inflow, amount of storage space available in the reservoir, safety considerations of dam, spillway capacity, downstream flooding conditions, and downstream carrying capacity of river channel. Since most of these parameters change with time, the process of estimation of pre-release is a dynamic one. In such situations, computer based real time operation models serve the purpose of an efficient tool for taking operation decisions.

3.3 CONFLICTS IN RESERVOIR OPERATION

Operation of multipurpose reservoirs, which serve more than one purpose, involves a number of anomalies due to the competing and conflicting objectives of water uses. These conflicts in multipurpose reservoir operation are discussed here.

3.3.1 Conflict in Space

These types of conflicts occur, when a reservoir is required to satisfy divergent purposes, for example, water conservation and flood control. If the geological and topographic features of the dam site and the funds available for the project permit, a dam of sufficient height can be built and storage space can be clearly allocated for each purpose. However, this may not be an economical proposition. The conservational demands are best served when the reservoir is as much full as possible at the end of filling period. On the other hand, for flood control purposes, empty storage space in the reservoir need to be maximized for safely absorbing the flood waters. Because of the conflicting objectives, operation of multipurpose reservoirs is complex task, especially when integrated operation of system of reservoirs is contemplated.

3.3.2 Conflict in Time

The temporal conflicts in reservoir operation occur, when the use pattern of water varies with the purpose. The conflicts arise because release for one purpose does not agree with that for the other purpose. For example irrigation demands may show one pattern of variation depending upon the crops, season and rainfall; while the hydroelectric power demands may have a different variation. In such situations, the aim of deriving an operating policy is to optimally resolve these conflicts.

3.3.3 Conflict in Discharge

The conflicts in daily discharge are experienced for a reservoir, which serves more than one purpose. In case of a reservoir serving for consumptive use and hydroelectric power generation, the releases for the two purposes may vary considerably in the span of one day. Many times, a small conservation pool is created on the river downstream of the powerhouse, which is used to dampen the fluctuations in releases for meeting varying power demands.

3.4 HYDROLOGIC FORECAST

Hydrologic forecast plays a dominant role in reservoir operation. Forecast may be classified as short term (upto 2 days), medium term (2-10 days), long term (beyond 10 days) or seasonal (several months) according to WMO guide to Hydrological Practices, Publication No. 108 (1983). The short term forecasts, being of higher reliability, are often used for operation of reservoir. Long term forecasts, which are related to meteorological conditions, have low reliability in spite of extensive use of high technology of remote sensing, numerical techniques and electronic instrumentation in the area of weather prediction. Due to the low reliability, long term or seasonal forecasts are not very useful in operation of reservoirs.

3.4.1 Forecasts for Conservation

The main purpose of foreknowledge of inflows into reservoirs for conservational purposes is to utilize the available water fully when inflows are likely to be in excess and to restrict the supplies when inflows are expected to be lower, so as to minimize adverse effects. Forecasts required for conservational purposes are either long-term or seasonal. For management of over-the-year storage, forecast of even a year or more is required. Long-term seasonal or annual forecasts, being dependent on meteorology, are not reliable enough to be used in operation of reservoirs. However the pattern of precipitation and utilization in many regions of India is such that the reservoirs could be operated with foreknowledge of water availability for a part of the year.

Most of the inflow into reservoir on non-snow-fed rivers occurs during monsoon period. Winter rains are generally scanty and unreliable. Depending on the availability of water in the reservoir at the end of the monsoon season, the supplies for the subsequent Rabi season could be planned and any shortfalls can be distributed in such a way so as to minimize the associated adverse effects. One of the ways is to distribute it as uniformly as possible resulting in shortfalls of small magnitude spread over a large number of periods. The optimum distribution of shortfalls can be achieved by use of optimization models, which can consider long periods of inflows and demands. In real time operation such distribution is possible only with complete foresight, which is yet to be developed. The real problem in the operation of reservoirs in the absence of forecasts is for Kharif supplies during short-term failures of monsoon, when inflow into the reservoir decreases and demand rises.

3.5 PRINCIPLES OF RESERVOIR OPERATION

Reservoirs are operated according to a set of rules or guidelines for storing and releasing water, depending on the purpose to be served. Regulation plans to cover all the complicated situations may be difficult to evolve, but generally, it may be possible according to the following commonly adopted principles of reservoir operation for flood control and conservational uses in case of single purpose, multipurpose and system of reservoirs. These guidelines are broad generalization only and are indicative in nature. For actual operation of reservoir or a system of reservoirs, individual regulation schedules are required to be formulated after considering all critical factors involved.

3.5.1 Single Purpose Reservoir

a) **Flood Control:** Operation of flood control reservoirs is primarily governed by the available flood storage capacity, discharge capacity of outlets, their location and nature of damage centers to be protected, flood characteristics, ability and accuracy of flood / storm forecast and size of the uncontrolled drainage area. A regulation plan to cover all the complicated situations may be difficult to evolve, but generally, it should be possible according to one of the following principles.

i.) Effective use of available flood control storage --- Operation under this principle aims at reducing flood damages of the locations to be protected to the maximum extent possible, by effective use of flood control storage capacity available at the time of each flood event. Since the release under this plan would obviously be lower than those required for controlling the reservoir design flood, there is distinct possibility of having a portion of the flood control space occupied during the occurrence of a subsequent heavy flood. In order to reduce this element of risk, maintenance of an adequate network of flood forecasting stations both in the upstream and downstream areas would be necessary.

ii.) Control of Reservoir Design Flood --- According to this principle, releases from flood control reservoirs operated on this concept are made on the hypothesis that the full storage capacity would be utilized only when the flood develops into the Reservoir Design Flood. However, as the design flood is usually an extreme event, regulation of minor and major floods, which occur more often, is less satisfactory when this method is applied.

iii.) Combination of principles (i) and (ii) --- In this method, a combination of the principles (i) and (ii) is followed. The first principle is followed for the lower portion of the flood reserve to achieve the maximum benefits by controlling the earlier part of the flood. Thereafter the releases are made as scheduled for the reservoir design flood as in second principle. In most cases this plan will result in the best overall regulation, as it combines the good points of both the methods.

iv.) Flood moderation in emergencies --- It is advisable to prepare an emergency release schedule that uses information on reservoir data immediately available to Conservation: Reservoirs meant for augmentation of supplies during lean period should usually be operated to fill as early as possible during filling period, while meeting the requirements. All water in excess of the requirements of the filling period shall be impounded. No spilling of water over the spillway will normally be permitted until the FRL is reached. Should any flood occur when the reservoir is at or near FRL, release of flood waters should be effected so as not to exceed the discharge that would have occurred had there been no reservoir. In case the year happens to be dry, the draft for filling period should be curtailed by applying suitable factors. The depletion period should begin thereafter. However, in case the reservoir is planned with carry-over capacity, it is necessary to ensure that the regulation will provide the required carry-over capacity at the end of the depletion period. the operator. Such schedule should be available with the operator to enable him to comply with necessary precautions under extreme flood conditions.

3.5.2 Multi-Purpose Reservoir

Operation of multi-purpose reservoir should be governed by the manner in which various uses of the reservoir have been combined. While operating the reservoirs to meet the demands of end users, the priorities for allocation may be used as a guideline. In general five basic zones of reservoir space may be used in operating a reservoir for various functions. Typical storage allocations for various uses are indicated in the figure 3.1.

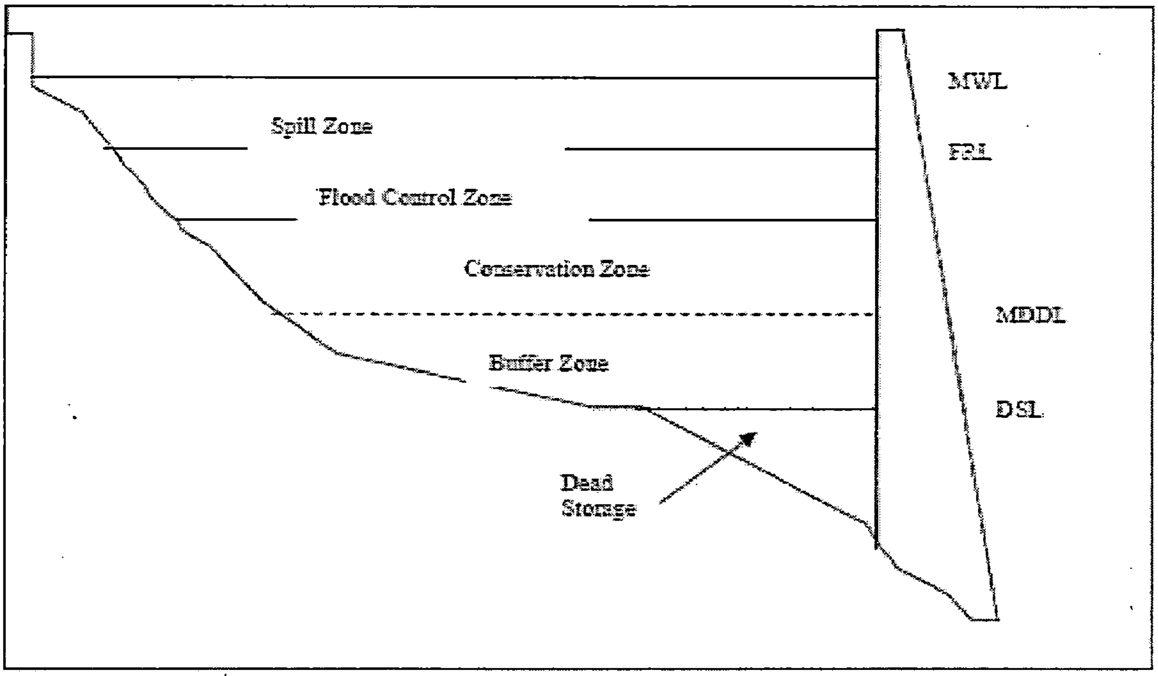


Fig. - 3.1: Typical Storage Allocation in Reservoirs [26].

a) Spill Zone: Storage space above the flood control zone between FRL and MWL is generally referred to as spill zone. This space is occupied mostly during high floods and the releases from this zone are trade-off between structural safety and downstream flood damages.

b) **Flood Control Zone:** This is the storage space earmarked as temporary storage for absorbing high flows for alleviating downstream flood damages. This space should be emptied as soon as possible to negotiate next flood event.

c) **Conservation Zone:** This storage space is used for conservation of water for meeting various future demands. This zone is generally between FRL and DSL.

d) **Buffer Zone:** This is the storage space above dead storage level which is used to satisfy only very essential water needs in case of extreme situation.

e) **Dead Storage Zone:** This is also called inactive zone. This is the lowest zone in which the storage is meant to absorb some of the sediments entering into the reservoir. The storage in this zone is not susceptible to release by the in-built outlet means.

The general principles of operation of reservoirs with these multiple storage spaces are described below:

a) **Separate allocation of capacities:** When separate allocations of capacity have been made for each of the conservational uses, in addition to that required for flood control, operation for each of the function shall follow the principles of respective functions. The storage available for flood control could however be utilized for generation of secondary power to the extent possible. Allocation of specific storage space to several purposes within the conservation zone may sometimes be impossible or very costly to provide water for the various purposes in the quantities needed and at the time they are needed.

b) **Joint use of storage space:** In multi-purpose reservoir where joint use of some of the storage space or storage water has been envisaged, operation becomes complicated due to competing and conflicting demands. While flood control requires low reservoir level, conservation interests require as high a level as is attainable. Thus, the objectives of these functions are not compatible and a compromise will have to be effected in reservoir operation by sacrificing the requirements of these functions. In some cases, parts of the conservational storage are utilized for flood moderation, during the earlier stages of the monsoon. This space has to be filled up for conservation purposes towards the end of monsoon progressively, as it might not be possible to fill up this space during the post-monsoon periods, when the flows are insufficient even to meet the current requirements. This will naturally involve some sacrifice of the flood control interests towards the end of the monsoon. The concept of joint use of storage space, with operational criteria to maximize the complementary effects and to minimize the competitive effects requires careful design. Such concepts, if designed properly, are easier to manage and will provide better service for all requirements. With the advancements of system analysis techniques, it is easy now to carefully design the joint use in a multi-purpose reservoir.

3.5.3 System of Reservoirs

In case of system of reservoirs, it is necessary to adopt a strategy for integrated operation of reservoirs to achieve optimum utilization of the water resources available and to benefit best out of the reservoir system.

In the preparation of regulation plans for an integrated operation of system of reservoirs, principles applicable to separate units are first applied to the individual reservoirs. Modifications of schedules so developed should then be considered by working out several alternative plans. In these studies optimization and simulation techniques may be extensively used with the application of computers in water resources development.

a.) **Flood control regulation:** The basin-wise flood conditions are considered, rather than the condition of the individual sub-basins. The occupancy of flood reserves in each of the reservoirs, distribution of releases among the reservoirs, and bank-full stages at critical locations should be considered simultaneously. For instance, if a reduction in outflows is required, it should be made from the reservoirs having the least capacity occupied or has the smaller flood run-off from its drainage area. If an increase in release is possible, it should be made from the reservoir where the percentage occupancy is highest or relatively higher value of flood run-off is occurring. Higher releases from reservoirs receiving excessive flood run-off may be thus counter balanced, particularly in cases of isolated storms, by reducing releases from receiving relatively less run-off.

b.) **Conservation regulation:** The current water demands for various purposes, the available conservation storage in individual reservoirs, and the distribution of releases among the reservoirs should be considered to develop a co-ordinate plan to produce the optimum benefits and minimize water losses due to evaporation and transmission.

CHAPTER 4

STUDY AREA

4.1 INTRODUCTION:

The domain of the present study encircles the 'Harabhangi irrigation project', an inter-basin irrigation project in Orissa state (India). Orissa state is very rich in natural resources, especially in water resources, but economically poorer in comparison with other states of the country due to its inability for proper management of these resources. Majority of the lands, barring 10 coastal districts out of 30 districts, in the state are covered with hilly terrain, mostly occupied by the tribal population, and face chronic ravages of rough nature, such as drought and flood. The coastal districts are very well facilitated with water resource projects, which create a wide disparity among the plain and hilly areas. During ninth and tenth five-year plans, Government of India stressed the need of exploitation of the water resources of the country to its maximum extent for overall development of the nation. Therefore, the irrigation planning authority shifted its focus for development of command areas for irrigation in the upper reaches of the river basins. Although, the conceptual planning of the Harabhangi irrigation project was initiated in way back since 1962, the recent implementation of the project is a step forward in such direction.

The command area of the irrigation project lay under the sub-basins of river Padma and Joro, the two upper most tributaries of river Rushikulya under Rushikulya basin. Harabhangi reservoir, which serves as the source of water for the irrigation project, is formed by construction of a dam on river Harabhangi a tributary of river Vansadhara in Vansadhara basin. The water is diverted from the Harabhangi reservoir through a tunnel to river Padma, which serves as a carrier for the transferred water for the said irrigation project [27].

4.2 RIVER BASINS UNDER STUDY

The study area comprises of parts of two adjoining river basins in the southern part of Orissa state; namely, Rushikulya basin and Vansadhara basin.

4.2.1 Rushikulya Basin:

It is one of the major river basins of Orissa covering larger portion of Ganjam and Gajapati districts, and few portions of Puri and Phulbani district of Orissa state. Although it is comparatively smaller than other major river basins, such as: Mahanadi, Brahmani, and Baitarani with respect to its water resources potential, but has abundant water resources, a part of which is being utilized since long for irrigation purposes in the Ganjam district. River Rushikulya originates from Arahbity and Kutarbar hills of Ganjam and Phulbani districts of Orissa, at an elevation of about 500 m, at latitude 20° North and longitude 84° 20′ East. It flows in the southeast direction, and meets Bay of Bengal near Chhatrapur, after traversing a length of 175 km covering a drainage area of 8200 sq km.

There are eight tributaries of the river. The prominent tributaries are Padma, Baranga nala, Joro, Baghua, Dhanei, and Ghodagoda. The project under study is under Padma sub-basin only. The basin map is shown in Figure 4.1.

Geological features in and around the basin, and in the catchments, mostly comprise of Khondalite and Chanokite rock formations. The rainfall in the basin is mainly from the southwest monsoon, and lasts from June to October. About 80 % of the annual precipitation occurs during these months. Besides monsoon rains, cyclonic rains are not uncommon in recent years. Annual rainfall varies from 3249 mm (at Soroda) to 414 mm (at Chakapada), with an average rainfall of about 1235 mm. Average maximum and minimum temperatures in summer is about 45° C and 27° C, respectively. Relative humidity is higher (about 88.93%) during July, August, and September.

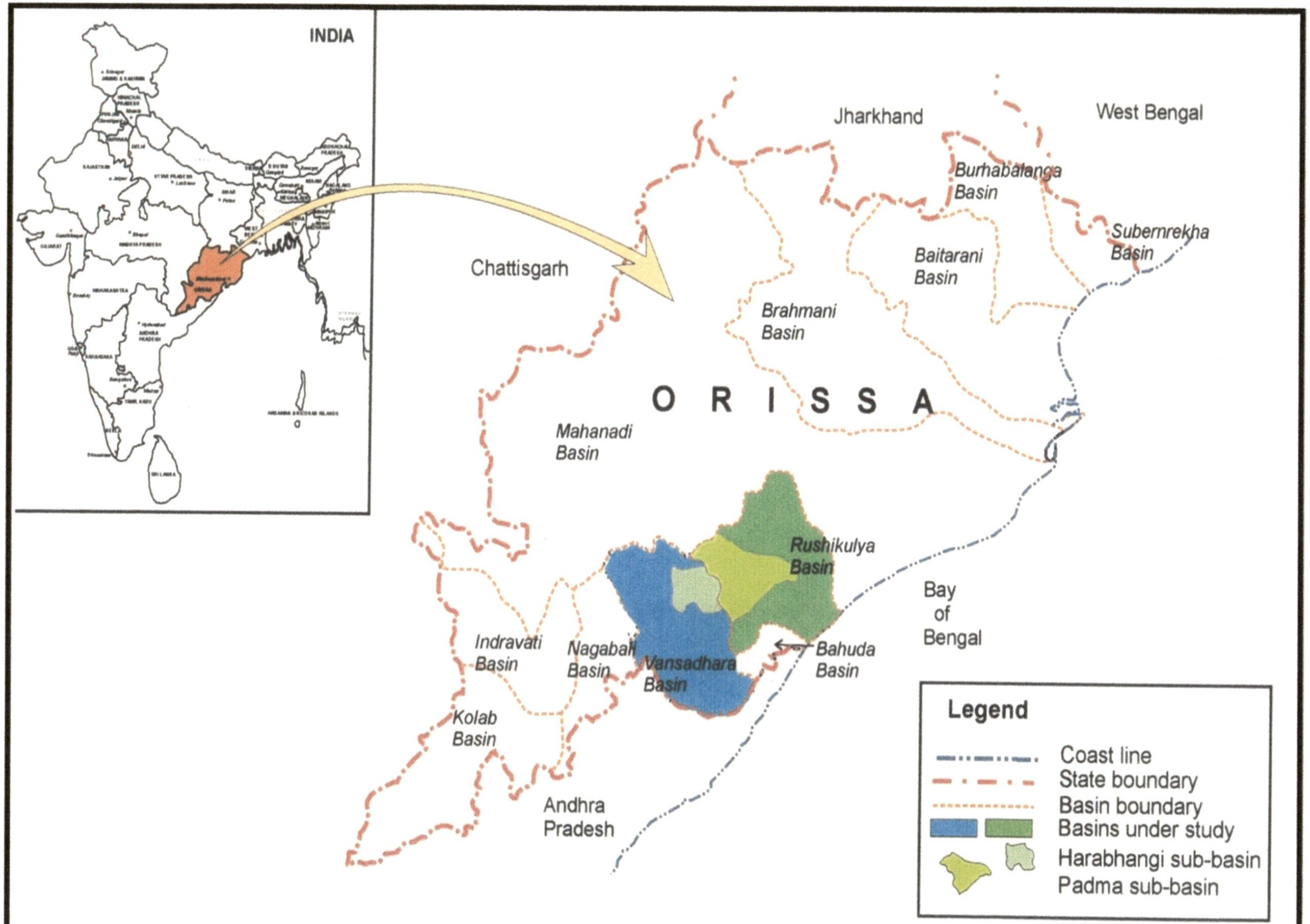


Fig 4.1 Orissa and its river basins

A meteorological station of Indian Meteorological Department (IMD) at Gopalpur port records the climatological and meteorological information.

The people of the basin mostly depend on agriculture and have small land holdings. Out of 820,000 ha of geographical area, total cultivable area is 336,510 ha, from which only 196,420 ha is provided with irrigation. Major and medium projects, irrigate 106,997 ha and minor projects 69,400 ha. About 20,020 ha are irrigated by other sources, and 400,000 ha are under the forestland. Schemes are being developed to provide irrigation to more of the cultivable command areas by adopting rotational irrigation practices in the farms.

4.2.2 Vansadhara Basin

The Vansadhara basin lies just adjacent to the Rushikulya basin towards its south, extending both in Orissa and Andhra Pradesh states. It covers a total drainage area of 11,377 sq km, out of which 8,960 sq km and 2,417 sq km lie in Orissa and Andhra Pradesh, respectively. This basin is also smaller in comparison to the other major river basins of the state. It has abundant water resources, and only a part of which is being utilized for irrigation purposes. It lies in the southern part of Orissa covering four districts, i.e., Kalahandi, Koraput, Ganjam, and Phulbani. The river Vansadhara originates from hills of Kalahandi district at an average elevation of 1150 m, at latitude 19° 15′ North and longitude 83° 29′ East. It flows in the southeast direction, and meets Bay of Bengal in Andhra Pradesh state, after traversing 239 km. There are 13 numbers of tributaries among which the prominent are: Panimunda, Sokta, Bhangi, Pedagodda, Balinala, Chaulakhia, Pallanai, Sonanadi, and Harabhangi. The project under study is on the river Harabhangi. The basin map is shown in Figure 4.1.

Geological features of the basin are similar to the Rushikulya basin. The maximum and the minimum temperatures of the basin are 33°C to 7°C, respectively. The rainfall distribution is fairly even with the average of 1235 mm, with the maximum of 3249 mm, and the minimum of 414 mm. Nearly 90% of the annual rainfall occurs during the monsoon period, i.e., from month of June to October.

There is no meteorological station inside the basin in the Orissa portion of the basin. Therefore, report of IMD station at Gopalpur is considered for climatological and meteorological data. There is a meteorological station at Kalingapattanam in Andhra Pradesh.

Out of the 896,000 ha of geographical area of the basin lying inside of Orissa state, 183,330 ha are culturable area. There are not much facilities of irrigation except through Badanala and Bondapippili medium projects, and few minor irrigation projects, comprising 11,800 ha and some ongoing projects altogether of 360,400 ha. About 420,000 ha are covered with forest.

4.3 THE HARABHANGI PROJECT

An overall view of the present Harabhangi irrigation project is shown in Figure 4.2. The entire sequencing of the project is being presented here in three distinct phases, as per the different phases of project concept evolution, and implementation at different times.

1. Pre-conceptual status of the project

2. Present status of the project

4.3.1 Pre-conceptual status of the present project (Soroda dam project)

Soroda reservoir served as a part of the old Rushikulya irrigation project, and is utilizing the water potential of River Padma, a tributary of river Rushikulya. River Padma, a right tributary of river Rushikulya lies in the upper middle portion of the basin. It originates from Kuduma hill ranges at latitude 19°35′ North and longitude 84°15′ East, at an average elevation of 500.0 m. The river has a drainage area of 499 sq km. Another river Joro joins river Padma, at the downstream of Soroda. A weir was constructed over river Padma near Soroda to divert water by a link channel for feeding Soroda reservoir, which was built over a small drain having a catchment area of 19.42 sq km. The surplus water was allowed to spill to the river Rushikulya through a surplus escape to Bantulinala, a drain connecting river Rushikulya. The reservoir is having a designed live storage of capacity of 3272 ham. The project was planned and implemented 100 years back, when population of this zone was very less, for which development of irrigation command area was not felt necessary. All the irrigation command area was developed towards the downstream of the river, near to the coast (plain area). Therefore, this project was implemented as a storage reservoir at the downstream of the river Rushikulya. Thus, the reservoir at Soroda was mainly fed from river Padma, and was acting as a balancing reservoir for the Rushikulya irrigation system.

4.3.2 Present status of the project (Harabhangi Irrigation Project):

Subsequently, when the irrigation authority planned to develop irrigation command area in the upper zone of Rushikulya basin (Padma valley), the water resources of river Padma, which were being utilized for the downstream projects as stated above, was not available for this purpose. To develop the command area in the Padma valley the water resources of Harabhangi river in the adjacent Vansadhara basin were chosen for transferring into this basin as an alternate water resource.

River Harabhangi is the upper most and major potential tributary of river Vansadhara. It originates from Ramgiri hills of southern Orissa at general elevation around 1100 m. A dam has been built to harness water, at village Adava,

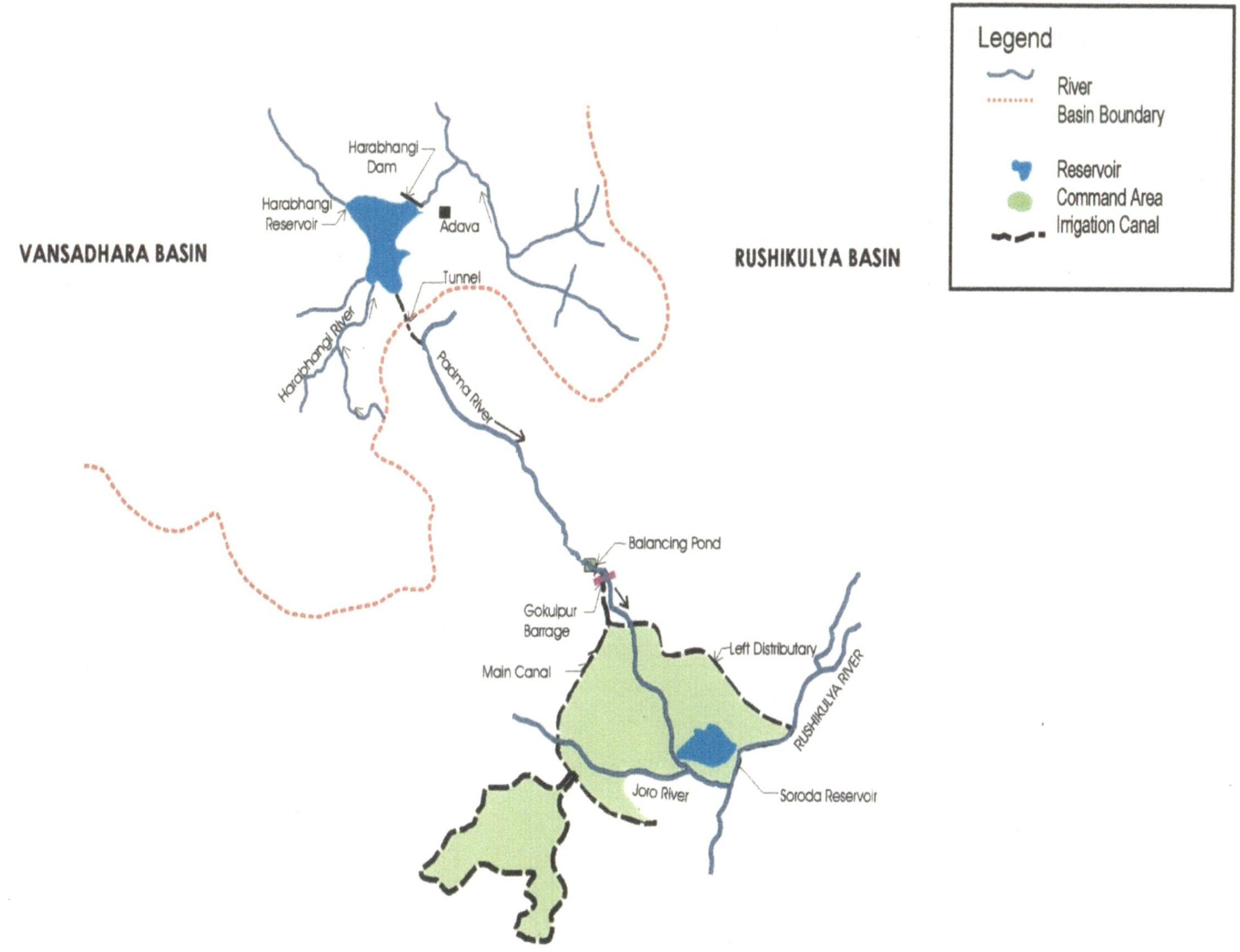


Fig 4.2 Harabhangi Irrigation Project

about 90 km downstream of its origin. The catchment area intercepted at the dam site is 503 sq km. Consequent upon the completion of the dam, a reservoir has been formed having a live storage capacity of 10025 ham between DSL (RL 375.000 m) and FRL (RL 387.500 m).

The stored water is being utilized for inter-basin transfer from Vansadhara basin to Rushikulya basin, cutting across the dividing line through a lined D-shaped tunnel of 3 m diameter and 2.2 km long, along with the approach and exit channel, for irrigation supplies. At the exit end, the water emerges out at RL 367.00 m and flows into river Padma, which is a tributary of river Rushikulya. A pickup weir has been constructed over river Padma at Gokulpur with FRL (RL137.00 m) at about 33 km downstream of tunnel exit to tap the transferred water from Harabhangi reservoir for irrigation of the area between Soroda and Badagada. The main canal under study begins on the right flank of Gokulpur weir and runs for about 2.5 km before bifurcating. The left canal, 15.9 km long, crosses the Padma river on a 225 m long aqueduct to supply water to 2,170 ha area. The right canal is 20.9 km long and is supplying 6,980 ha area.

The portion of the river Padma from the diversion tunnel exit to the Gokulpur barrage is being used as a carrier or natural water conductor system for Harabhangi irrigation system only, because practically the water of the river Padma is not being utilized by the Harabhangi irrigation project. Construction work of the irrigation system is complete, and water is being released from Harabhangi reservoir as per the quantum of irrigation requirements.

4.4 PHYSICAL CHARACTERISTICS OF THE PROJECT AREA

4.4.1 Location

The Harabhangi irrigation project is located in Ganjam and Gajapati districts. The dam at Adava is located at about longitude 84°08′ East and latitude 19°30′ North with MWL of the reservoir at 387.5 m above the sea level. The catchment area at the dam site is 503.8 sq km and extends from longitude 84°03′ to 84°22′ East and latitude 19°17′ to 19°34′

North. The elevation of the command area under Soroda and Badagada block vary from 130 m to 90 m above sea level. The canal network of the project for distribution of water begins on the right flank of Gokulpur barrage. The salient features of the project are shown in Table 4.1.

4.4.2 Soil and Land Suitability for Irrigation

Based on the soil survey, five soil series were recognized in the command area. Soil textures vary from loamy sand to loam, with soil reactions (PH) varying from neutral to slightly acidic. Infiltration rates on the vast majority of the soils are reported to be from 24 to 144 mm per day, indicating very high water demands.

Table 4.1 SALIENT FEATURES OF THE PROJECT

Item	Feature
Name of the project	Harbhangi Irrigation Project
Name of the Basin	Rushikulya and Vansadhara
Location	Longitude 84030' East
	Latitude 18030' North
State	Orissa
District	Gajpati and Ganjam
Hydrology	
Catchment area	503.8 sqkm
Maximum annual rainfall	3249 mm
Minimum annual rainfall	414 mm
Average annual rainfall	1235 mm
75% year's dependable inflow	21.576 Tham
Reservoir	
Type of Dam	Earth dam
Crest level of Dam	RL 390.500 m
Spillway discharge capacity	4608.000 cumecs
Live storage capacity	10.025 Tham
FRL/MWL	RL 387.500 m

Item	Feature
DSL	RL 375.000 m
FRA	RL 1215.000 ha
DSA	RL 535.000 ha
FRC	RL 14125.000 ham
DSC	RL 4100.000 ham
Diversion Tunnel	
Shape	D- shaped
Diameter	2.8000 m
Length	2.200 Km
Barrage	
Catchment area	200.98 sqkm
FRL/MWL	RL 137.200 m
MFD	1252.000 cumecs
HFL	RL 140.640 m
Irrigation	
CCA	9650.00 ha
Gross annual irrigation requirements	16.370 Tham

N.B.:-Area-elevation-capacity data of the reservoir is furnished in the Table-2.4 which will be used for the reservoir yield analysis.

4.4.3 Climate

The project has a tropical monsoon climate with pronounced wet season from June to October with an average of about 80 % of the annual precipitation. The mean daily air temperature varies from about 27° to 33°. The rainfall are recorded at Soroda and is therefore applicable to the command area but other meteorological data are obtained from IMD station at Gopalpur, situated at an aerial distance of about 80 km. The climatological data considered for the study are shown in Table 4.2.

Table 4.2 Climatic data of Harabhangi irrigation project [27]

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Average Rainfall (mm)	1.5	26.8	20.2	59.7	103.5	183	230.5	242	186.7	162.4	76.7	1.38	1294
Mean Air Temp. (^{0}C): Max.	27.9	29.4	31.1	31.5	32.7	32.4	31.4	31.7	32.4	32	30	28	--
Min.	17	20	23.1	25.2	26.7	26.9	26.3	26.2	26	24	20.2	16.8	--
Relative Humidity (%)	77.5	76.9	77.3	82	78.4	81	85.2	84.1	84.4	81.8	78.8	76.7	--
Monthly Pan Evaporation(mm)	162	162	241	218	249	200	182	163	242	186	160	158	2323
Mean Wind Speed (km/hour)	6.7	5	6.1	9.7	9.8	6.7	6	5.7	5.6	7.3	8.9	8.2	--
Sun Shine (hours)	9.9	10.2	10.4	10	9.4	7.4	5.2	6.2	6.7	7.9	9	9.3	--
Actual Evaporation	113	113	169	153	174	160	146	130	193	148	116	110	1725

Note: Source: Meteorological station of IMD at Gopalpur port (on sea)

Depending on the topography, soil type and drainage characteristics, the command area was classified into land suitability for irrigation. Out of the total CCA of 9150 ha, 6497 ha (71%) is assessed under classes-I and II, i.e., moderately suitable for irrigation, and 2653 ha (29%) as class-III, i.e., fairly suitable but severe limitations for the sustained use for irrigation. These limitations are due to adverse topology, i.e., steep slopes or due to light soils (loamy sands), which are excessively or well drained, with high water infiltration (Not all runoff flows into rivers, much of it soaks into the ground as infiltration.) rates.

4.4.4 Population

According to the 2001 census, the population of the project area was 80,950 out of which 21,038 belongs to the schedule caste and schedule tribe. Out of the 16,200 households, with an average of five members per family, about 6,600 families do not have lands of their own. Thus the average family land holding is low of about 1.7 ha.

4.5 PROJECT PARAMETERS

4.5.1 Water Resources

The catchment area of river Harabhangi at the dam site is 503.8 sq km. The mean annual flow at the dam site was estimated at 273 Mm^3 per year (8.7 Cumecs), which corresponds to 540 mm of runoff. The mean daily rainfall for 16 years at damsite and at padagam, a village situated close to the dam site. The reservoir would provide live storage of about 100 Mm^3. The dead storage level of reservoir is at R.L. 375 m. The elevation-area-capacity for the Harabhangi reservoir is presented in Table 4.3.

Table 4.3 Elevation-Area-Capacity of Harabhangi reservoir [27]

Elevation (m) (1)	Area (ha) (2)	Capacity (ham) (3)	Elevation (m) (4)	Area (ha) (5)	Capacity (ham) (6)
370.00	330.00	2100.00	380.00	758.00	7300.00
371.00	370.00	2425.00	381.00	810.00	8100.00
372.00	420.00	2750.00	382.00	870.00	8925.00
373.00	440.00	3200.00	383.00	927.00	9700.00
374.00	490.00	3600.00	384.00	985.00	10525.00
375.00	535.00	4100.00	385.00	1045.00	11400.00
376.00	575.00	4625.00	386.00	1100.00	12350.00
377.00	620.00	5200.00	387.00	1157.00	13500.00
378.00	665.00	5500.00	387.50	1215.00	14125.00
379.00	710.00	6550.00			

4.5.2 Cropping Pattern

The total command area under the project is 9150 ha and the irrigation is provided to whole of the CCA in Kharif season (June to October), and for about 8500 ha in Rabi season (November to May). The present cropping pattern at the full development of project is given in Table 4.4. Paddy is the principal crop grown in Kharif season with the early, medium and late paddy's covering an area of 7450 ha out of the total area of 9150 ha. Sugarcane is grown in only about 4% of the area totaling the cropping intensity at 193%.Prior to the implementation of the irrigation project, out of 9,650 ha of CCA, about 8,485 ha were under cultivation, which is about 88% of the present CCA.

Table 4.4 Cropping pattern [27]

Season (1)	Crop (2)	Area (ha) (3)	Yield (Kg/ha) (4)
Kharif	Early Paddy	2500	2000
	Medium Paddy	3100	3500
	Late Paddy	1850	3500
	Ragi	440	900
	Groundnuts	750	2000
	Maize	150	1800
	Sub-total	8790	---
Perrenial	Sugar cane	360	20000
	Total	9150	
Rabi	Dalua Paddy	1500	3500
	Pulses	1050	900
	Groundnuts	2050	2000
	Vegetables - Upland	1400	10000
	Vegetables - Lowland	1400	10000
	Potato	400	19000
	Mustard	700	400
	Total	8500	---
Grand Total		17650	

4.5.3 Canal Operational Plan

An operational plan for the canals of the project has been prepared by the authorities to provide guidance to the system operators for supply of irrigation water to the entire command area. The irrigation is provided to the command area on a rotational basis. The monthly operation plan is given in Table 4.5. The canal is kept open for whole of the month in case of July, August and September and for limited number of days in other months.

Table 4.5 Monthly operational plan of irrigation canals [27]

Month (1)	Duration of canal operation (2)	Number of days of canal operation (3)
Jan	8-15*, 22-30**	17
Feb	7-14, 22-28	15
Mar	8-15, 23-31	17
April	8-14, 22-29	14
May	4-5	2
June	15-25	11
July	3-31	29
Aug	1-31	31
Sept	1-30	30
Oct	1-10	10
Nov	23-30	8
Dec	8-15, 23-30	16

* Starting date, ** Closure date

4.5.4 Details of Canal Network

The canal network of Harabhangi irrigation project for distribution of the water begins on the right flank of Gokulpur barrage. The main canal runs for a length of 2.515 km before the Left distributary canal takes off, which is 15.854 km long, and crosses the river Padma on a 225 m long aqueduct to irrigate 2170 ha land. The length of the main canal is 23.985 km, and it irrigates 6980 ha command area. The network comprises of a total number of 15 branch canals out of which the distributaries are only four and the rest are the minors and sub-minors. The command areas under the branch canals are given in Table 4.6. The Left distributary, the Khariguda distributary and the Kadaguda distributary are the three main distributaries irrigating large command areas.

Table 4.6 Details of the branch canals [27]

S.No. (1)	Name of branch canal (2)	Off-taking at RD Km (3)	Command Area Ha (4)
1	Left distributary	2.525	2170
2	Kaithapali sub-minor	3.98	137
3	Takarda distributary	6.169	781.57
4	Raibandha minor	7.232	626.29
5	Khariguda distributary	8.275	1718.53
6	Kadaguda distributary	12.155	2814.94
7	Batasasan sub-minor	14.095	75.51
8	Gangapur sub-minor No.I	15.055	78
9	Gangapur sub-minor No.II	16.335	84.3
10	Sidhapur sub-minor	16.915	110.82
11	Kalakhadi sub-minor	17.845	140.39
12	Goberlundi sub-minor No.I	19	78.14
13	Goberlundi sub-minor No.II	19.48	62.6
14	Lembakumpa sub-minor	19.93	62.4

4.6. THE PROBLEM:

River Harabhangi is the upper most and major potential tributary of river Rushikulya. The major portion of the Rushikulya basin is covered by Ganjam district. This district was seriously affected by famine in 1865-66. This necessitated the development of irrigation system. This system was named as Rushikulya irrigation system, and was categorized as major irrigation project, providing Class-I irrigation. This system is an integrated project, and was undertaken a century back as a draught measure in this district. The old system consisted of two reservoirs schemes namely (1) Bhanjanagar reservoir and (2) Soroda reservoir, and four diversion weirs, i.e., (1) Janivilli (2) Madhaba barida (3) Sorisamuli, and (4) Padma. The storage capacities of these reservoirs were reduced due to siltation during past 100 years. Supply of water was not adequate. The structures were weakened, and required immediate renovation. Initially the command area of Rushikulya irrigation system was less than 30000 ha. It gradually increased to 61,790 ha, providing irrigation during the Kharif season only. The project has been renovated with the World Bank assistance under the Water Resources Consolidated Project (WRCP) of Government of Orissa.

The catchment area intercepted at the dam site is 503 sq km. Consequent upon the completion of the dam, a reservoir has been formed having a live storage capacity of 10025 ham between DSL (RL 375.000 m) and FRL (RL 387.500 m).The project is intended to provide irrigation to dry areas which faces chronic droughts very frequently due to erratic and failure of rains.

Now that an irrigation scheme is proposed by the concerned authority to provide certain relief measures to the people of the drought—prone area, it is very much imperative on the part of the agency who executes the scheme to devise a suitable operation policy and implement the same, so that the limited amount of water that may be available in the reservoir during both normal and drought periods, can be used in the best possible manner. Every drop of water is so valuable in the area that its wastage is intolerable. There should be motives behind this policy to save some water in the reservoir judiciously, distribute it in right manner so as to make timely utilization. This aspect is very important.

Thus in the present problem keeping in view of the above facts an operation policy is to be devised so as to be applied in the reservoir operation and if found effective the same can very well be adoptable as an operation policy of the proposed scheme in future.

Several approaches may be available with their effects on different criteria on reservoir operation. But no such information is available on the performance of these methods under drought conditions. Complicated system approaches using simulation techniques are now widely used, due to the advent of digital computers. But rarely the operation techniques are formulated for purposes of reservoir operation.Thus sincere effort is put here to formulate an operation procedure based on principle of multiple regressions so as to be examined the deficit periods of the reservoir.

But in the project report only a very short period of historical flows are available, where it is but a handicap to study the reservoir behavior in a complete and proper manner. The existing working table represents only for forty two years whereas the life of the project is about hundred years. However, this working table is found useful in the work to formulate the monthly operation policy.

TABLE 4.7 Monthly Inflows To The Harabhangi Reservoir In MCM

YEAR	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	TOTAL
1950-51	51.87	63.29	72.27	46.29	32.27	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**273.70**
1951-52	17.89	64.74	143.53	73.87	44.53	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**352.27**
1952-53	14.30	105.23	46.83	168.95	98.04	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**441.06**
1953-54	35.92	47.77	103.98	97.66	35.65	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**328.69**
1954-55	22.65	30.79	125.77	97.82	84.8	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**369.54**
1955-56	28.62	38.07	90.29	92.74	15.17	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**272.60**
1956-57	40.98	79.79	74.75	80.22	12.33	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**295.78**
1957-58	38.25	20.31	75.38	18.13	11.48	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**171.26**
1958-59	15.49	54.80	85.32	127.58	16.72	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**307.62**
1959-60	42.49	61.84	74.76	46.65	91.29	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**324.74**
1960-61	23.34	42.19	75.38	78.59	83.1	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**310.31**
1961-62	36.88	89.74	83.53	97.1	16.76	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**331.72**
1962-63	28.89	39.53	121.1	31.77	65.42	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**294.42**
1963-64	30.15	42.80	102.53	29.85	72.57	12.94	2.68	1.03	0.64	1.04	1.05	0.61	**297.89**
1964-65	16.95	48.00	95.66	62.86	62.85	21.57	2.05	1.04	0.72	0.38	0.97	1.96	**315.01**
1965-66	4.97	57.37	52.46	56.86	45.9	1.82	0.82	1.06	0.64	1.26	0.52	0.52	**224.20**
1966-67	21.58	41.75	56.49	51.3	11.97	15.3	2.51	1.08	0.31	0.22	1.46	1.58	**294.42**
1967-68	34.27	45.69	65.83	12.69	16.55	1.9	1.17	1.26	0.36	5.07	0.48	0.62	**185.89**
1968-69	9.58	21.07	23.55	11.6	8.25	4.41	3.3	0.56	0.39	0.4	0.6	0.61	**84.32**
1969-70	31.15	95.65	49.59	86.58	4.26	13.65	5.17	3.6	1.07	0.97	0.6	0.62	**189.56**
1970-71	20.85	37.56	59.88	21.59	27.87	4.11	3.71	3.68	2.59	3.91	1.57	2.24	**189.56**
1971-72	16.52	11.16	92.58	58.28	65.9	4.83	3.97	2	1.52	0.58	2.71	1.92	**261.97**
1972-73	35.62	10.43	42.3	49.64	73.7	4.11	0.97	0.56	0.38	0.47	6	0.62	**224.80**

1973-74	3.87	38.96	41.59	48.92	29.88	4.11	0.97	0.56	0.38	0.47	0.6	0.62	**170.93**
1974-75	7.89	7.6	11.98	38.62	86.55	1.81	0.97	1.03	0.49	1.31	1.35	1.31	**160.91**
1975-76	31.75	33.26	51.49	92.17	48.16	7.71	1.69	0.55	0.65	1.25	1.07	2.04	**271.79**
1976-77	1.92	61.84	114.86	28.96	22.86	2.16	0.53	1.09	0.64	0.47	0.95	1.33	**237.61**
1977-78	1.27	12.55	46.13	56.45	2.72	18.11	2.16	0.26	0.15	0.61	0.51	0.72	**141.64**
1978-79	27.57	81.55	71.26	46.71	8.86	7.32	0.36	0.38	0.37	1.84	2.15	3.09	**251.46**
1979-80	24.38	30.49	71.68	27.98	68.12	25.16	0.69	0.38	0.37	1.84	2.15	9	**262.24**
1980-81	28.32	10.64	56.71	152.84	51.15	10.69	16.97	3.22	2.43	7.17	7.78	7.58	**355.50**
1981-82	31.16	45.33	62.48	60.66	11.01	3.09	2.86	3.5	2.61	6.44	7.78	7.58	**244.50**
1982-83	28.73	14.19	15.1	18.32	15.93	3.52	2.67	1.61	2.35	5.86	8.66	9.65	**126.59**
1983-84	24.13	19.83	30.89	39.87	76.79	3.51	2.87	2.57	2.79	7.17	7.97	8.92	**227.31**
1984-85	24.30	12.02	43.76	10.76	40.53	3.07	2.18	3.16	2.43	6.45	6.79	9.65	**165.10**
1985-86	16.27	35.43	50.39	24.26	50.34	2.51	2.38	3.22	3.11	7.17	9.63	11.05	**215.76**
1986-87	18.33	24.32	70.04	25.65	58.28	3.51	2.89	1.6	2.61	7.33	8.82	9.61	**232.99**
1987-88	19.93	45.2	23.9	38.24	30.37	39	9.08	1.46	3.23	5.51	7.21	7.59	**230.72**
1988-89	7.56	14.19	10.94	93.99	43.29	5.61	1.69	4.25	3.41	1.62	30.8	6.15	**223.51**
1989-90	40.31	48.43	45.81	26.86	9.81	9.81	8.53	2.67	2.81	5.94	7.99	39.3	**248.27**
1990-91	27.58	16.34	123.94	72.62	175.23	390.1	19.42	7.84	2.27	2.57	2.3	176.3	**1016.55**
1991-92	11.02	89.24	7.84	85.02	53.08	17.05	5.55	14.73	6.44	9.64	5.8	3.36	**308.77**
MEAN	**23.70**	**42.64**	**65.82**	**59.23**	**44.77**	**16.56**	**2.94**	**1.84**	**1.26**	**2.41**	**3.43**	**7.96**	**272.23**

TABLE 4.8 Various Irrigation Demands In MCM

DESCRIPTION	TOTAL	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Early Paddy	37.045	8.983	10.75	7.167	7.621	0	0	0	0	0	0	0	2.529
Mid Paddy	49.763	5.915	16.99	8.96	9.866	8.031	0	0	0	0	0	0	0
Late Paddy	35.467	3.523	10.35	5.334	5.862	7.465	2.929	0	0	0	0	0	0
Raggi	0.000	0	0	0	0	0	0	0	0	0	0	0	0
Groundnut	0.410	0	0	0	0	0.053	0.356	0	0	0	0	0	0
Maize	0.000	0	0	0	0	0	0	0	0	0	0	0	0
Sugarcane	2.265	0.046	0	0	0	0.022	0.251	0.514	0.157	0	0.191	0.5031	0.5811
Duala Paddy	47.861	0	0	0	0	0	0	9.257	16.47	0	12.92	9.2079	0
Pulses	4.553	0	0	0	0	0	0	1.313	2.249	0.991	0	0	0
Groundnut	12.856	0	0	0	0	0	0	0	0.569	2.469	5.481	4.3368	0
Vegetable up	6.230	0	0	0	0	0	0.276	2.267	2.824	0.863	0	0	0
Vegetable Low	10.822	0	0	0	0	0	0	1.184	2.287	2.847	3.555	0.949	0
Potato	1.947	0	0	0	0	0	0	0.558	0.888	0.502	0	0	0
Mustard	3.563	0	0	0	0	0	0	0.875	1.508	1.18	0	0	0
TOTAL	**212.78**	**18.46**	**38.09**	**21.46**	**23.34**	**15.57**	**3.812**	**15.97**	**26.95**	**8.852**	**22.15**	**14.997**	**3.1109**

TABLE 4.9 Monthly Evaporation Values in m/months

MONTH	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Evaporation	**0.141**	**0.118**	**0.098**	**0.096**	**0.092**	**0.082**	**0.080**	**0.094**	**0.124**	**0.155**	**0.189**	**0.228**

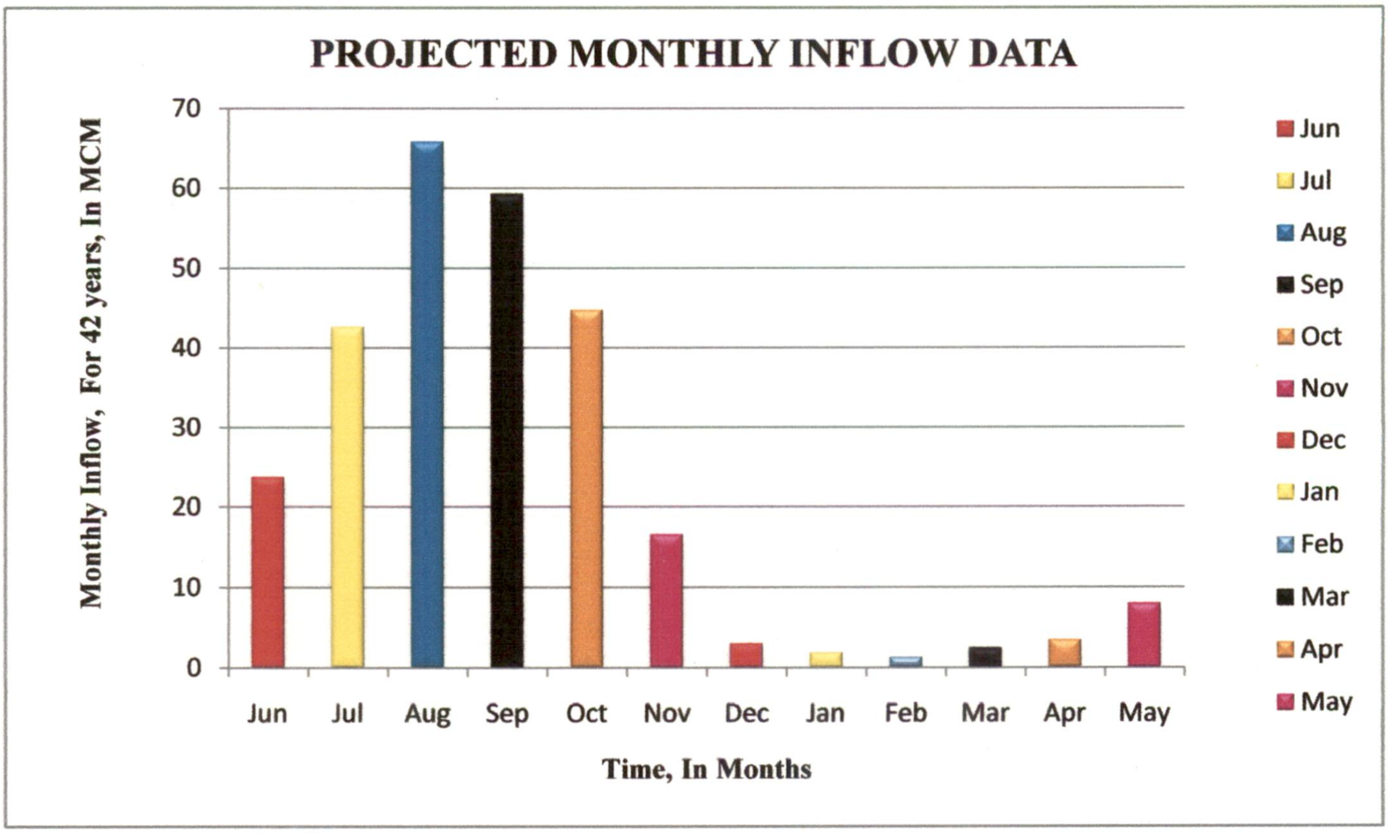


Fig 4.3 Projected Monthly Inflows

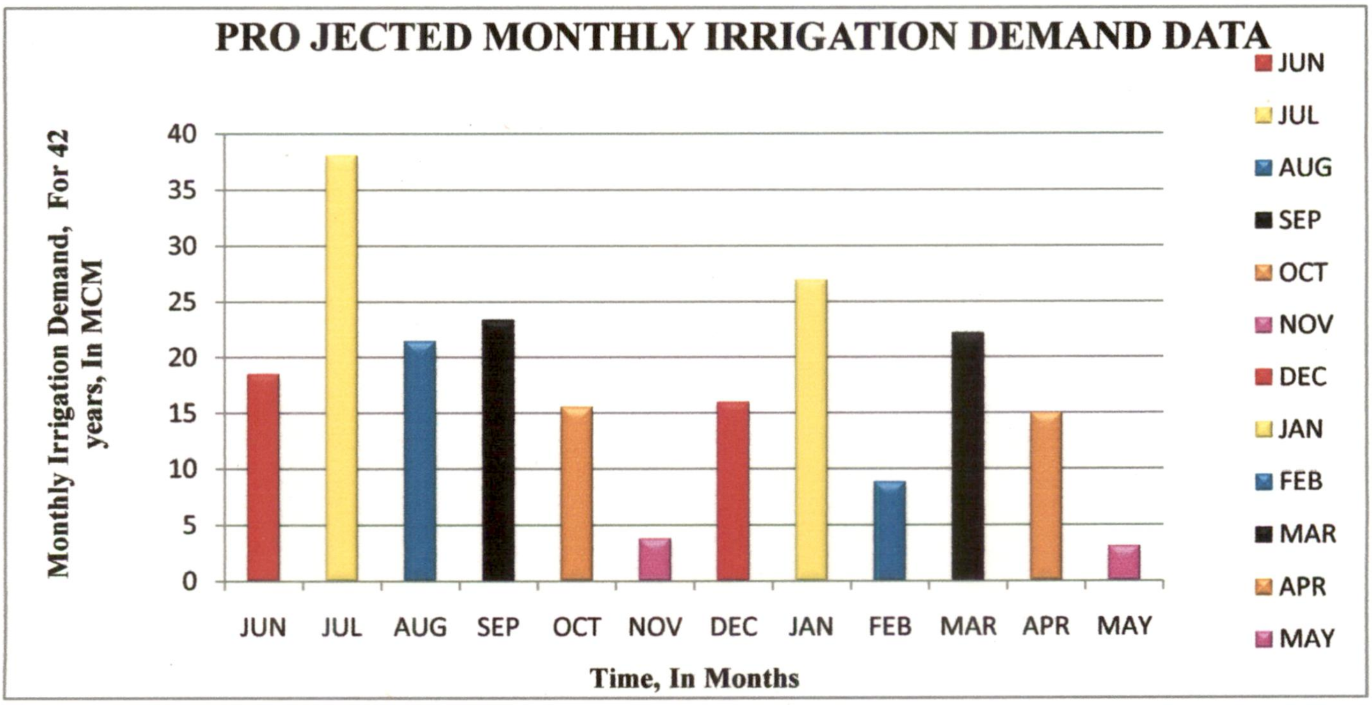


Fig 4.4 Projected Monthly Irrigation Demand

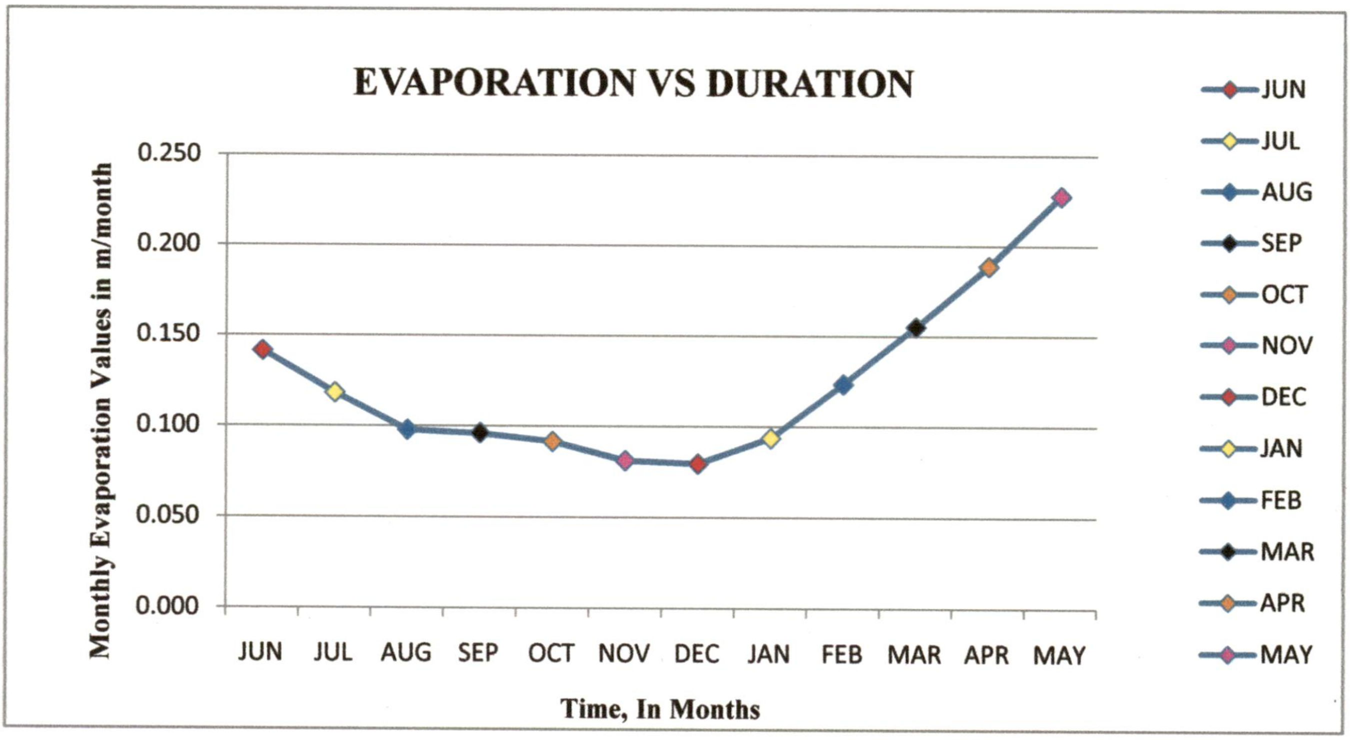


Fig 4.5 Evaporation Vs Duration Curve

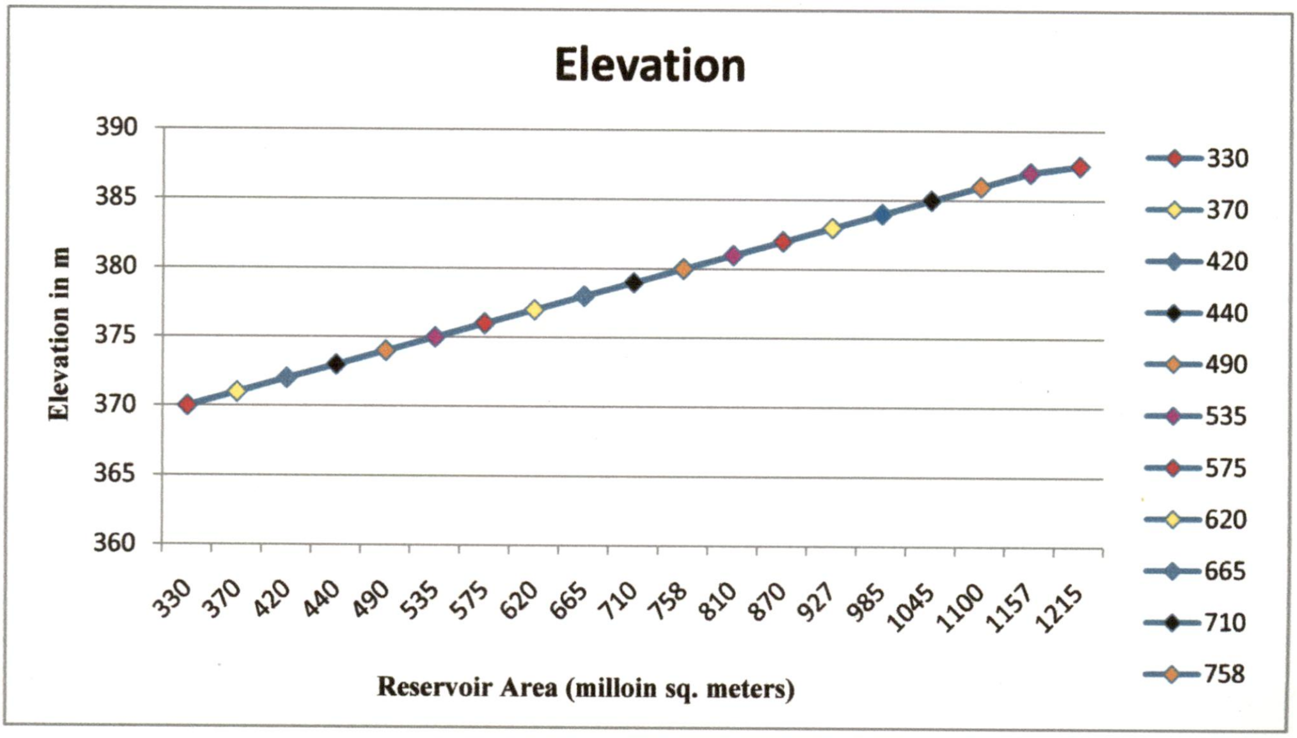


Fig 4.6 Elevation vs Reservoir area

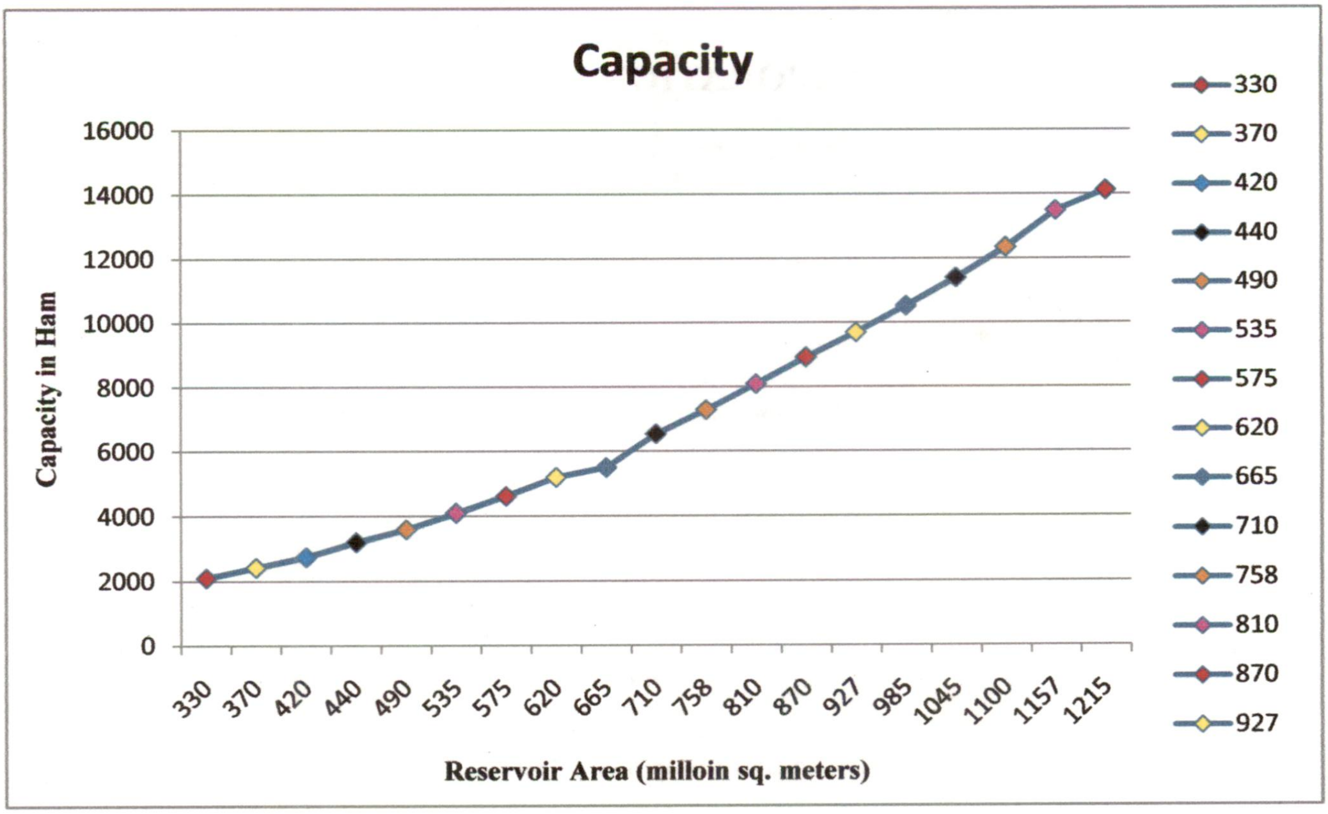


Fig 4.7 Reservoir Capacity vs Reservoir area

CHAPTER 5

SYSTEM ENGINEERING TECHNIQUES

System engineering is a powerful tool which can be used to analyze various strategies aimed to achieve a certain objective. Generally, water resources problems are Single objective or multi objective. These objectives may be of benefit to some and may affect others. A planner has therefore to select the most acceptable strategy so that the desired objectives are met with the least discordance. For such decision, system engineering techniques like simulation and optimization become handy. The advancements made in the field of system analysis techniques and speedy computing facilities now available could be effectively used for integrated operation of reservoirs [29].

5.1 SYSTEM ENGINEERING APPROACH

System engineering approach to the water resources system resorts to a schematic analysis of the numerous choices and options to the policy and decision makers. Not only much larger number of alternatives is considered, but each alternative representing a complex problem of inter-related effects must be evaluated in respect of their effects at various locations. System engineering approach offers a dynamic facility for continuous evaluation and re-planning to encounter the challenging scenarios. It can markedly improve the operation of water resources systems, provided both the managers and the analysts are clear about the limitations of this approach.

With the advent of digital computers, it has been possible to handle large amount of data efficiently and also to analyze the problems for mathematical solutions speedily. The system engineering techniques, which have extensive applications in the field of water resources, are linear programming, dynamic programming, goal programming, integer programming, simulation techniques, etc. However, there is no general algorithm that covers all types of problems. The choice of technique depends upon the characteristics of the system, availability of data, objectives, and constraints.

5.2 SYSTEM ENGINEERING CONCEPTS

Water resources system is very complex in nature because of multiplicity of goals and objectives, the planner has to adopt the best among the various alternatives. Because of this inherent nature of the water resources system, logical procedures are required which can rationally eliminate alternatives, reduce thousands of measures to relatively few on the basis of formidable mass of information. The same is true, not only for planning water resources development projects, but for their management also.

Hall and Dracup have defined system engineering as an art and science of selecting from a number of feasible alternatives, involving substantial engineering content that particular set of actions which will best accomplish the decision makers, within the constraints of law, morality, economics, resources, political and social aspects, and the laws governing the physical life and other natural sciences. The selection could consist of elimination of large number of alternatives based on the judgement, without the necessity of detailed analysis. However, even after applying the judgement, a number of potentially viable alternatives are left. The science of system engineering is required to achieve the best feasible alternatives by evaluating these, relatively small number of, alternatives. System engineering aids a decision maker to arrive at better decisions than otherwise possible, by better understanding of the system and inter-linkages of various sub-systems by predicting the consequences of several alternatives, course of actions, or by selecting a suitable course of action which will accomplish the desired results.

5.3 TOOLS AVAILABLE

In order to evaluate the system performance, it is necessary to have a mathematical model, which is simplified and rational representation of the reality. The model conceptualizes the real system and makes the actual situation less complex. Using the models, various alternative systems and policies can be evaluated without interfering with the real system or actually having a prototype. The mathematical models provide a link between the description of the system and electronic computers, by means of operational mathematical techniques. The most popularly followed approaches are simulation and optimization.

5.3.1 Simulation

Simulation is perhaps the most widely used method for evaluating alternatives due to its mathematical simplicity and versatility. Simulation is surrogate for asking "What-if" and thereby providing a rapid means for evaluating the anticipated performance of the system. Simulation methods do not identify the optimal design and operating policy but they are excellent means of evaluating the expected performance resulting from any design and operating policy.

Simulation may be deterministic or stochastic. If the system is subject to random input events, or generates them internally, the model is said to be stochastic. If no random components are involved, the model is said to be deterministic. The stochastic simulation is a powerful tool for reservoir operation studies. For example, in reservoir studies, the reservoir may be empty, half filled, or full in the beginning, the stream flow and rainfall are random and so are the demands and therefore, stochastic simulation is better suited for reservoir operation problems.

The simulation is time sequenced or event sequenced. In a simulation model a fixed time interval is selected and it examines the state of the system (flows, storage volumes, demands, etc.) at successive time intervals. The increment should be small enough so that no significant information is lost. But the smaller the time increment larger will be the computational time; on the other hand if the time increment is large, the chance of missing an event of interest increases. Thus a judicious choice of time increment is necessary in time sequenced models.

5.3.2 Optimisation

Optimisation is the science of choosing the best solution from a number of possible alternatives, without having to evaluate beyond all possible alternatives. Optimisation implies use of an appropriate optimization model in conjunction with an optimization algorithm. Optimisation methods find out a set of decision variables such that the objective function is optimized. The most common optimization algorithm adopted for solving water resources problems are linear programming, dynamic programming, nonlinear programming, and goal programming.

a) **Linear Programming** (L.P.) is a very popular optimization technique, which finds application in many disciplines in the field of water resources systems, as a result of the readily available software packages of algorithms. The disadvantage of L.P. technique is primarily the limitation of its use for linear relationship only. Since most of he functions involved in water resources planning are non-linear, they are approximated by piecewise linearization for obtaining the optimal solution. Unlike most other major optimization techniques, LP packages are readily available at most of the major scientific computer facility centers in India. It is not necessary to have full understanding of the linear programming algorithm or solution algorithm procedures for using these packages. The system analysts need only to have knowledge of how to use the computer programs and understand the meaning of outputs. This is a distinct advantage over most other types of optimization methods. The fact that linear programming solution procedures are readily available has created the incentive to structure many problems involving nonlinear objective functions and constraints as linear optimization models. Various methods for converting nonlinear relationships to linear ones are now available.

b) **Dynamic Programming** (D.P.) is a powerful analytical optimization technique, widely used in system analysis approach to water resources system designs, operation and allocation problems. The popularity and success of this technique can be attributed to the fact that the nonlinear and stochastic features, which characterize a large number of water resource systems, can be translated into a D.P. formulation. In addition, it has the advantage of effectively decomposing highly complex problems with a large number of variables into a series of sub-problems, which could be solved recursively.

c) **Combination of LP and DP** – For multi-reservoir problems, use of a single algorithm is often not adequate and sometimes computationally expensive. This necessitates the use of combination of algorithms. In the early application of optimization models to multi-reservoir problems, the trend had been to decompose the problem into a master and a number of sub-problems, which were then solved one after the other in an iterative fashion to achieve an optimal configuration or an operating policy. In such cases, the necessity of combination of two different optimization models was felt and normally a LP-DP combination was adopted. Hall and Shepherd (1967) and Hall and Dracup (1970) have presented problems solved by such decomposition. In another approach, different algorithms are used for different individual aspects of the problem and the results are then integrated through an interaction between the algorithms. For example, one algorithm may solve for multiple optimal solutions and the other may select the best among these solutions as in the LP-DP. Most of such application use LP-DP combinations. Such a combination was used for developing monthly, daily, and hourly operation models for the reservoir system of Central Valley Project, USA.

d) **Nonlinear Programming** has not enjoyed the popularity that LP and DP have in water resources system analysis. This is particularly due to the fact that the optimization process is usually slow and takes large amount of computer storage and time. The mathematics involved is much more complicated than linear programming; a major drawback is that the solution obtained by this technique does not ensure a global optimum and all the possible local optimum solutions have to be exhausted, before a final decision is arrived at.

e) **Goal Programming** (GP) is a popular technique capable of considering multiple goals in the objective function. In contrast to the LP model, hierarchy of goals defines the operation objectives of the goal programming. In GP, all the objectives are assigned target levels for achievement and a relative priority on achieving these levels. GP treats these targets as goal, but not as absolute constraints mandatory and attempts to find an optimal solution, as closely as possible, to the targets in the order of specific priority, whereas the real constraints are absolute restrictions on the decision variables. The method uses simplex algorithm for finding optimal solutions of a single or multi-dimensional objective function with a given set of constraints, which are expressed in linear form. It is based on the minimization of weighted absolute deviations from targets of each objective. This technique is essentially a sequential optimization process, in which successive optimizations are carried out as per priority. GP has been shown to be a very useful tool for multiobjective decision making and is computationally efficient.

5.3.3 Simulation Vs. Optimisation

Water resources studies generally aim at finding an optimal solution with respect to the water resources developments for a certain region. "Optimal" usually in the sense of least cost, greatest benefits, most efficient water use and so on. Different approaches can be followed for the modeling of basin-wise water allocation, viz:

- a *simulation approach* in which water is allocated using a routing of the water through the system: in most cases iterative feedback steps will then be required to create the desired allocation pattern;

- an *optimization approach* which allows to make simultaneous allocation decisions directly.

Optimisation directly leads to an optimal solution, according to a predefined set of objectives. Simulation provides "only" an illustration of the consequences of one predefined situation, as specified by us in the input of the program. In simple words: in simulation we specify input and just see what result we get, whereas in optimization we specify the result that we want to obtain (the objective), starting from a certain amount of input. In optimization, we expect the program to find out how to get to the objective.

Use of an optimization model has the advantage that it sorts automatically through the possible combinations based on a specified objective and a set of equations describing the allocation process and its limitations. The disadvantage is however that the tradeoffs in allocation are rigidly internalized within a mathematical formulation; this means also that for practical applications the approach is limited to linear relationships and linearised objective function. In most cases this strongly limits the possibilities to analyze different allocation strategies and is particularly constraining if different types of users are involved.

The simulation approach is not limited to linearised problems and thus more generally applicable but requires to make successive feedback iterations to resolve simultaneous allocation decisions. For a large combinatorial problem this may require a large number of simulations to arrive at a synthesis. The approach is however indispensable to analyze systems with real-time operation aspects and in most cases can handle much better the stochastic aspects of the problem.

Many types of feedback can be conveniently included as automatic options in the simulation model. Other more complicated options such as e.g. optimization of rotation strategies for water rationing in a river basin require essential judgment from the analyst and can best be handled by repeated simulations closely guided by the analyst who interprets previous results and specifies new input for subsequent test simulations.

The conflicting requirements of a flexible technique and potential for generating a synthesis, has been resolved in the applications by selecting a combined approach. The simulation model is considered as the base instrument which can handle most cases sufficiently; optimization is further considered as an add-on possibility for those cases in which the allocation becomes a relatively large combinatorial problem and which can to a sufficient extent be linearised.

5.3.4 Technique used for Present Project (Harabhangi irrigation project):

A simulation technique has been developed on Harabhangi irrigation project. In this system, computer based MATLAB programme was developed along with the Microsoft Excel sheet to simulate the various components of the reservoir to obtain the near optimum values of the design variables. Search techniques would be used for sampling the set of data.

5.4 MATLAB:

MATLAB, which stands for MATrix LABoratory, is a state-of-the-art mathematical software package, which is used extensively in both academia and industry. It is an interactive program for numerical computation and data visualization, which along with its programming capabilities provides a very useful tool for almost all areas of science and engineering. Unlike other mathematical packages, such as MAPLE or MATHEMATICA, MATLAB cannot perform symbolic manipulations without the use of additional Toolboxes. It remains however, one of the leading software packages for numerical computation. As you might guess from its name, MATLAB deals mainly with matrices. One of the many advantages of MATLAB is the natural notation used. It looks a lot like the notation that you encounter in a linear algebra course. This makes the use of the program especially easy and it is what makes MATLAB a natural choice for numerical computations [30].

CHAPTER 6

METHODOLOGY

6.1 GENERAL:

Several research workers have contributed different methods of reservoir operation policy in different time. But no such information is available on the performance of these methods as to their effectiveness under drought conditions. Reservoir operation studies being a major hydrologic problem, further and further researches are necessary to find out more effective operation techniques, especially under situations of droughts.

For greater research in this field certain prerequisites like hydrologic data such as available stream flows into the reservoir, probable demand of water with its seasonal distribution, optimum design of storage capacity and other relevant information's are necessary.

However, in the problem the flow data and its pattern with seasonal distribution, the month wise distribution of demand pattern and tentative optimum storage capacity of the reservoir etc. are available. It only emphasizes the need to determine a suitable operation policy with the above information.

In achieving the optimal design in reservoir planning usually three techniques mathematical programming, simulation and combination of these are generally used. The mathematical model is an abstract idealization of the system. There will be approximations and simplifications to fit into the model certain mathematical forms. Simulation is a descriptive technique. A simulation model incorporates the quantitative relationship among the variables and describes the outcome or the response of the operating system under a given set of inputs and operating conditions. Most planners resort to simulation because, as it deals effectively for the large complex problem, without much simplification and approximation of the real problems. The water resources planning are one such example. In simulation there is freedom to test different combinations of structure and targets. The simulation approach is essentially a search technique which resembles and trial and error approach used in traditional operation studies. There is no such flexibility for the operating procedure which is once fixed in the programme. Limited hydrological inputs in simulation model in reservoir planning may not represent the true configuration of the series of hydrological events. This can be over com with generated synthetic streams flows sequences for sufficiently long periods. In the well-know Harvard water programme, simulation techniques were applied to the economic analysis of water resources system design. The U.S.Army corps of Engineers simulated the Columbia River System using 25 storage dams and 45 runs of the river facilities. This report indicates that the simulation technique have gained wide acceptance in the actual design and operation of water resource project. Single purpose reservoirs in Harbhangi river system were simulated using systematic and random sampling. The simulation studies of Harbhangi Irrigation Project were carried out firstly, to know how best and by now much further irrigation facilities can be provided in the proposed new scheme [6]

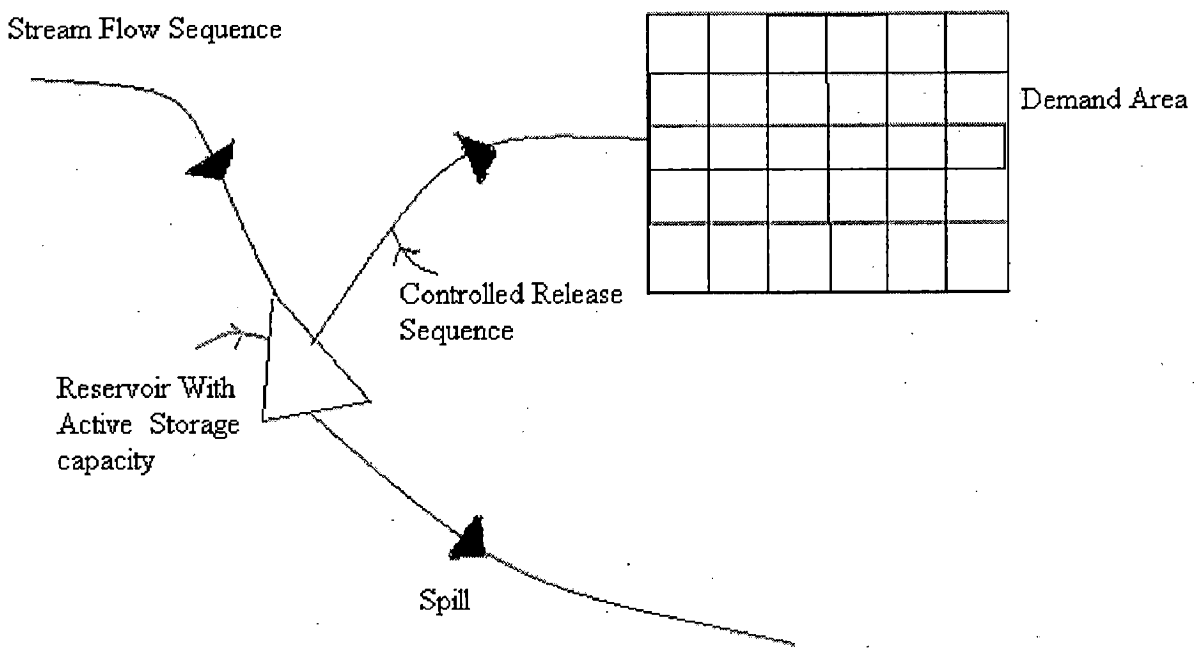


Fig. 6.1.Elements of Water Resource System [23]

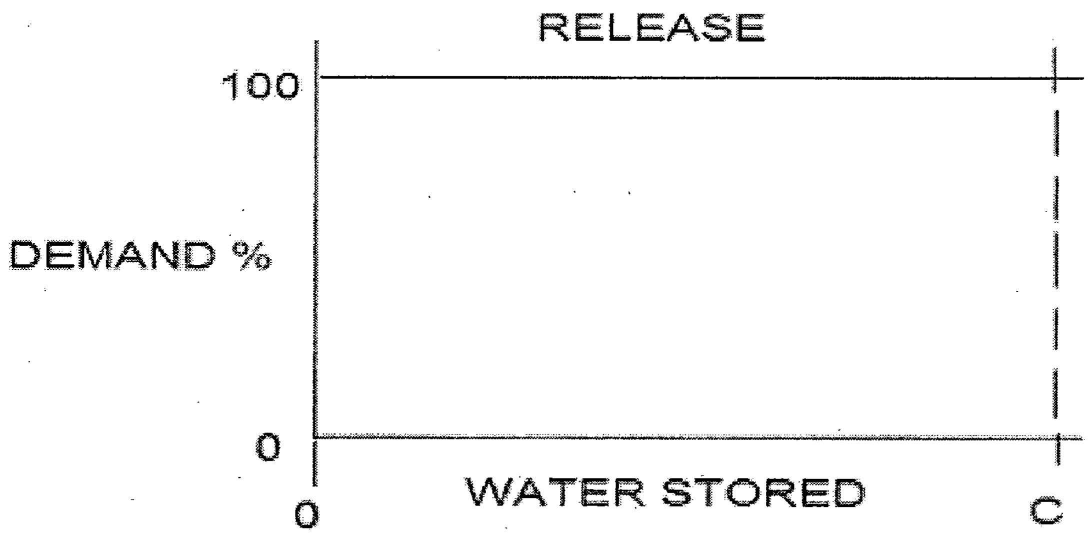


Fig 6.2 Simple Operating Rule [32]

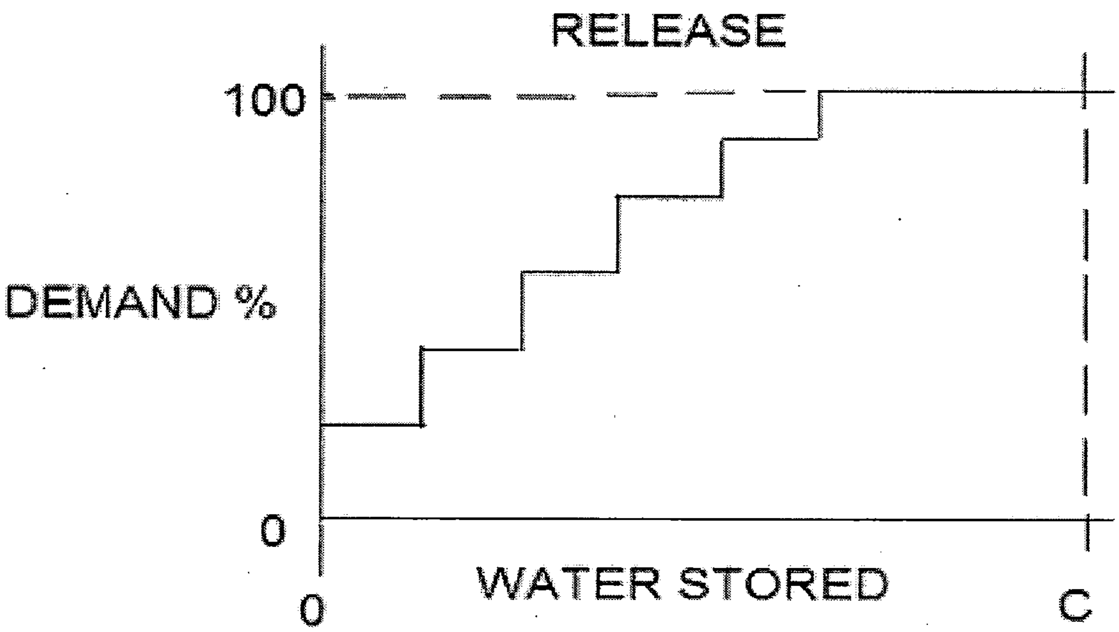


Fig 6.3 Operating Rule with Restrictions [32]

6.2 DEFINITION OF TERMS:

6.2.1 Active Storage: Active storage of a reservoir is the water stored above the level of the lowest off take. It is equal to the total volume of water stored less the volume of 'dead' storage (the volume below the level of off take).

6.2.2 Release or Draft: Release is the volume of controlled water released from a reservoir during a given time interval. It describes regulated flow from the reservoir.

6.2.3 Spill: Spill is the uncontrolled flow from the reservoir and will take place only when the water stored in the reservoir is above full supply level.

6.2.4 Operation or Release rule: Usually the volume of water released from a reservoir is equal to the volume of water required or demanded by the consumers. There may be periods when either the reservoir level is so low that the water required cannot be supplied, or that prudence dictates that only part of the water demanded can be released from storage. Another factor may be the time of the year or the expected inflows for the subsequent period.

Thus the way in which the draft or release is controlled is the release or the operating rule. The simplest operation rule is to supply all of the water demanded. In this situation, the draft is independent of reservoir content and season. If there is insufficient water in the reservoir to meet the required draft, the storage empties. As the volume of water stored in he headwater reservoir decreases, restrictions are placed on users, so that demand falls and releases are lowered. The example of two operating rules (A) simple operating rule (B) Operating rule with restrictions are illustrated in figure 6.2 and Fig 6.3 respectively.

6.3 SEARCH TECHNIQUES:

Having noted earlier that the simulation is a trial and error technique rather than an analytical process which converges to a global optimum, it is useful to ask how the analyst proceeds from trail to trail and how reliable are the results of a given number of trails. In other words, ask first if the iteration should continue, and, if so, to which next sample point (or trial design). This is general question of search techniques. Systematic, random samplings are the two most commonly used search techniques.

6.3.1 Systematic sampling: In this system of sampling the decision variables are sub divided into a number of steps or increments, the step-size depending primarily on the number of variables involved, the speed with which the computation can be performed and some judgment about the sensitivity of the system response to small changes in the design variables. A course mesh would be suitable for some variables, particularly those to which system response is sluggish; other variables would necessarily have to be subdivided on a finer grid. Except in most simple situation the use of systematic sampling procedure is highly infeasible.

6.3.2 Random Sampling: Random sampling technique is very much useful under two dimensional decision problems in which it is desired to maximize the response, measured in the third coordinated dimension. The difficulties involved in such a procedure are that random sample chose may be on infeasible zones, and the total number of combination samples may be inadequate. In this technique ranges are selected for each variable. Combination samples are chosen at random by assigning values to all variables at random, within the ranges specified for them.

Correlate the Reservoir capacity, Irrigation demand (Y, I_r) in terms of Benefits **B**, by using "***Sigmaplot***" software.

$$B = e^{4.5512} * Y^{-0.6829} * I_r^{0.7322}$$

Where,

B = Present value of net benefits in Rs.

Y = Reservoir Capacity

I_r = Irrigation Demand

6.3.3 Cost-Benefit Functions:

For the simulation model of the reservoir, along with the hydrologic data, the cost-benefit functions are required as inputs into the model. These functions are capital cost of reservoir, capital cost of irrigation works, irrigation benefit, loss in irrigation benefit due to irrigation deficit, and operation and maintenance cost.

The design values for cost and benefit were available for only one capacity. These were, therefore, estimated for different possible ranges for the project on the basis of appropriate engineering approaches and suitable functions were developed. On the basis of project design, sections for a concrete dam (over flow and non overflow sections) and an earth dam were developed and quantities and cost were worked out. The auxiliary works costs were developed on a unit cost basis. Under these two major headings, both direct and indirect charges were estimated for 1984 prices. Although they involved considerable work, it must be understood that the estimates are for methodological study rather than for detailed design.

6.4 ESTABLISHNING AN OPEARTING PROCEDURE:

The operating procedure may be based on the inflow pattern of the Harbhangi Irrigation Project. The following characteristics will then establish the procedure.

1. The hydrological character of the basin, which is dependent on the rainfall and the topography is such that Harbhangi river will be in floods during June to October months, the reservoir will start depleting from November to May;
2. The irrigation withdrawals from the reservoir will be less during monsoon month from June to October and high during non-monsoon months from November to May;
3. Monthly average flows for 42 years of river Inflows, percent Irrigation Demand and Evaporation values in the manner given in table 4.7, 4.8, and 4.9 respectively.

6.4.1 Basic Reservoir Operation Criteria

The basic reservoir operation criterion is expressed in terms of simple continuity equation

$$S_t = S_{t\_1} + I_t + I'_t + Pt - E_{It} - O_t - O'_t \qquad \text{for all t} \qquad (1)$$

Subject to the following two equations:

$$O_t \leq S_{t\_1} + I_t + I'_t + P_t - E_{lt} - O'_t - Y_{mint} \qquad \text{for all } t \qquad (2)$$

And

$$O_t = O_{r\ t}' + O_{a\ t}' + O_{a\ t}'' + S_{pt} \qquad \text{for all } t \qquad (3)$$

Where

S_{t_1} = Reservoir storage at the beginning of time t

I_t = Inflow into reservoir during time t

I'_t = Local inflow to the reservoir from the surrounding area in time t

P_t = Precipitation in the reservoir in time t

E_{lt} = Evaporation losses from the reservoir in time t

O_t = Total outflow (release) from the reservoir in time t

O'_t = Release to natural channel from reservoir in time t

S_t = Reservoir storage at the end of time t

$O_{r\ t}'$= Actual release for water supply from reservoir in time t

$O_{a\ t}'$= Actual irrigation release from reservoir in time t

$O_{a\ t}''$ = Additional release from reservoir to fulfill energy demand in time t

and

S_{pt} = Reservoir spill in time t

$$Y_d \leq Y_{mint} \leq S_{t\_1} \leq Y_{maxt} \leq Y \quad \text{for all } t \text{ [34]} \qquad (4)$$

6.4.2 Operating Procedure:

The operation of reservoir will be carried out using the operating procedure, that is, rules for storing and releasing water from the reservoir in each month in the following manner:

1. The simulation will start in the month of June in the first year of the study, and the initial reservoir content in the month will be equal to the dead storage, i.e., zero live storage,
2. The release from the reservoir I any month will be made from the total available water, i.e., sum of the initial reservoir content in that month plus the inflow minus the evaporation from reservoir during the month
3. The continuity equation will hold good in each month, and
4. The reservoir content in any month cannot be more than the reservoir capacity.

6.5 THE SIMULATION MODEL:

The simulation problem for the reservoir system may be defined as follows. Sampling the variables by using search technique and determine

1. The annual target level of irrigation output, and
2. The reservoir capacity.

Given,

1. Monthly runoff values, and
2. A suitable operating procedure for storing and releasing water from the reservoir, which is given in APPENDIX I

System Design Variables, parameters and constants:

A. Major Design variables:

(i) Gross and live capacity of the reservoir,

(ii) Target Outputs; (a) target outputs for irrigation for command area (yearly),

(b) A 12-element vector of annual target output for irrigation (monthly percentage of annual values).

B. Cost and Benefit Functions:

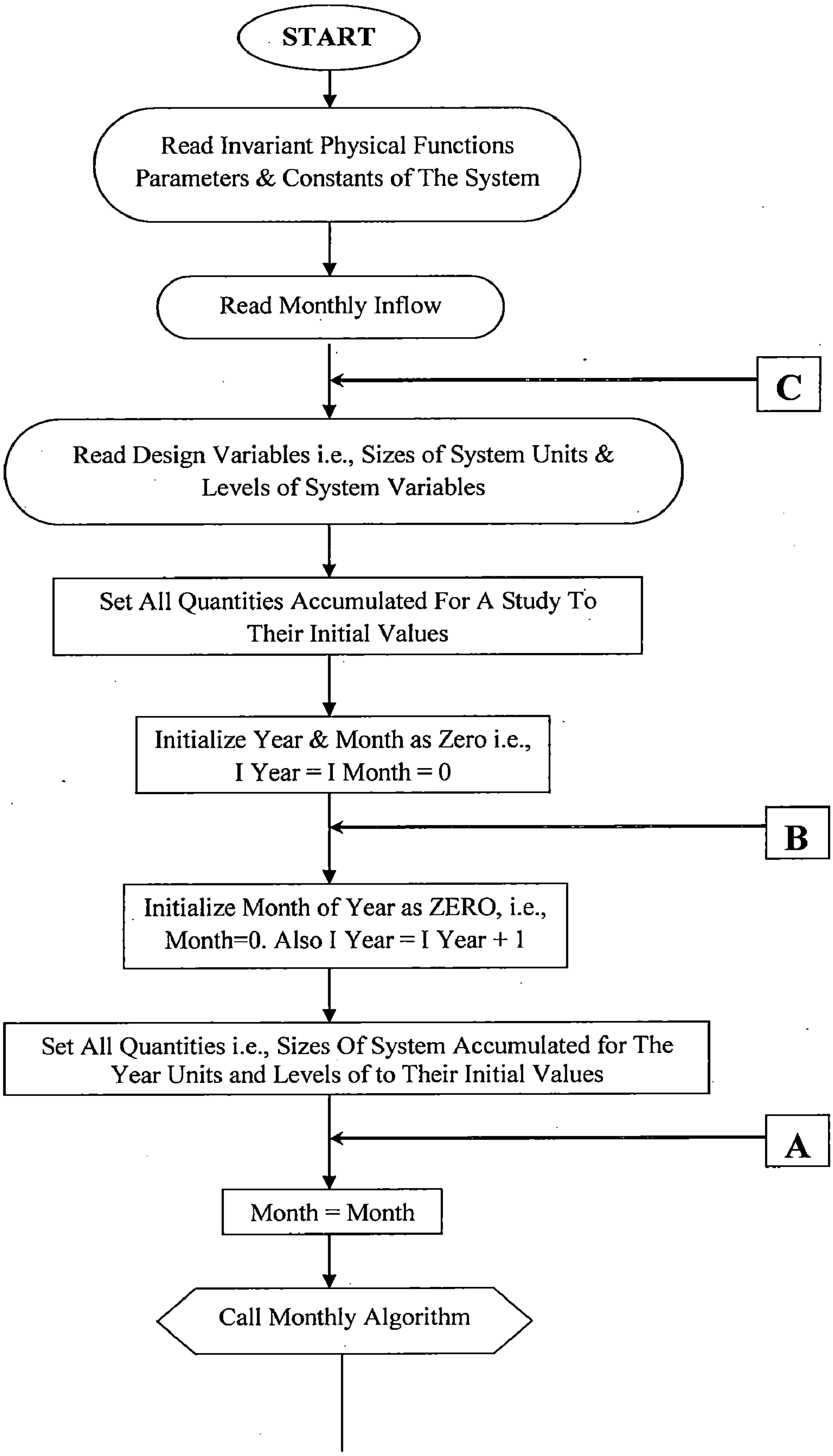
(1) Irrigation- for irrigation area. (i) Annual target output for irrigation vs. unit gross irrigation benefits relation, (ii) annual irrigation shortage vs. irrigation loss relation, (iii) annual target output for irrigation vs. capital costs of irrigation diversion, distribution, and pumping works relation, and (iv) annual target output for irrigation vs. annual OM cost of irrigation diversion, distribution, and pumping works relation.

(2) Reservoir Costs and Characteristics. (i) Capacity of reservoir vs. capital costs of reservoir relation and (ii) capacity of reservoir vs. annual OM cost of reservoir relation.

(3) Other Functions. Interest rates and formula used for discounting.

6.6 SIMULATION COMPUTATIONS:

Simulation calculation was carried out using the developed MATLAB programme consisting of the main programme, two subroutine and one function subprogramme. Two design variables, i.e., reservoir capacity, and annual irrigation requirement were sampled using systematic and random techniques. Number of sampled combinations were simulated and tested. Analysis period was for 42 years for which the river flows were taken from the metrological department in Orissa. The simulation model was run for monthly periods. The period of analysis was 42 years. Loss in irrigation benefits due to deficit in irrigation, and evaporation losses from the reservoir were considered were considered. All nonlinearities in the model were maintained as far as possible. A new general flow chart of step involved in the simulation is given in Fig 6.4 and the conventional reservoir operation used for storing and releasing water from the reservoir is given in Fig 6.5.


START
Read Invariant Physical Functions Parameters & Constants of The System
Read Monthly Inflow
C
Read Design Variables i.e., Sizes of System Units & Levels of System Variables
Set All Quantities Accumulated For A Study To Their Initial Values
Initialize Year & Month as Zero i.e., I Year = I Month = 0
B
Initialize Month of Year as ZERO, i.e., Month=0. Also I Year = I Year + 1
Set All Quantities i.e., Sizes Of System Accumulated for The Year Units and Levels of to Their Initial Values
A
Month = Month
Call Monthly Algorithm

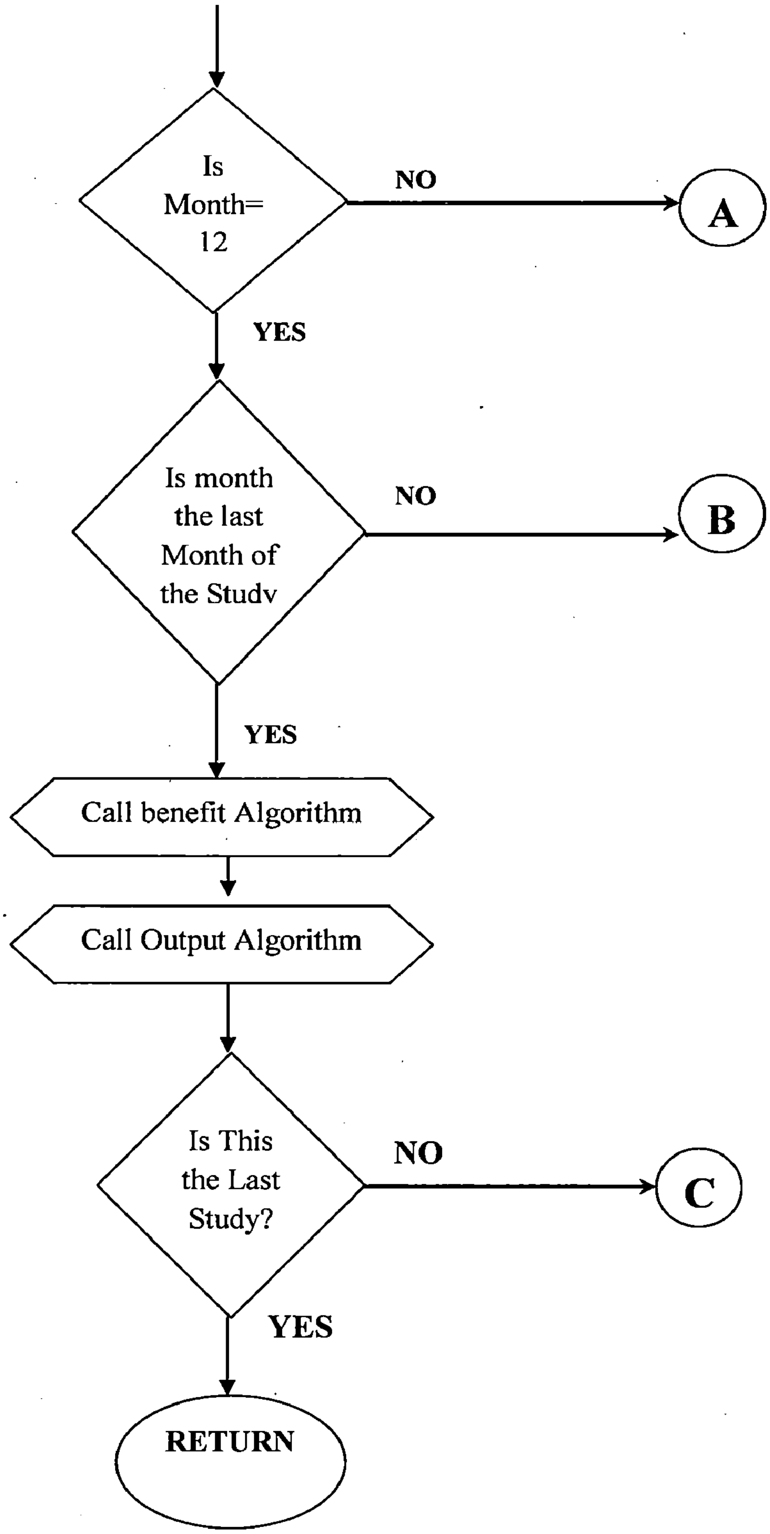


Fig. 6.4 General Simulation Flow Chart [11]

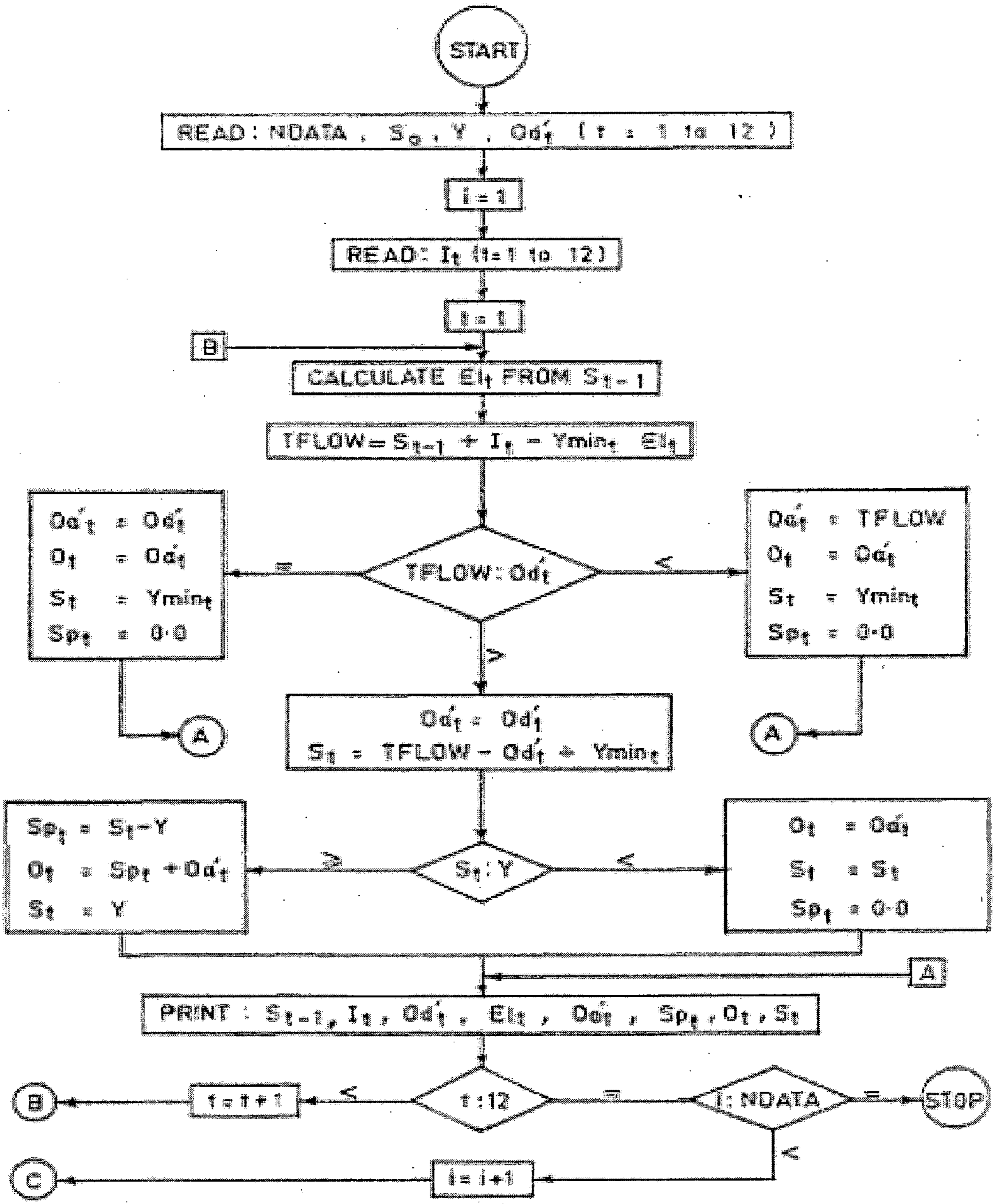


Fig 6.5 Flow chart for conventional reservoir operation [11]

Systematic searches were made in two steps in order to obtain the near optimal values of the design variables Y and $I_{r.}$ In the first search a course grid of 17 alternatives was chosen. The gross reservoir capacity and the annual irrigation target were varied with increments of 20 and $5*10^6$ m^3, respectively, as per the ranges:

$$100 \leq Y \leq 200 \qquad \text{and} \qquad 200 \leq I_R \leq 220$$

Out of these 17 alternatives, the feasibility ones with project dependability of 80% (35 years out of 42 years) or more are given in Table 6.1. A successful year was defined in terms of different allowances in deficits in annual irrigation targets. These allowances were 0, 5, and 10%. Looking at the results, it may not be advisable to select a reservoir capacity and annual irrigation target as 120 and $220*10^6$ m^3 respectively to the trail No. 8 in table 6.1.

Table 6.1 Results of simulation model

Trail No. (alternative)	Y	I_R	Number of failure years (Annual irrg. deficit allowed)			Present value of net benefit in Rs. 10^5
First search With variables Y and Ir			0%	5%	10%	
1	100	200	18	11	9	197.51
2	120	200	10	5	4	174.39
3	140	200	6	5	2	156.96
4	160	200	4	3	1	143.29
5	180	200	2	1	1	132.21
6	200	200	1	1	1	123.03
7	100	220	24	12	10	211.79
8	120	220	16	10	9	186.99
9	140	220	14	10	9	168.61
10	160	220	14	8	6	153.64
11	180	220	12	6	5	141.76
12	200	220	10	6	4	131.93

Second search

1	141.25	200	6	5	2	156.01
2	141.25	205	9	3	2	158.86
3	141.25	210	13	5	4	161.69
4	141.25	215	14	9	5	164.50
5	141.25	220	14	9	8	167.29

In the first systematic sampling the ranges for reservoir capacity and annual irrigation requirement selected are given in table, keeping in view the present existing reservoir capacity and the future proposed irrigation requirement of 141.25M.C.M and 220 M.C.M respectively. In all 17 combinations were simulated and it was observed from the results that the net benefits (present worth) obtained in all the combinations.

In the second search, the gross reservoir capacity was kept as equal to the project provision of $141.25*10^6$ m^3 and the annual irrigation target was varied from 200 to $220*10^6$ m^3 with the increment of $5*10^6$ m^3. In all, there were 17 alternatives. Out of all these 17 feasible alternatives, selected ones are shown in the table 6.1. From the results, it is found that with a project provision of Y equal to $141.25*10^6$ m^3 for 0% allowance in the annual irrigation deficit, about to $205*10^6$ m^3 annual irrigation, I_R, can be satisfied with about 80% dependability. The value of I_R, for a 5% allowance may be about $210*10^6$ m^3 and, for 10% it may be still higher than a value of about $220*10^6$ m^3.

6.7 RESPONSE OF HARIBANGI IRRIGATION PROJECT:

It can be easily observed from the results obtained from the simulation run by the two search techniques that the net benefit (present worth) increases with lower reservoir capacity and higher annual irrigation requirement. Average annual irrigation deficit is also on the increase, whenever there is combination of lower reservoir capacity with higher annual irrigation requirement. The spillage is also considerable for lower capacities. Table 6.2, 6.3, 6.4 shows that how the net benefit, the percentage average annual irrigation deficit, and the percentage average annual spill from the reservoir change with the change in reservoir capacity for the present annual irrigation requirement of 212.780 MCM respectively. There is a fast decrease in the benefit as compared to other two items.

Table 6.2 **Variation in Net Benefit with Reservoir Capacity**

S.No	Reservoir Capacity	Net Benefit
1	100	197.512
2	120	174.39
3	140	156.96
4	160	143.29
5	180	132.211
6	200	123.03

Table 6.3 **Variation in Irrigation Deficit with Reservoir Capacity**

S.No	Reservoir Capacity	Average Irrigation Deficit (for 42 years)
1	100	14.62
2	120	11.88
3	140	9.51
4	160	7.62
5	180	6.91
6	200	6.23

Table 6.4 **Variation in Irrigation Deficit with Reservoir Capacity**

S.No	Reservoir Capacity	Average Spill (for 42 Years)
1	100	61.8
2	120	57.1
3	140	52.8
4	160	49.1
5	180	46.9
6	200	44.6

CHAPTER 7

ANALYSIS OF RESULTS, DISCUSSIONS, CONCLUSIONS AND SUGGESTIONS

7.1. RESERVOIR PERFORMANCE DURING OBSERVATION PERIOD:

Desired information, regarding the reservoir behavior during the operative periods on specific reservoir operation techniques followed in the present work, are obtained.

- The monthly reservoir storages during the reservoir operation.
- The no. of times the reservoir spills during operative period.
- The number of times there is irrigation deficit during operation.
- The value of Irrigation deficit of particular year for whole 42 years
- The value of reservoir spill of particular year for whole 42 years
- The volume of average annual irrigation deficiency in million cubic meters.
- The volume of average annual spill in million cubic meters.
- The irrigation shortage Index due to operation policy.
- The number of times of irrigation deficiency in a particular month of the whole operation period.
- The average monthly irrigation deficiency allowed in 0%, 5%, 10% percentage.
- The volume of average monthly spill in million cubic meters.
- The value of Minimum deficit, which month for the whole 42 years.
- The value of Maximum deficit, which month for the whole 42 years.
- The value of Minimum Spill, which month for the whole 42 years.
- The value of Minimum Spill, which month for the whole 42 years.

These information of reservoir behavior which had done on both MATLAB program and Microsoft Excel spreadsheet during the whole operative period as listed above are tabulated in the table given as ANNEXURE II and ANNEXURE III respectively which are self explanatory, give clues on the effectiveness of the operation technique.

7.2. ANALYSIS OF RESULTS AND DISCUSSIONS:

As explained earlier, the simulation runs were carried for a period of 42 years (June 1950 to May 1992). The analysis of simulation results is as given in the Table 7.1. Mainly the failure in meeting various demands are in the water years 1968-69 and 1974-75. In these years there was a severe drought in particular Harabhangi Irrigation project. The yearly total inflows into Harabhangi irrigation project during 1968-69 and 1974-75 are 84.32 Mm^3 and 160.91 Mm^3 against an average inflow of 272.23 Mm^3during these 42 years.

Table-7.1: Failure Years in Various Strategies in Harabhangi Irrigation Project

S.No	Year Of Failure	Month Of Failure	Irrigation		Deficit
			Demand	***Supply***	
1	1957-58	Apr – 57	14.99	9.42	5.58
		May - 57	3.11	0.61	2.50
2	1958-59	Jun - 58	18.47	15.33	3.13
3	1967-68	Apr - 67	14.99	9.92	5.08
		May - 68	3.11	0.61	2.50
4	1968-69	Jun - 68	18.74	9.48	8.98
		Jul - 68	38.10	20.85	17.23
		Sep - 68	23.35	13.32	10.03
		Oct - 68	15.57	8.17	7.40
		Dec - 68	15.97	3.81	12.15
		Jan - 68	25.95	0.55	26.10
		Feb - 68	8.85	0.04	8.47
		Mar - 68	22.15	0.39	21.75
		Apr - 68	14.99	0.59	14.10

		May - 68	3.11	0.60	2.51
5	1971-72	Jul - 71	38.10	26.79	11.30
6	1974-75	Jun - 74	18.47	9.18	9.28
		Jul - 74	38.10	7.52	30.57
		Aug - 74	21.46	11.86	9.60
		Apr - 74	14.99	10.86	4.13
		May - 74	3.11	1.29	1.81
7	1977-78	Mar - 77	22.15	8.73	13.42
		Apr - 77	14.99	0.50	14.49
		May - 77	3.11	0.71	2.39
8	1982-83	Jan - 82	26.95	24.47	2.47
		Feb - 82	8.85	2.33	6.52
		Mar - 82	22.15	5.8	16.35
		Apr - 82	14.99	8.57	6.42
9	1983-84	Jul - 83	38.09	31.31	6.78
10	1984-85	Jan - 84	26.95	21.33	5.62
		Feb - 84	8.85	2.40	6.44
		Mar - 84	22.15	6.38	15.77
		Apr - 84	14.99	6.72	8.28
11	1985-86	Apr - 85	14.99	11.56	3.44
12	1986-87	Jul - 86	38.09	31.43	6.66
13	1988-89	Aug - 88	21.46	11.77	9.70

7.3 SUPPORTS FOR THE USE OF SIMULATION:

From the results as shown in Fig 7.1 it is seen that if the annual irrigation target is kept constant and reservoir capacity is increased the net benefit decreases and the variation is rapid. Same is the case with the average annual irrigation deficit and the average annual spill from reservoir, but the variations are slow as shown in the Fig 7.2, 7.3 respectively. These behaviors seem to be due to the fact the cost of reservoir is quite large as compared to the loss in irrigation benefit due to irrigation deficit. Now, compare the combination of the new proposal at series no. 12 (Systematic sampling) in Table 6.1 having a reservoir capacity of 200 MCM and annual irrigation requirement of 220 MCM which gives a net benefit of Rs. 131.92 crores with the combination at series no. 1 having 100 MCM reservoir capacity and 220 MCM annual irrigation requirement which gives a net benefit of Rs.211.79 crores. This comparison means that the new proposed annual irrigation requirement of 220 MCM may as well be satisfied, even giving more net benefit, with a lower reservoir capacity than the existing capacity of 141.25 MCM. This could only be answered efficiently by using simulation technique, as done here. Therefore, it is evident that if the planning of reservoir by simulation studies would have been carried out before construction of this reservoir, it would have been more appropriate.

Simulation which predicts the behavior of the system in more detail or rather is more descriptive than any of the mathematical techniques may provide answer to many such problems as discussed above which other methods of planning may fail to do so. In the light of the above findings the simulation technique may be a powerful tool for reservoir planning.

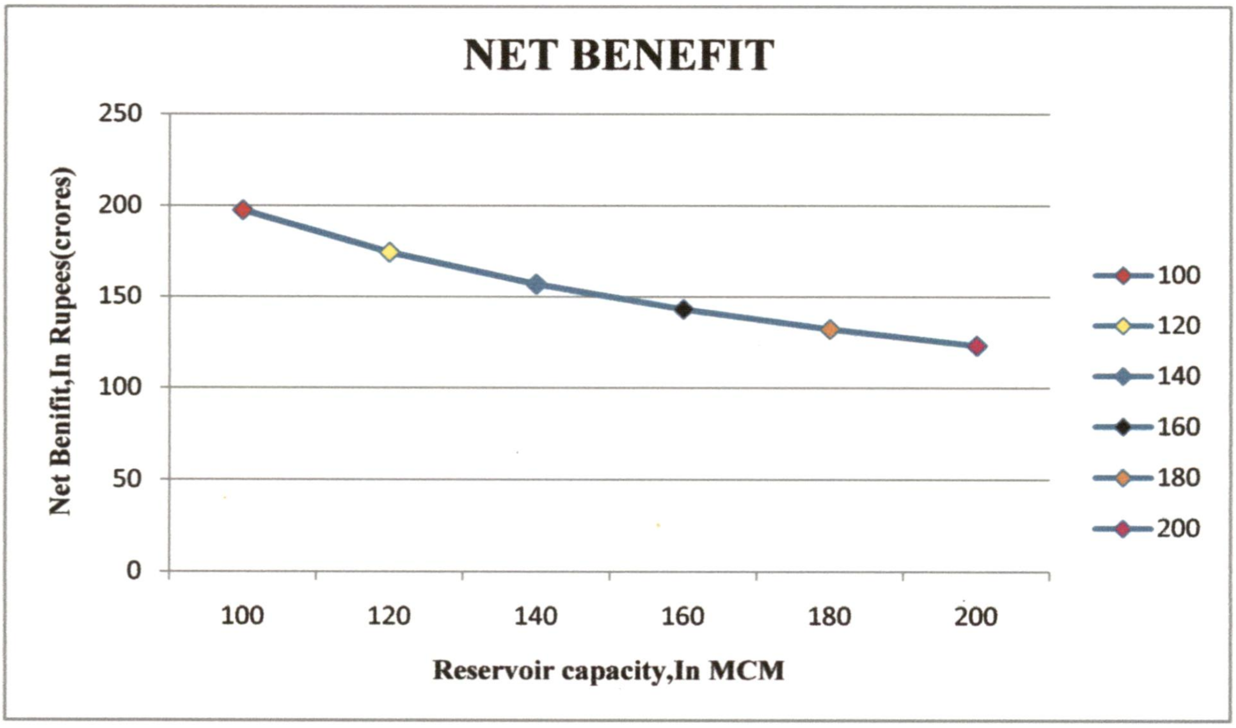


Fig 7.1 Variation in Net benefit with Reservoir capacity

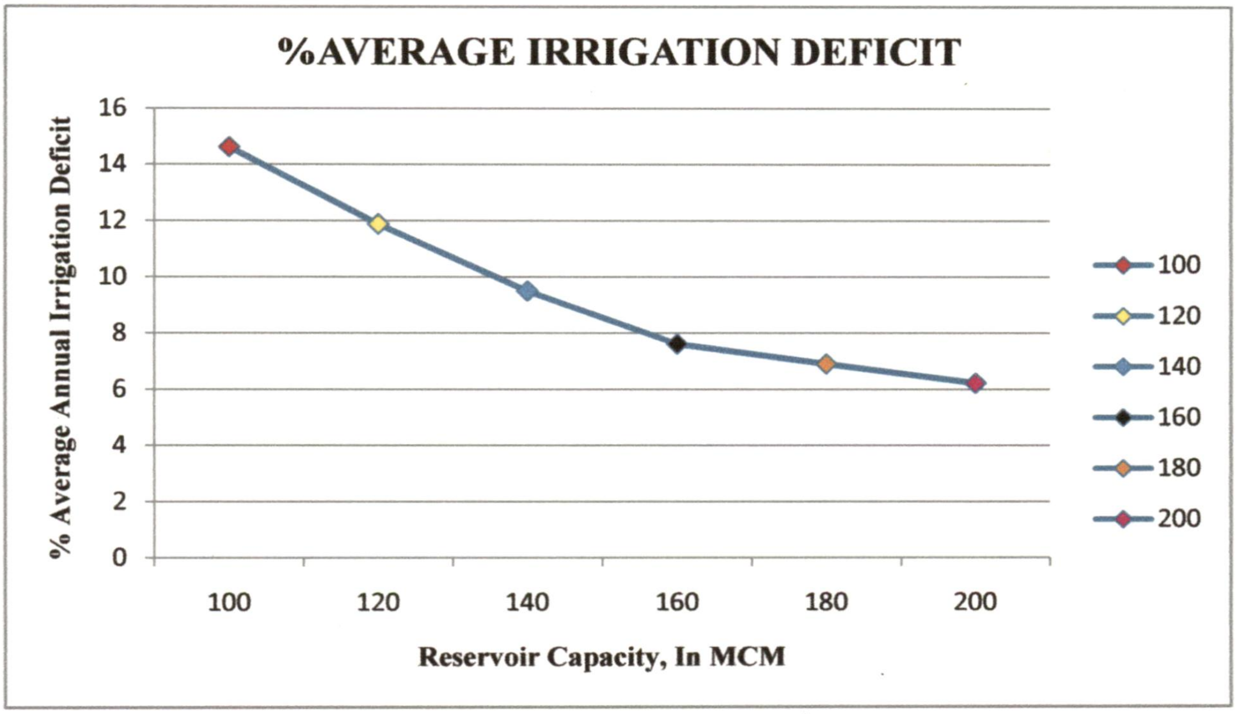


Fig 7.2 Variation in Irrigation Deficit with Reservoir capacity

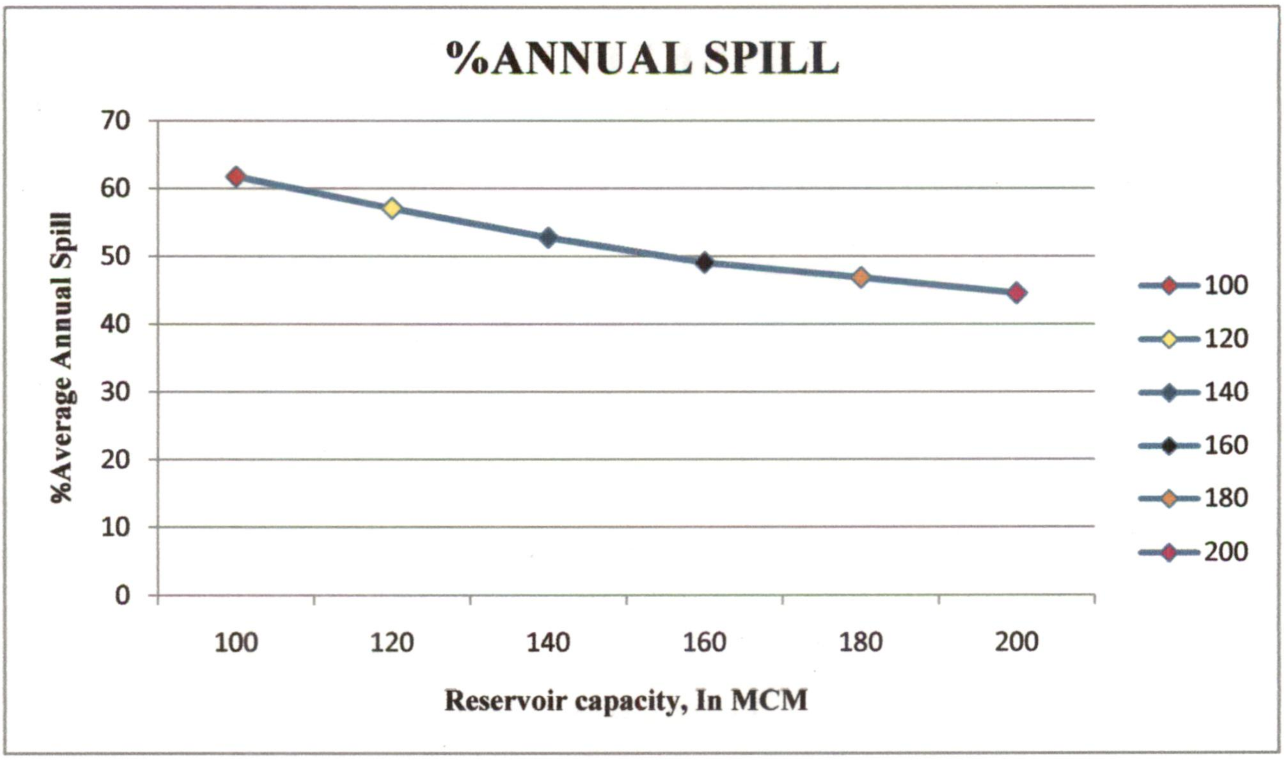


Fig 7.3 Variation in Annual Spill with Reservoir capacity

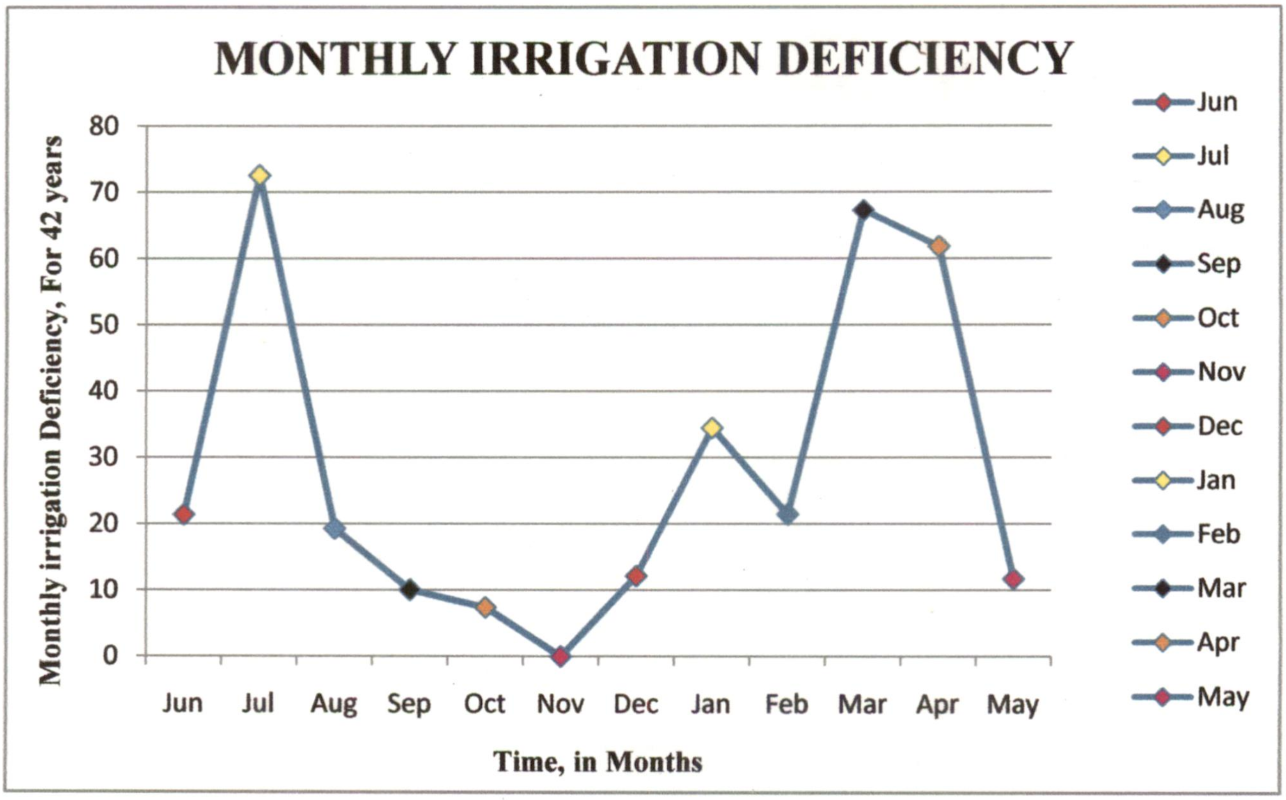


Fig 7.4 Average Monthly Irrigation Deficiency

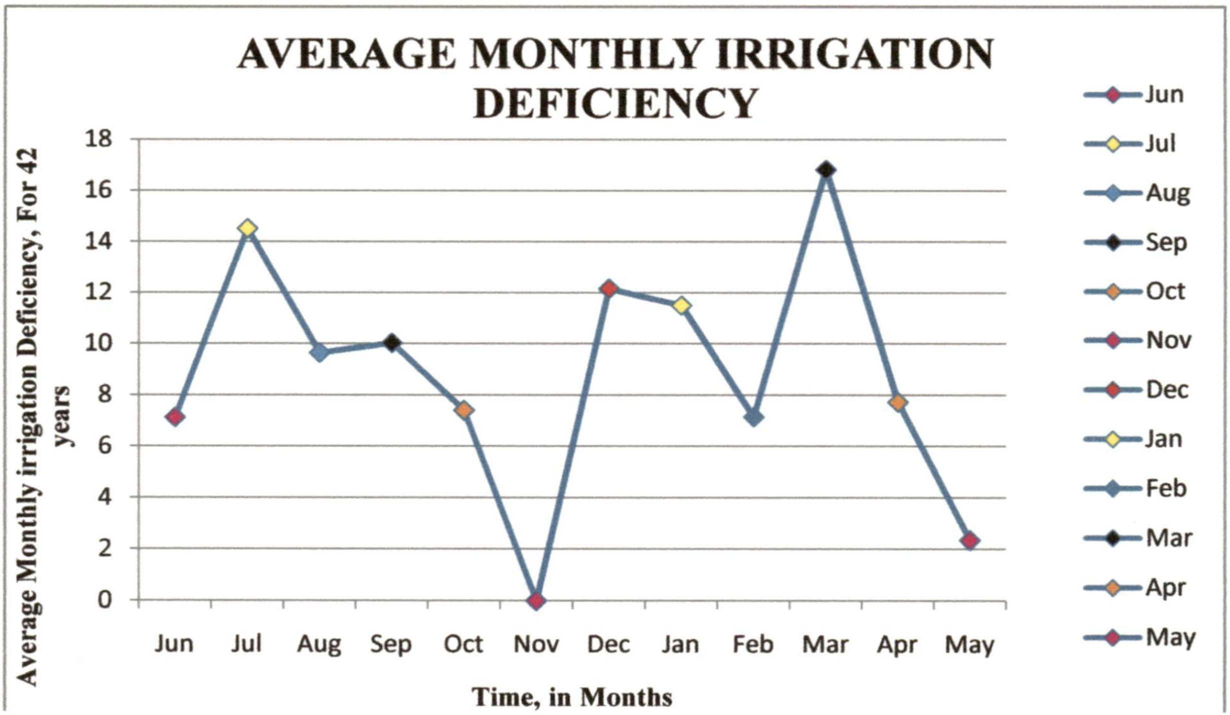


Fig 7.5 Average Monthly Irrigation Deficiency

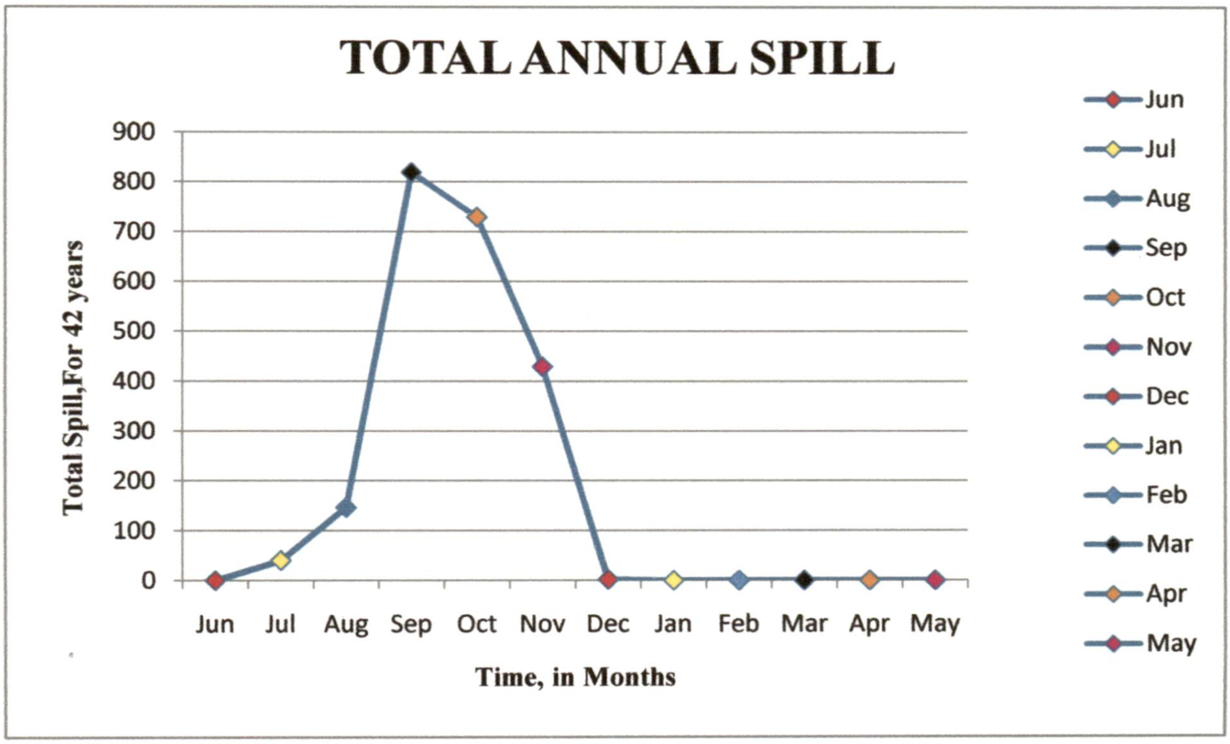


Fig 7.6 Monthly Annual Spills

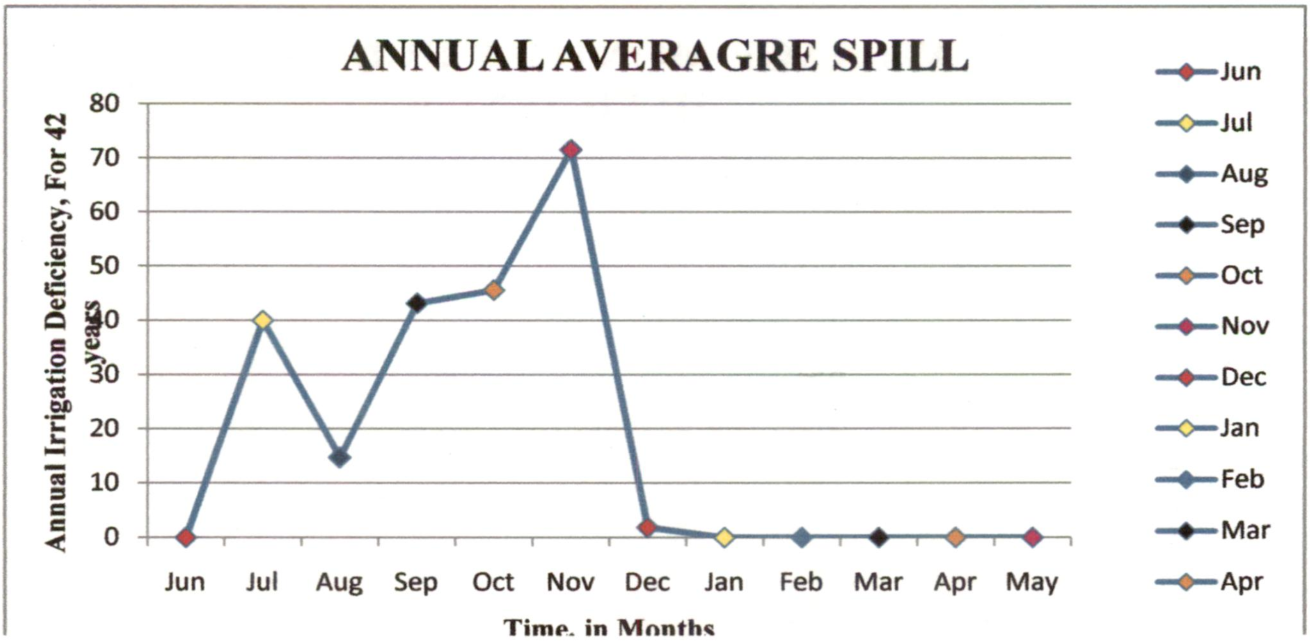


Fig 7.7 Annual Average Spills

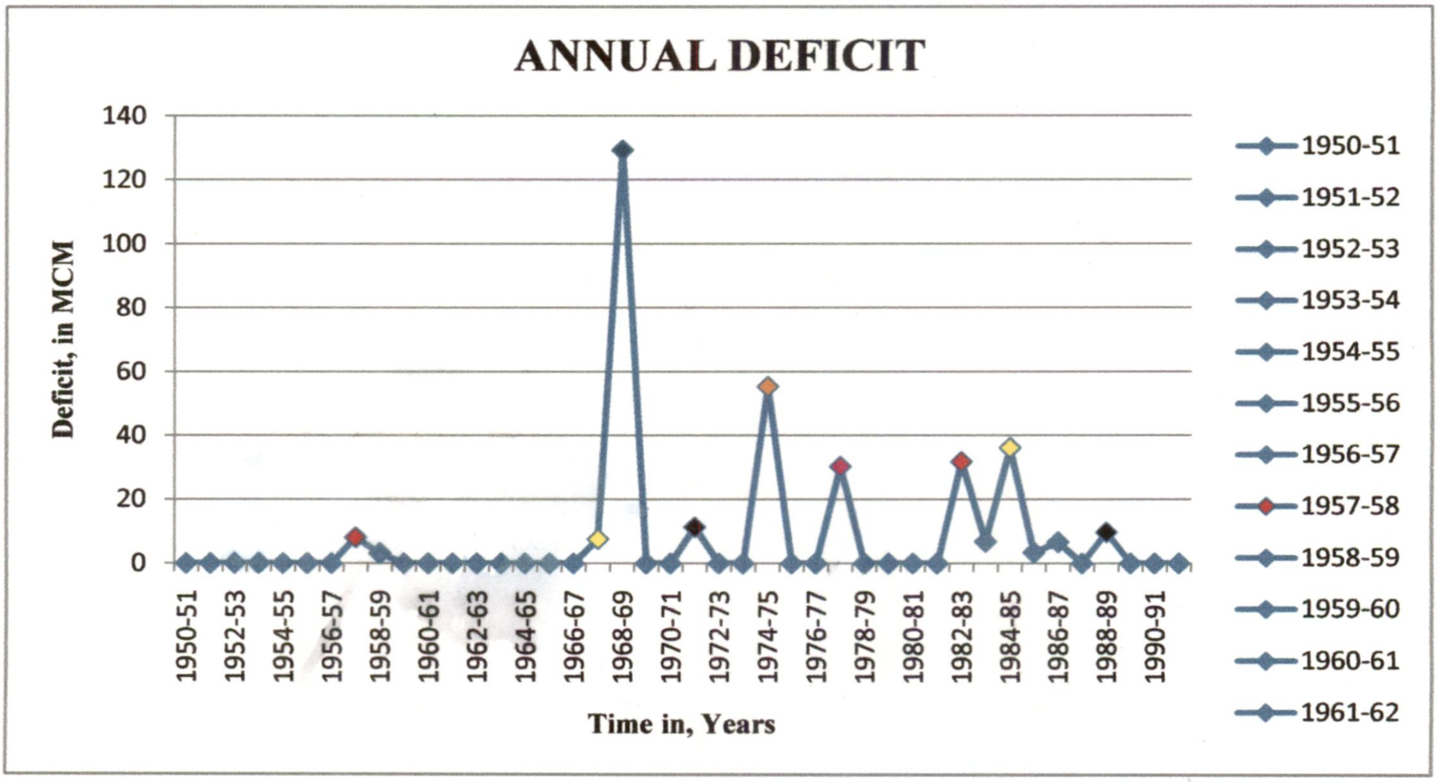


Fig 7.8 Annual Deficits

7.4 CONCLUSION:

Simulation models were used here to see the applicability of it in the reservoir planning and further analysis of water resources system. The Harabhangi irrigation project was taken as the system. The following conclusions are drawn.

(i) This project already existed and was analyzed for its further development.

(ii) Simulation technique was used to simulate the various components of the reservoir to obtain the near optimum values of the design variables by refining them by eliminating infeasible alternatives due to excess irrigation shortages based on number of failure years in the project target.

(iii) Two sampling techniques namely, systematic and random were used to explore the response (net benefit) surface. It was found that a lower capacity of 120MCM may only be required to satisfy the future annual irrigation requirement of 220 MCM at 80% annual dependability where as the existing reservoir capacity is already in excess (21.25 MCM) see in the Table 6.1.

(iv) Near perfect behavior of reservoir for water conservation may only be predicted by simulation, making it the most feasible method for reservoir planning.

7.5 RECOMMENDATIONS:

Water which was once considered as abundant and inexhaustible has now become a rare resource and its availability to meet the ever increasing demands is becoming a challenging task. There is an urgent need for conservation of the available water resources and their optimal and effective management using scientific approach. Water resource development projects are mostly operated and managed considering them as single entity, instead of attempting integrated operation for deriving maximum benefits and operating decisions are taken based on empirical methods, their experience and judgment. Such operation procedures have their own inherent disadvantages and often result in suboptimal utilization of water. The simulation technique could be gainfully applied to various reservoirs system. The usefulness of the technique will be accelerated if the following points are kept in view:

- The technique has the potential of significantly improving water resources planning and management. The use of these techniques will rapidly increase, with increasing complexities of water resources development problems, as no other present technique could provide objectivity and flexibility required for the solution;
- More interaction between operation personnel and software developers be encouraged, so as to have their practical difficulties and limitations in view;

In view of the above, the following recommendations emerge:

- The models employed must have the capability of analyzing / processing the data received through automatic data transmission system quickly so that the decision maker can take a judicious and technically sound decision and the operator has enough time to implement the decision;
- The software must be user-friendly, easy to understand, and must have graphic user interface for better presentation;
- The efficiency of the operation of a reservoir system mainly depends upon the data observation and transmission network in the basin. As far as possible efforts be made to install automatic data collection and transmission system.
- PCs be installed at all reservoir operation head quarters and field officers involved in the reservoir operation must be trained in the use of computers and system engineering techniques.

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APPENDIX A

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}												
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t												
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t												
5	River Inflow (in MCM)	I_t												
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0												
7	Dead Storage	Y_d												
8	BALANCE 2 [W1=W0-Yd]	W_1												
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'												
10	BALANCE 3 [W2=W1-Ot']	W2												
11	Irrigation demand / Dependable flow	Oi_{dt}												
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat												
13	Deficit	D_{ef}												
14	BALANCE 4 [W3=W2-Oiat]	W3												
15	Reservoir capacity (MCM)													
16	Reservoir Spill													
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t												

APPENDIX B

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1950-51

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	0.000	32.937	57.227	106.794	128.257	143.402	142.276	125.898	98.292	88.885	66.361	51.347
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	3.800	7.126	9.493	14.112	16.027	17.350	17.252	15.819	13.339	12.475	10.365	8.927
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001
5	River Inflow (in MCM)	It	51.870	63.290	72.270	46.290	32.270	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	51.869	96.226	129.496	153.082	160.525	147.510	143.244	126.456	98.670	89.353	66.960	51.966
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	46.519	90.876	124.146	147.732	155.175	142.160	137.894	121.106	93.320	84.003	61.610	46.616
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.465	0.909	1.241	1.477	1.552	1.422	1.379	1.211	0.933	0.840	0.616	0.466
10	BALANCE 3 [W2=W1-Ot']	W2	46.054	89.968	122.904	146.255	153.623	140.738	136.515	119.895	92.386	83.163	60.994	46.150
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	27.587	51.877	101.444	122.907	138.052	136.926	120.548	92.942	83.535	61.011	45.997	43.039
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	**32.937**	**57.227**	**106.794**	**128.257**	**143.402**	**142.276**	**125.898**	**98.292**	**88.885**	**66.361**	**51.347**	**48.389**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1951-52

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	48.389	47.202	72.785	146.600	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.640	8.525	10.973	17.626	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
5	River Inflow (in MCM)	I_t	17.890	64.740	143.530	73.870	44.530	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	66.278	111.941	216.313	220.468	191.128	150.708	146.411	129.590	101.773	92.425	70.001	54.976
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	60.928	106.591	210.963	215.118	185.778	145.358	141.061	124.240	96.423	87.075	64.651	49.626
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.609	1.066	2.110	2.151	1.858	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	60.319	105.525	208.853	212.967	183.920	143.904	139.650	122.998	95.459	86.204	64.004	49.130
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	41.852	67.435	187.393	189.619	168.349	140.093	123.682	96.045	86.607	64.053	49.007	46.019
15	Reservoir capacity (MCM)	.	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0	0	46	48	27	0	0	0	0	0	0	0
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	47	73	147	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1952-53

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	51.369	46.598	112.272	136.102	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.929	8.466	14.605	16.715	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	14.300	105.230	46.830	168.950	98.040	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	65.668	151.827	159.100	305.050	244.638	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	60.318	146.477	153.750	299.700	239.288	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.603	1.465	1.538	2.997	2.393	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	59.715	145.013	152.213	296.703	236.895	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	41.248	106.922	130.752	273.355	221.324	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	132.105	80.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	47	112	136	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1953-54

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	51.370	68.003	76.577	146.600	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.929	10.521	11.329	17.626	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	35.920	47.770	103.980	97.660	35.650	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	87.289	115.772	180.555	244.258	182.248	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	81.939	110.422	175.205	238.908	176.898	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.819	1.104	1.752	2.389	1.769	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	81.120	109.318	173.453	236.519	175.129	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	62.653	71.227	151.993	213.171	159.558	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	10.743	71.921	18.308	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	68	77	147	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1954-55

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	51.370	54.866	46.761	146.600	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.929	9.266	8.482	17.626	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	22.650	30.790	125.770	97.820	84.800	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	74.019	85.655	172.530	244.418	231.398	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	68.669	80.305	167.180	239.068	226.048	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.687	0.803	1.672	2.391	2.260	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	67.982	79.502	165.509	236.677	223.788	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	49.516	41.411	144.048	213.329	208.216	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	2.798	72.079	66.966	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	55	47	147	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1955-56

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	51.370	60.776	59.820	127.201	146.600	144.632	143.495	127.104	99.486	90.067	67.531	52.506
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.929	9.833	9.742	15.934	17.626	17.456	17.358	15.926	13.448	12.584	10.476	9.039
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	
5	River Inflow (in MCM)	It	28.620	38.070	90.290	92.740	15.170	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	79.989	98.845	150.109	219.939	161.768	148.740	144.463	127.662	99.864	90.535	68.130	53.126
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	74.639	93.495	144.759	214.589	156.418	143.390	139.113	122.312	94.514	85.185	62.780	47.776
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.746	0.935	1.448	2.146	1.564	1.434	1.391	1.223	0.945	0.852	0.628	0.478
10	BALANCE 3 [W2=W1-Ot']	W2	73.893	92.560	143.311	212.443	154.854	141.957	137.722	121.089	93.569	84.333	62.153	47.298
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	55.426	54.470	121.851	189.095	139.282	138.145	121.754	94.136	84.717	62.181	47.156	44.187
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	47.845	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	61	60	127	147	145	143	127	99	90	68	53	50

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1956-57

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	**Opening Balance (in MCM)**	S_{t_1}	49.537	71.198	111.439	146.600	146.600	141.821	140.711	124.348	96.758	87.366	64.858	49.859
3	**Water spread (in m2)** [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.751	10.823	14.530	17.626	17.626	17.213	17.117	15.682	13.199	12.335	10.223	8.783
4	**Evaporation (in MCM)** [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	
5	**River Inflow (in MCM)**	I_t	40.980	79.790	74.750	80.220	12.330	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	**NET WATER AVAILABILITY** [W0=St_1-Elt-It]	W_0	90.516	150.986	186.187	226.818	158.928	145.929	141.679	124.906	97.136	87.834	65.457	50.479
7	**Dead Storage**	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	**BALANCE 2 [W1=W0-Yd]**	W_1	85.166	145.636	180.837	221.468	153.578	140.579	136.329	119.556	91.786	82.484	60.107	45.129
9	**Release to the natural Channel** [Ot'=0.01*W1]	Ot'	0.852	1.456	1.808	2.215	1.536	1.406	1.363	1.196	0.918	0.825	0.601	0.451
10	**BALANCE 3 [W2=W1-Ot']**	W2	84.315	144.180	179.029	219.253	152.042	139.173	134.966	118.361	90.868	81.659	59.506	44.678
11	**Irrigation demand / Dependable flow**	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	**Actual Irrigation release** [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	**Deficit**	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	**BALANCE 4 [W3=W2-Oiat]**	W3	65.848	106.089	157.568	195.905	136.471	135.361	118.998	91.408	82.016	59.508	44.509	41.567
15	**Reservoir capacity (MCM)**		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	**Reservoir Spill**		0.000	0.000	16.318	54.655	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	**CLOSING BALANCE** BALANCE 5 [W4=W3-d17+d8]	S_t	**71**	**111**	**147**	**147**	**142**	**141**	**124**	**97**	**87**	**65**	**50**	**47**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1957-58

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	46.917	65.901	47.311	100.056	93.708	88.616	88.039	72.202	45.133	36.259	14.262	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.497	10.322	8.535	13.500	12.919	12.450	12.397	10.918	8.323	7.454	5.257	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	38.250	20.310	75.380	18.130	11.480	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	85.166	86.210	122.690	118.184	105.186	92.724	89.007	72.760	45.512	36.728	14.861	5.970
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	79.816	80.860	117.340	112.834	99.836	87.374	83.657	67.410	40.162	31.378	9.511	0.620
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.798	0.809	1.173	1.128	0.998	0.874	0.837	0.674	0.402	0.314	0.095	0.006
10	BALANCE 3 [W2=W1-Ot']	W2	79.017	80.051	116.166	111.706	98.837	86.500	82.820	66.736	39.760	31.064	9.416	0.614
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	9.416	0.614
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.581	2.497
14	BALANCE 4 [W3=W2-Oiat]	W3	60.551	41.961	94.706	88.358	83.266	82.689	66.852	39.783	30.909	8.912	0.000	0.000
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	66	47	100	94	89	88	72	45	36	14	5	5

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1958-59

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	5.350	5.350	21.510	84.354	146.600	146.167	145.014	128.608	100.975	91.541	68.991	53.950
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.350	4.350	5.987	12.055	17.626	17.589	17.489	16.058	13.584	12.720	10.615	9.178
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	15.490	54.800	85.320	127.580	16.720	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	20.839	60.149	106.829	211.932	163.318	150.275	145.982	129.166	101.353	92.009	69.589	54.570
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	15.489	54.799	101.479	206.582	157.968	144.925	140.632	123.816	96.003	86.659	64.239	49.220
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.155	0.548	1.015	2.066	1.580	1.449	1.406	1.238	0.960	0.867	0.642	0.492
10	BALANCE 3 [W2=W1-Ot']	W2	15.334	54.251	100.465	204.516	156.388	143.476	139.226	122.578	95.043	85.792	63.596	48.727
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	15.334	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	3.132	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	0.000	16.160	79.004	181.168	140.817	139.664	123.258	95.625	86.191	63.641	48.600	45.616
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	39.918	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	5	22	84	147	146	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1959-60

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	50.966	74.108	96.549	146.600	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.890	11.098	13.180	17.626	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	42.490	61.840	74.760	46.650	91.290	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	93.455	135.946	171.307	193.248	237.888	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	88.105	130.596	165.957	187.898	232.538	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.881	1.306	1.660	1.879	2.325	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	87.224	129.290	164.298	186.019	230.213	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	68.758	91.199	142.837	162.671	214.641	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	1.587	21.421	73.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	74	97	147	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1960-61

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	51.370	55.549	58.724	111.355	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.929	9.332	9.637	14.523	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	23.340	42.190	75.380	78.590	83.100	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	74.709	97.738	134.103	189.943	229.698	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	69.359	92.388	128.753	184.593	224.348	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.694	0.924	1.288	1.846	2.243	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	68.666	91.464	127.465	182.747	222.105	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	50.199	53.374	106.005	159.399	206.533	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	18.149	65.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	56	59	111	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1961-62

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	**Opening Balance (in MCM)**	S_{t_1}	51.370	68.954	119.068	146.600	146.600	146.207	145.053	128.647	101.013	91.579	69.028	53.987
3	**Water spread (in m2)** [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.929	10.611	15.213	17.626	17.626	17.592	17.493	16.062	13.587	12.724	10.618	9.182
4	**Evaporation (in MCM)** [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	**River Inflow (in MCM)**	I_t	36.880	89.740	83.530	97.100	16.760	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	**NET WATER AVAILABILITY** [W0=St_1-Elt-It]	W_0	88.249	158.692	202.596	243.698	163.358	150.315	146.021	129.205	101.391	92.047	69.626	54.607
7	**Dead Storage**	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	**BALANCE 2 [W1=W0-Yd]**	W_1	82.899	153.342	197.246	238.348	158.008	144.965	140.671	123.855	96.041	86.697	64.276	49.257
9	**Release to the natural Channel** [Ot'=0.01*W1]	Ot'	0.829	1.533	1.972	2.383	1.580	1.450	1.407	1.239	0.960	0.867	0.643	0.493
10	**BALANCE 3 [W2=W1-Ot']**	W2	82.070	151.808	195.273	235.965	156.428	143.515	139.265	122.616	95.081	85.830	63.634	48.764
11	**Irrigation demand / Dependable flow**	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	**Actual Irrigation release** [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	**Deficit**	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	**BALANCE 4 [W3=W2-Oiat]**	W3	63.604	113.718	173.813	212.617	140.857	139.703	123.297	95.663	86.229	63.678	48.637	45.653
15	**Reservoir capacity (MCM)**		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	**Reservoir Spill**		0.000	0.000	32.563	71.367	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	**CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]**	S_t	**69**	**119**	**147**	**147**	**146**	**145**	**129**	**101**	**92**	**69**	**54**	**51**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1962-63

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	51.003	60.680	61.170	146.600	146.600	146.600	145.443	129.032	101.395	91.957	69.403	54.357
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.893	9.824	9.871	17.626	17.626	17.626	17.526	16.096	13.622	12.758	10.654	9.217
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	28.890	39.530	121.100	31.770	65.420	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	79.892	100.209	182.269	178.368	212.018	150.708	146.411	129.590	101.773	92.425	70.001	54.977
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	74.542	94.859	176.919	173.018	206.668	145.358	141.061	124.240	96.423	87.075	64.651	49.627
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.745	0.949	1.769	1.730	2.067	1.454	1.411	1.242	0.964	0.871	0.647	0.496
10	BALANCE 3 [W2=W1-Ot']	W2	73.797	93.911	175.150	171.288	204.601	143.904	139.650	122.998	95.459	86.204	64.004	49.131
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	55.330	55.820	153.690	147.940	189.030	140.093	123.682	96.045	86.607	64.053	49.007	46.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	12.440	6.690	47.780	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	61	61	147	147	147	145	129	101	92	69	54	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1963-64

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	**Opening Balance (in MCM)**	St_1	51.370	62.291	66.002	145.439	146.600	146.600	146.600	131.871	104.670	95.457	73.432	58.792
3	**Water spread (in m2)** [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.929	9.978	10.331	17.526	17.626	17.626	17.626	16.345	13.919	13.080	11.034	9.643
4	**Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]**	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	**River Inflow (in MCM)**	It	30.150	42.800	102.530	29.850	72.570	12.940	2.680	1.030	0.640	1.040	1.050	0.610
6	**NET WATER AVAILABILITY [W0=St_1-Elt-It]**	W0	81.519	105.090	168.531	175.287	219.168	159.538	149.278	132.899	105.308	96.495	74.480	59.402
7	**Dead Storage**	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	**BALANCE 2 [W1=W0-Yd]**	W1	76.169	99.740	163.181	169.937	213.818	154.188	143.928	127.549	99.958	91.145	69.130	54.052
9	**Release to the natural Channel [Ot'=0.01*W1]**	Ot'	0.762	0.997	1.632	1.699	2.138	1.542	1.439	1.275	1.000	0.911	0.691	0.541
10	**BALANCE 3 [W2=W1-Ot']**	W2	75.407	98.743	161.549	168.237	211.680	152.646	142.489	126.273	98.959	90.234	68.439	53.511
11	**Irrigation demand / Dependable flow**	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	**Actual Irrigation release [Oiat=min(Oit,W2)]**	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	**Deficit**	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	**BALANCE 4 [W3=W2-Oiat]**	W3	56.941	60.652	140.089	144.889	196.108	148.835	126.521	99.320	90.107	68.082	53.442	50.400
15	**Reservoir capacity (MCM)**		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	**Reservoir Spill**		0.000	0.000	0.000	3.639	54.858	7.585	0.000	0.000	0.000	0.000	0.000	0.000
17	**CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]**	St	62	66	145	147	147	147	132	105	95	73	59	56

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1964-65

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	55.750	53.559	62.506	135.176	146.600	146.600	146.600	131.247	104.063	94.935	72.262	57.554
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	9.351	9.140	9.999	16.634	17.626	17.626	17.626	16.290	13.864	13.032	10.924	9.525
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	16.950	48.000	95.660	62.860	62.850	21.570	2.050	1.040	0.720	0.380	0.970	1.960
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	72.699	101.558	158.165	198.034	209.448	168.168	148.648	132.285	104.781	95.313	73.230	59.514
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	67.349	96.208	152.815	192.684	204.098	162.818	143.298	126.935	99.431	89.963	67.880	54.164
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.673	0.962	1.528	1.927	2.041	1.628	1.433	1.269	0.994	0.900	0.679	0.542
10	BALANCE 3 [W2=W1-Ot']	W2	66.676	95.246	151.287	190.757	202.057	161.190	141.865	125.666	98.437	89.063	67.201	53.622
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	48.209	57.156	129.826	167.409	186.486	157.378	125.897	98.713	89.585	66.912	52.204	50.511
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	26.159	45.236	16.128	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	54	63	135	147	147	147	131	104	95	72	58	56

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1965-66

1	Time, *t* (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	55.861	41.809	60.149	90.075	122.169	146.600	143.176	126.639	99.521	90.359	68.603	53.487
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	9.362	7.999	9.773	12.585	15.489	17.626	17.330	15.885	13.451	12.611	10.578	9.133
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	
5	River Inflow (in MCM)	I_t	4.970	57.370	52.460	56.860	45.900	1.820	0.820	1.060	0.640	1.260	0.520	0.520
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	60.830	99.178	112.608	146.933	168.067	148.418	143.994	127.697	100.159	91.617	69.122	54.007
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	55.480	93.828	107.258	141.583	162.717	143.068	138.644	122.347	94.809	86.267	63.772	48.657
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.555	0.938	1.073	1.416	1.627	1.431	1.386	1.223	0.948	0.863	0.638	0.487
10	BALANCE 3 [W2=W1-Ot']	W2	54.926	92.890	106.186	140.167	161.090	141.637	137.257	121.124	93.861	85.405	63.134	48.171
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	36.459	54.799	84.725	116.819	145.519	137.826	121.289	94.171	85.009	63.253	48.137	45.060
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	4.269	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	42	60	90	122	147	143	127	100	90	69	53	50

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1966-67

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	50.410	52.856	55.622	89.583	116.178	111.346	121.620	106.972	80.070	70.776	48.186	34.205
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	8.836	9.072	9.339	12.539	14.955	14.522	15.440	14.128	11.656	10.784	8.620	7.251
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	
5	River Inflow (in MCM)	It	21.580	41.750	56.490	51.300	11.970	15.300	2.510	1.080	0.310	0.220	1.460	1.580
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	71.989	94.605	112.111	140.881	128.146	126.644	124.128	108.050	80.378	70.994	49.645	35.785
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	66.639	89.255	106.761	135.531	122.796	121.294	118.778	102.700	75.028	65.644	44.295	30.435
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.666	0.893	1.068	1.355	1.228	1.213	1.188	1.027	0.750	0.656	0.443	0.304
10	BALANCE 3 [W2=W1-Ot']	W2	65.972	88.362	105.693	134.176	121.568	120.081	117.590	101.673	74.278	64.988	43.852	30.131
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	47.506	50.272	84.233	110.828	105.996	116.270	101.622	74.720	65.426	42.836	28.855	27.020
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	53	56	90	116	111	122	107	80	71	48	34	32

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1967-68

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	32.370	47.560	54.279	97.500	85.792	85.798	83.061	67.473	41.145	32.291	14.888	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	7.070	8.560	9.210	13.267	12.189	12.189	11.935	10.471	7.934	7.062	5.320	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	34.270	45.690	65.830	12.690	16.550	1.900	1.170	1.260	0.360	5.070	0.480	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	66.639	93.249	120.108	110.188	102.340	87.696	84.229	68.732	41.504	37.360	15.367	5.970
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	61.289	87.899	114.758	104.838	96.990	82.346	78.879	63.382	36.154	32.010	10.017	0.620
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.613	0.879	1.148	1.048	0.970	0.823	0.789	0.634	0.362	0.320	0.100	0.006
10	BALANCE 3 [W2=W1-Ot']	W2	60.676	87.020	113.610	103.790	96.020	81.523	78.090	62.748	35.792	31.689	9.917	0.614
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	9.917	0.614
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.080	2.497
14	BALANCE 4 [W3=W2-Oiat]	W3	42.210	48.929	92.150	80.442	80.448	77.711	62.123	35.795	26.941	9.538	0.000	0.000
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	48	54	97	86	86	83	67	41	32	15	5	5

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1968-69

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	5.350	5.350	5.350	7.203	5.350	5.350	5.903	5.350	5.350	5.350	5.350	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.350	4.350	4.350	4.539	4.350	4.350	4.406	4.350	4.350	4.350	4.350	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	9.580	21.070	23.550	11.600	8.250	4.410	3.300	0.560	0.390	0.400	0.600	0.610
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	14.929	26.419	28.899	18.802	13.599	9.759	9.202	5.909	5.739	5.749	5.949	5.960
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd']	W1	9.579	21.069	23.549	13.452	8.249	4.409	3.852	0.559	0.389	0.399	0.599	0.610
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.096	0.211	0.235	0.135	0.082	0.044	0.039	0.006	0.004	0.004	0.006	0.006
10	BALANCE 3 [W2=W1-Ot']	W2	9.483	20.858	23.314	13.318	8.167	4.365	3.814	0.553	0.385	0.395	0.593	0.604
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	9.483	20.858	21.460	13.318	8.167	3.812	3.814	0.553	0.385	0.395	0.593	0.604
13	Deficit	Def	8.983	17.232	0.000	10.030	7.405	0.000	12.154	26.399	8.467	21.757	14.404	2.507
14	BALANCE 4 [W3=W2-Oiat]	W3	0.000	0.000	1.853	0.000	0.000	0.553	0.000	0.000	0.000	0.000	0.000	0.000
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	5	5	7	5	5	6	5	5	5	5	5	5

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1969-70

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	5.350	17.721	74.199	101.142	146.600	133.832	142.247	130.026	105.388	96.594	74.488	59.392
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.350	5.606	11.106	13.599	17.626	16.517	17.250	16.183	13.985	13.184	11.133	9.701
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	31.150	95.650	49.590	86.580	4.260	13.650	5.170	3.600	1.070	0.970	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	36.499	113.370	123.787	187.720	150.858	147.480	147.415	133.624	106.456	97.562	75.086	60.012
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	31.149	108.020	118.437	182.370	145.508	142.130	142.065	128.274	101.106	92.212	69.736	54.662
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.311	1.080	1.184	1.824	1.455	1.421	1.421	1.283	1.011	0.922	0.697	0.547
10	BALANCE 3 [W2=W1-Ot']	W2	30.838	106.940	117.253	180.547	144.053	140.708	140.644	126.991	100.095	91.290	69.038	54.115
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	12.371	68.849	95.792	157.199	128.482	136.897	124.676	100.038	91.244	69.138	54.042	51.004
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	15.949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	18	74	101	147	134	142	130	105	97	74	59	56

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1970-71

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	56.354	58.018	56.584	93.892	91.030	102.192	101.478	88.220	64.080	57.204	38.404	24.630
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	9.409	9.569	9.432	12.936	12.673	13.694	13.630	12.414	10.149	9.491	7.665	6.300
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	20.850	37.560	59.880	21.590	27.870	4.110	3.710	3.680	2.590	3.910	1.570	2.240
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	77.203	95.577	116.463	115.480	118.898	106.300	105.186	91.898	66.669	61.113	39.973	26.870
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	71.853	90.227	111.113	110.130	113.548	100.950	99.836	86.548	61.319	55.763	34.623	21.520
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.719	0.902	1.111	1.101	1.135	1.009	0.998	0.865	0.613	0.558	0.346	0.215
10	BALANCE 3 [W2=W1-Ot']	W2	71.135	89.325	110.002	109.028	112.413	99.940	98.838	85.683	60.706	55.205	34.276	21.304
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	52.668	51.234	88.542	85.680	96.842	96.128	82.870	58.730	51.854	33.054	19.280	18.193
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	58	57	94	91	102	101	88	64	57	38	25	24

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1971-72

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	23.543	21.249	5.350	75.543	109.188	146.600	146.156	132.708	106.460	98.100	75.593	62.574
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	6.191	5.961	4.350	11.232	14.328	17.626	17.588	16.418	14.081	13.322	11.237	10.005
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	16.520	11.160	92.580	58.280	65.900	4.830	3.970	2.000	1.520	0.580	2.710	1.920
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	40.062	32.408	97.929	133.821	175.086	151.428	150.124	134.706	107.978	98.678	78.301	64.494
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	34.712	27.058	92.579	128.471	169.736	146.078	144.774	129.356	102.628	93.328	72.951	59.144
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.347	0.271	0.926	1.285	1.697	1.461	1.448	1.294	1.026	0.933	0.730	0.591
10	BALANCE 3 [W2=W1-Ot']	W2	34.365	26.787	91.653	127.186	168.039	144.617	143.326	128.062	101.601	92.394	72.221	58.553
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	26.787	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	11.303	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	15.899	0.000	70.193	103.838	152.467	140.806	127.358	101.110	92.750	70.243	57.224	55.442
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	11.217	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	21	5	76	109	147	146	133	106	98	76	63	61

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1972-73

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	60.792	77.034	48.550	68.534	93.696	146.600	145.443	129.032	101.395	91.957	69.403	59.703
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*	At	9.835	11.372	8.656	10.571	12.918	17.626	17.526	16.096	13.622	12.758	10.654	9.731
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	35.620	10.430	42.300	49.640	73.700	4.110	0.970	0.560	0.380	0.470	6.000	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	96.411	87.462	90.849	118.173	167.394	150.708	146.411	129.590	101.773	92.425	75.401	60.323
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	91.061	82.112	85.499	112.823	162.044	145.358	141.061	124.240	96.423	87.075	70.051	54.973
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.911	0.821	0.855	1.128	1.620	1.454	1.411	1.242	0.964	0.871	0.701	0.550
10	BALANCE 3 [W2=W1-Ot']	W2	90.150	81.291	84.644	111.694	160.424	143.904	139.650	122.998	95.459	86.204	69.350	54.424
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	71.684	43.200	63.184	88.346	144.853	140.093	123.682	96.045	86.607	64.053	54.353	51.313
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	3.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	77	49	69	94	147	145	129	101	92	69	60	57

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1973-74

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	56.663	41.513	41.631	60.980	85.506	98.712	98.034	82.097	54.930	45.957	23.864	9.275
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	9.439	7.970	7.981	9.853	12.162	13.378	13.316	11.845	9.272	8.404	6.223	4.751
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	3.870	38.960	41.590	48.920	29.880	4.110	0.970	0.560	0.380	0.470	0.600	0.620
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	60.532	80.472	83.220	109.899	115.384	102.820	99.002	82.655	55.309	46.426	24.463	9.895
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	55.182	75.122	77.870	104.549	110.034	97.470	93.652	77.305	49.959	41.076	19.113	4.545
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.552	0.751	0.779	1.045	1.100	0.975	0.937	0.773	0.500	0.411	0.191	0.045
10	BALANCE 3 [W2=W1-Ot']	W2	54.630	74.371	77.091	103.504	108.934	96.496	92.715	76.532	49.459	40.665	18.922	4.499
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	36.163	36.281	55.630	80.156	93.362	92.684	76.747	49.580	40.607	18.514	3.925	1.389
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	42	42	61	86	99	98	82	55	46	24	9	7

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1974-75

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	6.739	5.350	5.350	5.350	20.235	90.198	87.328	71.499	44.902	36.139	14.975	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.492	4.350	4.350	4.350	5.859	12.596	12.331	10.852	8.301	7.442	5.329	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	7.890	7.600	11.980	38.620	86.550	1.810	0.970	1.030	0.490	1.310	1.350	1.310
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	14.628	12.949	17.329	43.969	106.784	92.006	88.296	72.527	45.391	37.448	16.324	6.660
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	9.278	7.599	11.979	38.619	101.434	86.656	82.946	67.177	40.041	32.098	10.974	1.310
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.093	0.076	0.120	0.386	1.014	0.867	0.829	0.672	0.400	0.321	0.110	0.013
10	BALANCE 3 [W2=W1-Ot']	W2	9.185	7.523	11.859	38.233	100.419	85.790	82.116	66.505	39.640	31.777	10.864	1.297
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	9.185	7.523	11.859	23.348	15.571	3.812	15.968	26.953	8.852	22.152	10.864	1.297
13	Deficit	Def	9.282	30.568	9.601	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.132	1.814
14	BALANCE 4 [W3=W2-Oiat]	W3	0.000	0.000	0.000	14.885	84.848	81.978	66.149	39.552	30.789	9.625	0.000	0.000
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	**5**	**5**	**5**	**20**	**90**	**87**	**71**	**45**	**36**	**15**	**5**	**5**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1975-76

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	5.350	18.315	13.021	42.458	109.986	141.045	143.507	127.829	100.194	91.035	69.262	54.684
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.350	5.666	5.131	8.062	14.400	17.146	17.359	15.990	13.513	12.673	10.640	9.249
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	31.750	33.260	51.490	92.170	48.160	7.710	1.690	0.550	0.650	1.250	1.070	2.040
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	37.099	51.574	64.510	134.627	158.144	148.753	145.195	128.377	100.842	92.283	70.330	56.724
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	31.749	46.224	59.160	129.277	152.794	143.403	139.845	123.027	95.492	86.933	64.980	51.374
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.317	0.462	0.592	1.293	1.528	1.434	1.398	1.230	0.955	0.869	0.650	0.514
10	BALANCE 3 [W2=W1-Ot']	W2	31.432	45.762	58.569	127.984	151.266	141.969	138.447	121.797	94.537	86.064	64.330	50.860
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	12.965	7.671	37.108	104.636	135.695	138.157	122.479	94.844	85.685	63.912	49.334	47.749
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	18	13	42	110	141	144	128	100	91	69	55	53

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1976-77

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	53.099	36.055	58.878	146.600	146.600	146.600	143.512	126.686	99.596	90.434	67.895	53.212
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	9.096	7.434	9.652	17.626	17.626	17.626	17.359	15.889	13.458	12.618	10.511	9.107
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	
5	River Inflow (in MCM)	I_t	1.920	61.840	114.860	28.960	22.860	2.160	0.530	1.090	0.640	0.470	0.950	1.330
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	55.018	97.894	173.737	175.558	169.458	148.758	144.040	127.774	100.234	90.902	68.844	54.542
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	49.668	92.544	168.387	170.208	164.108	143.408	138.690	122.424	94.884	85.552	63.494	49.192
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.497	0.925	1.684	1.702	1.641	1.434	1.387	1.224	0.949	0.856	0.635	0.492
10	BALANCE 3 [W2=W1-Ot']	W2	49.171	91.618	166.703	168.506	162.467	141.974	137.303	121.199	93.936	84.696	62.859	48.700
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	30.705	53.528	145.243	145.158	146.896	138.162	121.336	94.246	85.084	62.545	47.862	45.589
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	3.993	3.908	5.646	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	36	59	147	147	147	144	127	100	90	68	53	51

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1977-78

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	50.939	33.273	7.327	31.514	63.789	50.325	63.992	49.575	22.436	13.561	5.350	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885* St_1^2+0.0000000295399*St_1^3]	At	8.887	7.159	4.552	6.985	10.121	8.828	10.140	8.755	6.080	5.186	4.350	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	1.270	12.550	46.130	56.450	2.720	18.110	2.160	0.260	0.150	0.610	0.510	0.720
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	52.208	45.822	53.456	87.963	66.508	68.434	66.151	49.834	22.585	14.170	5.859	6.070
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	46.858	40.472	48.106	82.613	61.158	63.084	60.801	44.484	17.235	8.820	0.509	0.720
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.469	0.405	0.481	0.826	0.612	0.631	0.608	0.445	0.172	0.088	0.005	0.007
10	BALANCE 3 [W2=W1-Ot']	W2	46.389	40.067	47.625	81.787	60.546	62.453	60.193	44.039	17.063	8.732	0.504	0.713
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	8.732	0.504	0.713
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.420	14.493	2.398
14	BALANCE 4 [W3=W2-Oiat]	W3	27.923	1.977	26.164	58.439	44.975	58.642	44.225	17.086	8.211	0.000	0.000	0.000
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	33	7	32	64	50	64	50	22	14	5	5	5

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1978-79

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	5.350	14.177	56.731	105.304	127.197	119.177	121.472	104.697	77.125	67.920	46.963	33.677
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	4.350	5.248	9.446	13.977	15.934	15.223	15.427	13.922	11.381	10.513	8.502	7.199
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	
5	River Inflow (in MCM)	It	27.570	81.550	71.260	46.710	8.860	7.320	0.360	0.380	0.370	1.840	2.150	3.090
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	32.919	95.726	127.990	152.012	136.055	126.495	121.830	105.075	77.493	69.759	49.112	36.767
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	27.569	90.376	122.640	146.662	130.705	121.145	116.480	99.725	72.143	64.409	43.762	31.417
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.276	0.904	1.226	1.467	1.307	1.211	1.165	0.997	0.721	0.644	0.438	0.314
10	BALANCE 3 [W2=W1-Ot']	W2	27.293	89.472	121.414	145.195	129.398	119.933	115.315	98.728	71.421	63.764	43.324	31.103
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	8.827	51.381	99.954	121.847	113.827	116.122	99.347	71.775	62.570	41.613	28.327	27.992
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	14	57	105	127	119	121	105	77	68	47	34	33

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1979-80

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	33.342	38.731	30.491	79.741	83.347	134.433	146.600	129.901	102.077	92.622	71.417	57.886
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	7.166	7.697	6.884	11.626	11.962	16.569	17.626	16.172	13.684	12.819	10.844	9.557
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	24.380	30.490	71.680	27.980	68.120	25.160	0.690	0.380	0.370	1.840	2.150	9.000
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	57.721	69.220	102.170	107.719	151.465	159.591	147.288	130.279	102.445	94.460	73.565	66.886
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	52.371	63.870	96.820	102.369	146.115	154.241	141.938	124.929	97.095	89.110	68.215	61.536
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.524	0.639	0.968	1.024	1.461	1.542	1.419	1.249	0.971	0.891	0.682	0.615
10	BALANCE 3 [W2=W1-Ot']	W2	51.848	63.231	95.852	101.345	144.654	152.699	140.519	123.679	96.124	88.219	67.533	60.921
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	33.381	25.141	74.391	77.997	129.083	148.887	124.551	96.727	87.272	66.067	52.536	57.810
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	7.637	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	39	30	80	83	134	147	130	102	93	71	58	63

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1980-81

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	63.160	72.151	43.924	78.220	146.600	146.600	146.600	146.018	120.844	113.241	97.107	88.893
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	10.061	10.913	8.205	11.483	17.626	17.626	17.626	17.576	15.371	14.692	13.231	12.476
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	28.320	10.640	56.710	152.840	51.150	10.690	16.970	3.220	2.430	7.170	7.780	7.580
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	91.479	82.789	100.633	231.058	197.748	157.288	163.568	149.236	123.272	120.409	104.885	96.473
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	86.129	77.439	95.283	225.708	192.398	151.938	158.218	143.886	117.922	115.059	99.535	91.123
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.861	0.774	0.953	2.257	1.924	1.519	1.582	1.439	1.179	1.151	0.995	0.911
10	BALANCE 3 [W2=W1-Ot']	W2	85.268	76.665	94.330	223.451	190.474	150.419	156.636	142.447	116.743	113.909	98.540	90.212
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	66.801	38.574	72.870	200.103	174.903	146.607	140.668	115.494	107.891	91.757	83.543	87.101
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	58.853	33.653	5.357	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	72	44	78	147	147	147	146	121	113	97	89	92

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1981-82

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	92.451	103.960	109.758	146.600	146.600	140.514	138.408	123.939	99.263	92.054	75.409	67.412
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	12.804	13.855	14.379	17.626	17.626	17.099	16.916	15.646	13.428	12.767	11.220	10.465
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	31.160	45.330	62.480	60.660	11.010	3.090	2.860	3.500	2.610	6.440	7.780	7.580
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	123.609	149.288	172.236	207.258	157.608	143.602	141.266	127.437	101.871	98.492	83.187	74.992
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	118.259	143.938	166.886	201.908	152.258	138.252	135.916	122.087	96.521	93.142	77.837	69.642
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	1.183	1.439	1.669	2.019	1.523	1.383	1.359	1.221	0.965	0.931	0.778	0.696
10	BALANCE 3 [W2=W1-Ot']	W2	117.076	142.498	165.217	199.889	150.735	136.869	134.557	120.866	95.556	92.211	77.059	68.945
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	98.610	104.408	143.756	176.541	135.164	133.058	118.589	93.913	86.704	70.059	62.062	65.835
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	2.506	35.291	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	**104**	**110**	**147**	**147**	**141**	**138**	**124**	**99**	**92**	**75**	**67**	**71**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1982-83

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	71.185	80.500	55.704	48.689	43.043	42.864	42.161	28.468	5.350	5.350	5.350	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	10.822	11.696	9.347	8.669	8.119	8.102	8.033	6.683	4.350	4.350	4.350	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	28.730	14.190	15.100	18.320	15.930	3.520	2.670	1.610	2.350	5.860	8.660	9.650
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	99.913	94.688	70.803	67.008	58.972	46.383	44.830	30.077	7.699	11.209	14.009	15.000
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	94.563	89.338	65.453	61.658	53.622	41.033	39.480	24.727	2.349	5.859	8.659	9.650
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.946	0.893	0.655	0.617	0.536	0.410	0.395	0.247	0.023	0.059	0.087	0.097
10	BALANCE 3 [W2=W1-Ot']	W2	93.617	88.445	64.799	61.041	53.086	40.623	39.086	24.479	2.326	5.800	8.572	9.554
11	Irrigation demand / Dependable flow	O_{idt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	24.479	2.326	5.800	8.572	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.473	6.526	16.351	6.424	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	75.150	50.354	43.339	37.693	37.514	36.811	23.118	0.000	0.000	0.000	0.000	6.443
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	81	56	49	43	43	42	28	5	5	5	5	12

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1983-84

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	11.793	17.149	5.350	14.470	30.501	90.699	89.507	75.537	50.424	43.883	28.443	21.105
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	5.007	5.549	4.350	5.278	6.885	12.642	12.532	11.232	8.837	8.201	6.680	5.947
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	24.130	19.830	30.890	39.870	76.790	3.510	2.870	2.570	2.790	7.170	7.970	8.920
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	35.922	36.978	36.239	54.339	107.290	94.207	92.375	78.105	53.213	51.052	36.412	30.025
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	30.572	31.628	30.889	48.989	101.940	88.857	87.025	72.755	47.863	45.702	31.062	24.675
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.306	0.316	0.309	0.490	1.019	0.889	0.870	0.728	0.479	0.457	0.311	0.247
10	BALANCE 3 [W2=W1-Ot']	W2	30.266	31.312	30.580	48.499	100.920	87.968	86.155	72.027	47.385	45.245	30.752	24.428
11	Irrigation demand / Dependable flow	Oid_t	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	31.312	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	6.778	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	11.799	0.000	9.120	25.151	85.349	84.157	70.187	45.074	38.533	23.093	15.755	21.317
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	**17**	**5**	**14**	**31**	**91**	**90**	**76**	**50**	**44**	**28**	**21**	**27**

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1984-85

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	26.667	32.043	5.585	27.443	14.526	38.986	37.877	23.741	5.350	5.350	5.350	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	6.503	7.037	4.374	6.581	5.284	7.722	7.613	6.211	4.350	4.350	4.350	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	24.300	12.020	43.760	10.760	40.530	3.070	2.180	3.160	2.430	6.450	6.790	9.650
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	50.966	44.062	49.344	38.202	55.055	42.055	40.056	26.900	7.779	11.799	12.139	15.000
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	45.616	38.712	43.994	32.852	49.705	36.705	34.706	21.550	2.429	6.449	6.789	9.650
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.456	0.387	0.440	0.329	0.497	0.367	0.347	0.215	0.024	0.064	0.068	0.097
10	BALANCE 3 [W2=W1-Ot']	W2	45.160	38.325	43.554	32.524	49.208	36.338	34.359	21.334	2.405	6.385	6.721	9.554
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	21.334	2.405	6.385	6.721	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.619	6.447	15.767	8.276	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	26.693	0.235	22.093	9.176	33.636	32.527	18.391	0.000	0.000	0.000	0.000	6.443
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	32	6	27	15	39	38	24	5	5	5	5	12

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1985-86

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	11.793	9.368	6.312	34.727	35.102	69.068	67.102	52.872	28.631	22.624	7.397	5.350
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	5.007	4.760	4.448	7.303	7.340	10.622	10.436	9.074	6.699	6.099	4.559	4.350
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	
5	River Inflow (in MCM)	It	16.270	35.430	50.390	24.260	50.340	2.510	2.380	3.220	3.110	7.170	9.630	11.050
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	28.062	44.797	56.701	58.986	85.441	71.576	69.481	56.091	31.740	29.793	17.026	16.400
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	22.712	39.447	51.351	53.636	80.091	66.226	64.131	50.741	26.390	24.443	11.676	11.050
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.227	0.394	0.514	0.536	0.801	0.662	0.641	0.507	0.264	0.244	0.117	0.111
10	BALANCE 3 [W2=W1-Ot']	W2	22.484	39.053	50.837	53.100	79.290	65.564	63.490	50.234	26.126	24.199	11.559	10.940
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	11.559	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.437	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	4.018	0.962	29.377	29.752	63.718	61.752	47.522	23.281	17.274	2.047	0.000	7.829
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	9	6	35	35	69	67	53	29	23	7	5	13

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1986-87

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	$St_{\_1}$	13.179	12.780	5.350	53.228	54.794	96.424	95.175	81.168	55.039	48.273	32.948	26.406
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	5.147	5.107	4.350	9.108	9.259	13.168	13.054	11.759	9.283	8.629	7.127	6.477
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	18.330	24.320	70.040	25.650	58.280	3.510	2.890	1.600	2.610	7.330	8.820	9.610
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	31.508	37.099	75.389	78.877	113.073	99.932	98.063	82.766	57.648	55.602	41.767	36.016
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	26.158	31.749	70.039	73.527	107.723	94.582	92.713	77.416	52.298	50.252	36.417	30.666
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.262	0.317	0.700	0.735	1.077	0.946	0.927	0.774	0.523	0.503	0.364	0.307
10	BALANCE 3 [W2=W1-Ot']	W2	25.896	31.431	69.339	72.792	106.646	93.636	91.786	76.642	51.775	49.750	36.053	30.359
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	31.431	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	6.660	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	7.430	0.000	47.878	49.444	91.074	89.825	75.818	49.689	42.923	27.598	21.056	27.248
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	13	5	53	55	96	95	81	55	48	33	26	33

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1987-88

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	32.598	33.589	39.963	41.817	55.961	69.948	104.099	96.131	69.713	63.414	46.135	37.868
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	7.092	7.190	7.818	8.000	9.372	10.705	13.868	13.141	10.683	10.085	8.421	7.612
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	
5	River Inflow (in MCM)	I_t	19.930	45.200	23.900	38.240	30.370	39.000	9.080	1.460	3.230	5.510	7.210	7.590
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	52.527	78.788	63.862	80.056	86.330	108.946	113.177	97.589	72.941	68.923	53.344	45.458
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	47.177	73.438	58.512	74.706	80.980	103.596	107.827	92.239	67.591	63.573	47.994	40.108
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.472	0.734	0.585	0.747	0.810	1.036	1.078	0.922	0.676	0.636	0.480	0.401
10	BALANCE 3 [W2=W1-Ot']	W2	46.706	72.704	57.927	73.959	80.170	102.560	106.749	91.316	66.915	62.937	47.514	39.706
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	28.239	34.613	36.467	50.611	64.598	98.749	90.781	64.363	58.064	40.785	32.518	36.596
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	34	40	42	56	70	104	96	70	63	46	38	42

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1988-89

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	S_{t_1}	41.946	30.597	6.301	5.350	75.051	101.638	102.415	87.148	63.582	57.523	36.453	51.646
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	8.012	6.894	4.447	4.350	11.186	13.644	13.715	12.314	10.101	9.522	7.473	8.956
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	
5	River Inflow (in MCM)	I_t	7.560	14.190	10.940	93.990	43.290	5.610	1.690	4.250	3.410	1.620	30.810	6.150
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	49.505	44.786	17.240	99.339	118.339	107.246	104.103	91.396	66.991	59.142	67.262	57.796
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W_1	44.155	39.436	11.890	93.989	112.989	101.896	98.753	86.046	61.641	53.792	61.912	52.446
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.442	0.394	0.119	0.940	1.130	1.019	0.988	0.860	0.616	0.538	0.619	0.524
10	BALANCE 3 [W2=W1-Ot']	W2	43.713	39.041	11.771	93.049	111.859	100.877	97.766	85.185	61.025	53.254	61.293	51.921
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	11.771	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	D_{ef}	0.000	0.000	9.690	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	25.247	0.951	0.000	69.701	96.288	97.065	81.798	58.232	52.173	31.103	46.296	48.810
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	31	6	5	75	102	102	87	64	58	36	52	54

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1989-90

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	54.160	75.112	84.267	107.368	109.589	102.685	107.610	99.062	73.813	67.057	50.168	42.632
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	9.198	11.192	12.047	14.164	14.364	13.739	14.185	13.409	11.070	10.431	8.813	8.079
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	
5	River Inflow (in MCM)	It	40.310	48.430	45.810	26.860	9.810	9.810	8.530	2.670	2.810	5.940	7.990	39.300
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	94.469	123.540	130.075	134.226	119.397	112.493	116.138	101.730	76.621	72.996	58.157	81.932
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	89.119	118.190	124.725	128.876	114.047	107.143	110.788	96.380	71.271	67.646	52.807	76.582
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	0.891	1.182	1.247	1.289	1.140	1.071	1.108	0.964	0.713	0.676	0.528	0.766
10	BALANCE 3 [W2=W1-Ot']	W2	88.228	117.008	123.478	127.587	112.906	106.072	109.680	95.416	70.559	66.970	52.279	75.816
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	69.762	78.917	102.018	104.239	97.335	102.260	93.712	68.463	61.707	44.818	37.282	72.705
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	75	84	107	110	103	108	99	74	67	50	43	78

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1990-91

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	78.055	86.164	63.440	146.600	146.600	146.600	146.600	146.600	125.994	118.181	97.444	83.801
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	At	11.468	12.223	10.088	17.626	17.626	17.626	17.626	17.626	15.828	15.134	13.262	12.004
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	Elt	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	It	27.580	16.340	123.940	72.620	175.230	390.130	19.420	7.840	2.270	2.570	2.300	176.310
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W0	105.633	102.502	187.379	219.218	321.828	536.728	166.018	154.438	128.262	120.749	99.742	260.111
7	Dead Storage	Yd	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Yd]	W1	100.283	97.152	182.029	213.868	316.478	531.378	160.668	149.088	122.912	115.399	94.392	254.761
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	1.003	0.972	1.820	2.139	3.165	5.314	1.607	1.491	1.229	1.154	0.944	2.548
10	BALANCE 3 [W2=W1-Ot']	W2	99.280	96.180	180.209	211.729	313.313	526.064	159.061	147.597	121.683	114.245	93.448	252.213
11	Irrigation demand / Dependable flow	Oidt	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	80.814	58.090	158.748	188.381	297.742	522.253	143.093	120.644	112.831	92.094	78.451	249.102
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	0.000	17.498	47.131	156.492	381.003	1.843	0.000	0.000	0.000	0.000	107.852
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	St	86	63	147	147	147	147	147	126	118	97	84	147

WORKING TABLE FOR RESERVOIR OPERATION FOR THE YEAR 1991-92

1	Time, t (in month)		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
2	Opening Balance (in MCM)	St_1	146.600	137.629	146.600	131.487	146.600	146.600	146.600	134.712	121.046	117.411	103.681	93.440
3	Water spread (in m2) [At=3.8003+0.10304*St_1-0.000063885*St_1^2+0.0000000295399*St_1^3]	A_t	17.626	16.848	17.626	16.311	17.626	17.626	17.626	16.594	15.389	15.065	13.830	12.895
4	Evaporation (in MCM) [Elt=At*Evapo rate from Table.3]	El_t	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
5	River Inflow (in MCM)	I_t	11.020	89.240	7.840	85.020	53.080	17.050	5.550	14.730	6.440	9.640	5.800	3.360
6	NET WATER AVAILABILITY [W0=St_1-Elt-It]	W_0	157.618	226.867	154.438	216.505	199.678	163.648	152.148	149.440	127.484	127.049	109.479	96.800
7	Dead Storage	Y_d	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350	5.350
8	BALANCE 2 [W1=W0-Y_d]	W_1	152.268	221.517	149.088	211.155	194.328	158.298	146.798	144.090	122.134	121.699	104.129	91.450
9	Release to the natural Channel [Ot'=0.01*W1]	Ot'	1.523	2.215	1.491	2.112	1.943	1.583	1.468	1.441	1.221	1.217	1.041	0.915
10	BALANCE 3 [W2=W_1-Ot']	W2	150.745	219.302	147.597	209.043	192.385	156.715	145.330	142.649	120.913	120.482	103.087	90.536
11	Irrigation demand / Dependable flow	Oi_{dt}	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
12	Actual Irrigation release [Oiat=min(Oit,W2)]	Oiat	18.467	38.091	21.460	23.348	15.571	3.812	15.968	26.953	8.852	22.152	14.997	3.111
13	Deficit	Def	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	BALANCE 4 [W3=W2-Oiat]	W3	132.279	181.211	126.137	185.695	176.813	152.903	129.362	115.696	112.061	98.331	88.090	87.425
15	Reservoir capacity (MCM)		141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250	141.250
16	Reservoir Spill		0.000	39.961	0.000	44.445	35.563	11.653	0.000	0.000	0.000	0.000	0.000	0.000
17	CLOSING BALANCE BALANCE 5 [W4=W3-d17+d8]	S_t	138	147	131	147	147	147	135	121	117	104	93	93

APPENDIX C:

%%MATLAB PROGRAM FOR RESERVOIR OPERATION%%%%%

```
f1 = fopen('river3.IN','r');
f2 = fopen('river3.OUT','w');
re_cap = fscanf(f1,'%f',1);
de_sto = fscanf(f1,'%f',1);
for j = 1:12
     ev_rate(1,j) = fscanf(f1,'%f',1);
end
for j = 1:12
     Ir_mdem(1,j) = fscanf(f1,'%f',1);
end
for k = 1:42
for j = 1:12
     In_flow(k,j) = fscanf(f1,'%f',1);
end
end
m=0;
 s_t(1,1) = 0;
 for k = 1:42
for i = 1:12

    At(k,i) = 3.8003 + 0.10304*s_t(k,i) -
0.000063885*(s_t(k,i)^2) + 0.0000000295399*(s_t(k,i)^3);
```

```
    E_t1(k,i) = At(k,i) * ev_rate(1,i);
    w0(k,i) = s_t(k,i) - E_t1(k,i) + In_flow(k,i);
    w1(k,i) = w0(k,i) - de_sto;
    ot(k,i) = 0.01 * w1(k,i);
    bal(k,i) = w1(k,i) - ot(k,i);
    Ir_rel(k,i) = min(bal(k,i),Ir_mdem(1,i));
    if de_sto > w0(k,i)
        Ir_rel(k,i) = 0;
    end
    bal1(k,i) = bal(k,i) - Ir_rel(k,i);
    def(k,i) = Ir_mdem(1,i) - Ir_rel(k,i);
    if def(k,i) >0
        m=m+1;


    end
    if (bal1(k,i) > re_cap)
        re_spl(k,i) = bal1(k,i) - re_cap;
    else
        re_spl(k,i) = 0;
    end
    s_t(k,i+1) = bal1(k,i) - re_spl(k,i) + de_sto;

end
fprintf(f2,'\ndeficits in year\t%f\tare\t%f\t\n',k,m);
m=0;
```

```
s_t(k+1,1) = s_t(k,i+1);
end
count =zeros(1,12);
    for i = 1:12
        for j =1:42
            x(1,i) = sum(def(:,i));

            if def(j,i)>0
                count(1,i)=count(1,i)+1;
                avg(1,i) = x(1,i)/count(1,i);
            end
        end
    end
    for k = 1:12
        d=max(avg);
        e=min(avg);
        if avg(1,k) == d

            fprintf(f2,'\nMaximum deficit is in\t%fth\tmonth
and value is\t%f\n',k,d);

        end
        if avg(1,k)==e
            fprintf(f2,'\nMinimum deficit is in\t%fth\tmonth
and value is\t%f\n',k,e);
        end
```

```
    end
   count1 =zeros(1,12);
    for i = 1:12
        for j =1:42
            x1(1,i) = sum(re_spl(:,i));

            if re_spl(j,i)>0
                count1(1,i)=count1(1,i)+1;
                avg1(1,i) = x1(1,i)/count1(1,i);
            end
        end
    end
    for k = 1:12
        d1=max(avg1);
        e1=min(avg1);
        if avg1(1,k) == d1

            fprintf(f2,'\nMaximum spill is in\t%fth\tmonth
and value is\t%f\n',k,d1);

        end
        if avg1(1,k)==e1
            fprintf(f2,'\nMinimum spill is in\t%fth\tmonth
and value is\t%f\n',k,e1);
        end
    end
```

```
 for k = 1:42
     fprintf(f1,'\n\tYear\t\t\t',k);

fprintf(f2,'\nMonth\tEv_rate\t\tIn_flow\t\t\tRelease\t\tSpil
l\t\tBalance\tDeficit\n');
for j = 1:12

    fprintf(f2,'\n%d\t%f\t%f\t%f\t',j,ev_rate(j));
    fprintf(f2,'%f\t\t%f\t',In_flow(k,j),Ir_rel(k,j));

fprintf(f2,'%f\t%f\t%f\t\n',re_spl(k,j),s_t(k,j+1),def(k,j));
end
 end
```

ANNXURE D: %%RESULTS OF THE MATLAB PROGRAM%%

```
Deficits in year  1.000000   are   0.000000
Deficits in year  2.000000   are   0.000000
Deficits in year  3.000000   are   0.000000
Deficits in year  4.000000   are   0.000000
Deficits in year  5.000000   are   0.000000
Deficits in year  6.000000   are   0.000000
Deficits in year  7.000000   are   0.000000
Deficits in year  8.000000   are   3.000000
Deficits in year  9.000000   are   1.000000
Deficits in year  10.000000  are   0.000000
Deficits in year  11.000000  are   0.000000
Deficits in year  12.000000  are   0.000000
Deficits in year  13.000000  are   0.000000
Deficits in year  14.000000  are   0.000000
Deficits in year  15.000000  are   0.000000
Deficits in year  16.000000  are   0.000000
Deficits in year  17.000000  are   1.000000
Deficits in year  18.000000  are   4.000000
```

```
Deficits in year  19.000000   are   10.000000
Deficits in year  20.000000   are   0.000000
Deficits in year  21.000000   are   2.000000
Deficits in year  22.000000   are   2.000000
Deficits in year  23.000000   are   0.000000
Deficits in year  24.000000   are   3.000000
Deficits in year  25.000000   are   5.000000
Deficits in year  26.000000   are   0.000000
Deficits in year  27.000000   are   0.000000
Deficits in year  28.000000   are   4.000000
Deficits in year  29.000000   are   0.000000
Deficits in year  30.000000   are   0.000000
Deficits in year  31.000000   are   0.000000
Deficits in year  32.000000   are   0.000000
Deficits in year  33.000000   are   4.000000
Deficits in year  34.000000   are   1.000000
Deficits in year  35.000000   are   5.000000
Deficits in year  36.000000   are   3.000000
Deficits in year  37.000000   are   1.000000
```

```
Deficits in year  38.000000   are   0.000000

Deficits in year  39.000000   are   2.000000

Deficits in year  40.000000   are   0.000000

Deficits in year  41.000000   are   0.000000

Deficits in year  42.000000   are   0.000000

Minimum deficit is in   6.000000th  month and value is      0.000000

Maximum deficit is in   8.000000th  month and value is      18.639770

Minimum spill is in     1.000000th  month and value is      0.000000

Minimum spill is in     8.000000th  month and value is      0.000000

Minimum spill is in     9.000000th  month and value is      0.000000

Minimum spill is in     10.000000th month and value is      0.000000

Minimum spill is in     11.000000th month and value is      0.000000

Maximum spill is in     12.000000th month and value is      97.291081
```

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	51.870000	18.467000	0.000000	32.407316	0.000000
2	0.118000	63.290000	38.091000	0.000000	55.876521	0.000000
3	0.098000	72.270000	21.460000	0.000000	104.550108	0.000000
4	0.096000	46.290000	23.348000	0.000000	124.715335	0.000000
5	0.092000	32.270000	15.571000	0.000000	138.466695	0.000000
6	0.082000	4.110000	3.811600	0.000000	136.019144	0.000000
7	0.080000	0.970000	15.967900	0.000000	118.381571	0.000000
8	0.094000	0.560000	26.952900	0.000000	89.442705	0.000000
9	0.124000	0.380000	8.851700	0.000000	78.588521	0.000000
10	0.155000	0.470000	22.151700	0.000000	54.402324	0.000000
11	0.189000	0.600000	14.996800	0.000000	37.783548	0.000000
12	0.228000	0.620000	3.110900	0.000000	33.245758	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	17.890000	18.467000	0.000000	31.211936	0.000000
2	0.118000	64.740000	38.091000	0.000000	56.142429	0.000000
3	0.098000	143.530000	21.460000	28.758276	146.600000	0.000000
4	0.096000	73.870000	23.348000	46.695621	146.600000	0.000000
5	0.092000	44.530000	15.571000	25.495820	146.600000	0.000000

6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	14.300000	18.467000	0.000000	34.426027	0.000000
2	0.118000	105.230000	38.091000	0.000000	99.372329	0.000000
3	0.098000	46.830000	21.460000	0.000000	122.030075	0.000000
4	0.096000	168.950000	23.348000	116.704875	146.600000	0.000000
5	0.092000	98.040000	15.571000	78.470720	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000

12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	35.920000	18.467000	0.000000	55.829827	0.000000
2	0.118000	47.770000	38.091000	0.000000	63.433008	0.000000
3	0.098000	103.980000	21.460000	0.000000	143.353745	0.000000
4	0.096000	97.660000	23.348000	67.060578	146.600000	0.000000
5	0.092000	35.650000	15.571000	16.704620	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	22.650000	18.467000	0.000000	42.692527	0.000000
2	0.118000	30.790000	38.091000	0.000000	33.765689	0.000000
3	0.098000	125.770000	21.460000	0.000000	135.834530	0.000000
4	0.096000	97.820000	23.348000	59.837079	146.600000	0.000000

5	0.092000	84.800000	15.571000	65.363120	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	28.620000	18.467000	0.000000	48.602827	0.000000
2	0.118000	38.070000	38.091000	0.000000	46.756842	0.000000
3	0.098000	90.290000	21.460000	0.000000	113.447001	0.000000
4	0.096000	92.740000	23.348000	32.832517	146.600000	0.000000
5	0.092000	15.170000	15.571000	0.000000	143.029420	0.000000
6	0.082000	4.110000	3.811600	0.000000	140.504086	0.000000
7	0.080000	0.970000	15.967900	0.000000	122.790736	0.000000
8	0.094000	0.560000	26.952900	0.000000	93.771293	0.000000
9	0.124000	0.380000	8.851700	0.000000	82.824894	0.000000
10	0.155000	0.470000	22.151700	0.000000	58.535678	0.000000

11	0.189000	0.600000	14.996800	0.000000	41.801239	0.000000
12	0.228000	0.620000	3.110900	0.000000	37.134312	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	40.980000	18.467000	0.000000	57.867155	0.000000
2	0.118000	79.790000	38.091000	0.000000	97.126900	0.000000
3	0.098000	74.750000	21.460000	0.867799	146.600000	0.000000
4	0.096000	80.220000	23.348000	52.982121	146.600000	0.000000
5	0.092000	12.330000	15.571000	0.000000	140.217820	0.000000
6	0.082000	4.110000	3.811600	0.000000	137.740396	0.000000
7	0.080000	0.970000	15.967900	0.000000	120.073721	0.000000
8	0.094000	0.560000	26.952900	0.000000	91.103909	0.000000
9	0.124000	0.380000	8.851700	0.000000	80.214305	0.000000
10	0.155000	0.470000	22.151700	0.000000	55.988535	0.000000
11	0.189000	0.600000	14.996800	0.000000	39.325328	0.000000
12	0.228000	0.620000	3.110900	0.000000	34.737930	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	38.250000	18.467000	0.000000	52.825007	0.000000
2	0.118000	20.310000	38.091000	0.000000	33.306662	0.000000
3	0.098000	75.380000	21.460000	0.000000	85.498395	0.000000

4	0.096000	18.130000	23.348000	0.000000	78.141780	0.000000
5	0.092000	11.480000	15.571000	0.000000	72.162825	0.000000
6	0.082000	4.110000	3.811600	0.000000	70.865968	0.000000
7	0.080000	0.970000	15.967900	0.000000	54.348481	0.000000
8	0.094000	0.560000	26.952900	0.000000	26.602317	0.000000
9	0.124000	0.380000	8.851700	0.000000	17.116753	0.000000
10	0.155000	0.470000	11.263437	0.000000	5.350000	10.888263
11	0.189000	0.600000	0.000000	0.000000	5.130120	14.996800
12	0.228000	0.620000	0.000000	0.000000	4.769377	3.110900
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	15.490000	14.161402	0.000000	5.350000	4.305598
2	0.118000	54.800000	38.091000	0.000000	21.002863	0.000000
3	0.098000	85.320000	21.460000	0.000000	83.277173	0.000000
4	0.096000	127.580000	23.348000	37.717880	146.600000	0.000000
5	0.092000	16.720000	15.571000	0.000000	144.563920	0.000000
6	0.082000	4.110000	3.811600	0.000000	142.012465	0.000000
7	0.080000	0.970000	15.967900	0.000000	124.273667	0.000000
8	0.094000	0.560000	26.952900	0.000000	95.227167	0.000000
9	0.124000	0.380000	8.851700	0.000000	84.249810	0.000000

10	0.155000	0.470000	22.151700	0.000000	59.926013	0.000000
11	0.189000	0.600000	14.996800	0.000000	43.152754	0.000000
12	0.228000	0.620000	3.110900	0.000000	38.442484	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	42.490000	18.467000	0.000000	60.639188	0.000000
2	0.118000	61.840000	38.091000	0.000000	82.069697	0.000000
3	0.098000	74.760000	21.460000	0.000000	132.705911	0.000000
4	0.096000	46.650000	23.348000	6.107459	146.600000	0.000000
5	0.092000	91.290000	15.571000	71.788220	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	23.340000	18.467000	0.000000	43.375627	0.000000
2	0.118000	42.190000	38.091000	0.000000	45.720161	0.000000

3	0.098000	75.380000	21.460000	0.000000	97.669575	0.000000
4	0.096000	78.590000	23.348000	3.340132	146.600000	0.000000
5	0.092000	83.100000	15.571000	63.680120	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	36.880000	18.467000	0.000000	56.780227	0.000000
2	0.118000	89.740000	38.091000	0.000000	105.913532	0.000000
3	0.098000	83.530000	21.460000	18.181203	146.600000	0.000000
4	0.096000	97.100000	23.348000	69.693321	146.600000	0.000000
5	0.092000	16.760000	15.571000	0.000000	144.603520	0.000000
6	0.082000	4.110000	3.811600	0.000000	142.051392	0.000000
7	0.080000	0.970000	15.967900	0.000000	124.311937	0.000000
8	0.094000	0.560000	26.952900	0.000000	95.264739	0.000000

9	0.124000	0.380000	8.851700	0.000000	84.286583	0.000000
10	0.155000	0.470000	22.151700	0.000000	59.961895	0.000000
11	0.189000	0.600000	14.996800	0.000000	43.187634	0.000000
12	0.228000	0.620000	3.110900	0.000000	38.476246	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	28.890000	18.467000	0.000000	47.208150	0.000000
2	0.118000	39.530000	38.091000	0.000000	46.837336	0.000000
3	0.098000	121.100000	21.460000	0.000000	144.027830	0.000000
4	0.096000	31.770000	23.348000	2.491280	146.600000	0.000000
5	0.092000	65.420000	15.571000	46.176920	146.600000	0.000000
6	0.082000	4.110000	3.811600	0.000000	144.013918	0.000000
7	0.080000	0.970000	15.967900	0.000000	126.241381	0.000000
8	0.094000	0.560000	26.952900	0.000000	97.159011	0.000000
9	0.124000	0.380000	8.851700	0.000000	86.140620	0.000000
10	0.155000	0.470000	22.151700	0.000000	61.770990	0.000000
11	0.189000	0.600000	14.996800	0.000000	44.946281	0.000000
12	0.228000	0.620000	3.110900	0.000000	40.178571	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	30.150000	18.467000	0.000000	50.117527	0.000000

2	0.118000	42.800000	38.091000	0.000000	52.921940	0.000000
3	0.098000	102.530000	21.460000	0.000000	131.610093	0.000000
4	0.096000	29.850000	23.348000	0.000000	134.999732	0.000000
5	0.092000	72.570000	15.571000	41.862872	146.600000	0.000000
6	0.082000	12.940000	3.811600	6.155618	146.600000	0.000000
7	0.080000	2.680000	15.967900	0.000000	130.476817	0.000000
8	0.094000	1.030000	26.952900	0.000000	101.782669	0.000000
9	0.124000	0.640000	8.851700	0.000000	90.923671	0.000000
10	0.155000	1.040000	22.151700	0.000000	67.002677	0.000000
11	0.189000	1.050000	14.996800	0.000000	50.477978	0.000000
12	0.228000	0.610000	3.110900	0.000000	45.523753	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	16.950000	18.467000	0.000000	42.268339	0.000000
2	0.118000	48.000000	38.091000	0.000000	50.388488	0.000000
3	0.098000	95.660000	21.460000	0.000000	122.324438	0.000000
4	0.096000	62.860000	23.348000	11.964712	146.600000	0.000000
5	0.092000	62.850000	15.571000	43.632620	146.600000	0.000000
6	0.082000	21.570000	3.811600	14.699318	146.600000	0.000000
7	0.080000	2.050000	15.967900	0.000000	129.853117	0.000000

8	0.094000	1.040000	26.952900	0.000000	101.180208	0.000000
9	0.124000	0.720000	8.851700	0.000000	90.413165	0.000000
10	0.155000	0.380000	22.151700	0.000000	65.851096	0.000000
11	0.189000	0.970000	14.996800	0.000000	49.279171	0.000000
12	0.228000	1.960000	3.110900	0.000000	45.699651	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	4.970000	18.467000	0.000000	30.579888	0.000000
2	0.118000	57.370000	38.091000	0.000000	48.227724	0.000000
3	0.098000	52.460000	21.460000	0.000000	77.437606	0.000000
4	0.096000	56.860000	23.348000	0.000000	108.575715	0.000000
5	0.092000	45.900000	15.571000	0.000000	136.113506	0.000000
6	0.082000	1.820000	3.811600	0.000000	131.439039	0.000000
7	0.080000	0.820000	15.967900	0.000000	113.730521	0.000000
8	0.094000	1.060000	26.952900	0.000000	85.371863	0.000000
9	0.124000	0.640000	8.851700	0.000000	74.862038	0.000000
10	0.155000	1.260000	22.151700	0.000000	51.548819	0.000000
11	0.189000	0.520000	14.996800	0.000000	34.930912	0.000000
12	0.228000	0.520000	3.110900	0.000000	30.386080	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	21.580000	18.467000	0.000000	32.073500	0.000000
2	0.118000	41.750000	38.091000	0.000000	34.225304	0.000000
3	0.098000	56.490000	21.460000	0.000000	67.697943	0.000000
4	0.096000	51.300000	23.348000	0.000000	93.516278	0.000000
5	0.092000	11.970000	15.571000	0.000000	87.738830	0.000000
6	0.082000	15.300000	3.811600	0.000000	97.246221	0.000000
7	0.080000	2.510000	15.967900	0.000000	81.795368	0.000000
8	0.094000	1.080000	26.952900	0.000000	54.047502	0.000000
9	0.124000	0.310000	8.851700	0.000000	43.887882	0.000000
10	0.155000	0.220000	22.151700	0.000000	20.310013	0.000000
11	0.189000	1.460000	14.996800	0.000000	5.511250	0.000000
12	0.228000	1.580000	0.738289	0.000000	5.350000	2.372611

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	34.270000	18.467000	0.000000	20.203120	0.000000
2	0.118000	45.690000	38.091000	0.000000	26.512568	0.000000
3	0.098000	65.830000	21.460000	0.000000	69.383196	0.000000
4	0.096000	12.690000	23.348000	0.000000	56.945610	0.000000
5	0.092000	16.550000	15.571000	0.000000	56.380967	0.000000

6	0.082000	1.900000	3.811600	0.000000	53.175990	0.000000
7	0.080000	1.170000	15.967900	0.000000	37.167145	0.000000
8	0.094000	1.260000	26.952900	0.000000	10.441497	0.000000
9	0.124000	0.360000	4.799232	0.000000	5.350000	4.052468
10	0.155000	5.070000	4.351832	0.000000	5.350000	17.799868
11	0.189000	0.480000	0.000000	0.000000	5.011320	14.996800
12	0.228000	0.620000	0.000000	0.000000	4.654510	3.110900

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	9.580000	8.198427	0.000000	5.350000	10.268573
2	0.118000	21.070000	20.351163	0.000000	5.350000	17.739837
3	0.098000	23.550000	21.460000	0.000000	6.782488	0.000000
4	0.096000	11.600000	12.474841	0.000000	5.350000	10.873159
5	0.092000	8.250000	7.771326	0.000000	5.350000	7.799674
6	0.082000	4.410000	3.811600	0.000000	5.551188	0.000000
7	0.080000	3.300000	3.120046	0.000000	5.350000	12.847854
8	0.094000	0.560000	0.149613	0.000000	5.350000	26.803287
9	0.124000	0.390000	0.000000	0.000000	5.202126	8.851700
10	0.155000	0.400000	0.000000	0.000000	4.934460	22.151700
11	0.189000	0.600000	0.000000	0.000000	4.726696	14.996800

12	0.228000	0.610000	0.000000	0.000000	4.369413	3.110900

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	31.150000	18.467000	0.000000	16.157558	0.000000
2	0.118000	95.650000	38.091000	0.000000	72.015474	0.000000
3	0.098000	49.590000	21.460000	0.000000	97.925354	0.000000
4	0.096000	86.580000	23.348000	11.501232	146.600000	0.000000
5	0.092000	4.260000	15.571000	0.000000	132.228520	0.000000
6	0.082000	13.650000	3.811600	0.000000	139.332196	0.000000
7	0.080000	5.170000	15.967900	0.000000	125.796630	0.000000
8	0.094000	3.600000	26.952900	0.000000	99.731965	0.000000
9	0.124000	1.070000	8.851700	0.000000	89.342100	0.000000
10	0.155000	0.970000	22.151700	0.000000	65.390007	0.000000
11	0.189000	0.600000	14.996800	0.000000	48.464592	0.000000
12	0.228000	0.620000	3.110900	0.000000	43.584455	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	20.850000	18.467000	0.000000	44.235835	0.000000
2	0.118000	37.560000	38.091000	0.000000	41.978258	0.000000
3	0.098000	59.880000	21.460000	0.000000	78.655526	0.000000
4	0.096000	21.590000	23.348000	0.000000	74.853320	0.000000

5	0.092000	27.870000	15.571000	0.000000	85.161439	0.000000
6	0.082000	4.110000	3.811600	0.000000	83.635891	0.000000
7	0.080000	3.710000	15.967900	0.000000	69.608539	0.000000
8	0.094000	3.680000	26.952900	0.000000	44.663007	0.000000
9	0.124000	2.590000	8.851700	0.000000	36.966122	0.000000
10	0.155000	3.910000	22.151700	0.000000	17.214683	0.000000
11	0.189000	1.570000	12.260880	0.000000	5.350000	2.735920
12	0.228000	2.240000	1.235777	0.000000	5.350000	1.875123
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	16.520000	15.747620	0.000000	5.350000	2.719380
2	0.118000	11.160000	10.540263	0.000000	5.350000	27.550737
3	0.098000	92.580000	21.460000	0.000000	75.122188	0.000000
4	0.096000	58.280000	23.348000	0.000000	107.709894	0.000000
5	0.092000	65.900000	15.571000	8.463462	146.600000	0.000000
6	0.082000	4.830000	3.811600	0.000000	144.726718	0.000000
7	0.080000	3.970000	15.967900	0.000000	129.912173	0.000000
8	0.094000	2.000000	26.952900	0.000000	102.188590	0.000000
9	0.124000	1.520000	8.851700	0.000000	92.192202	0.000000
10	0.155000	0.580000	22.151700	0.000000	67.785197	0.000000

11	0.189000	2.710000	14.996800	0.000000	52.882188	0.000000
12	0.228000	1.920000	3.110900	0.000000	49.148359	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	35.620000	18.467000	0.000000	64.290825	0.000000
2	0.118000	10.430000	38.091000	0.000000	34.748218	0.000000
3	0.098000	42.300000	21.460000	0.000000	54.162519	0.000000
4	0.096000	49.640000	23.348000	0.000000	78.595769	0.000000
5	0.092000	73.700000	15.571000	0.000000	134.206205	0.000000
6	0.082000	4.110000	3.811600	0.000000	131.831442	0.000000
7	0.080000	0.970000	15.967900	0.000000	114.264773	0.000000
8	0.094000	0.560000	26.952900	0.000000	85.401316	0.000000
9	0.124000	0.380000	8.851700	0.000000	74.633461	0.000000
10	0.155000	0.470000	22.151700	0.000000	50.543725	0.000000
11	0.189000	6.000000	14.996800	0.000000	39.379263	0.000000
12	0.228000	0.620000	3.110900	0.000000	34.790131	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	3.870000	18.467000	0.000000	18.839767	0.000000
2	0.118000	38.960000	38.091000	0.000000	18.516167	0.000000
3	0.098000	41.590000	21.460000	0.000000	37.546902	0.000000

4	0.096000	48.920000	23.348000	0.000000	61.587270	0.000000
5	0.092000	29.880000	15.571000	0.000000	74.132418	0.000000
6	0.082000	4.110000	3.811600	0.000000	72.800808	0.000000
7	0.080000	0.970000	15.967900	0.000000	56.249519	0.000000
8	0.094000	0.560000	26.952900	0.000000	28.467318	0.000000
9	0.124000	0.380000	8.851700	0.000000	18.940303	0.000000
10	0.155000	0.470000	13.040556	0.000000	5.350000	9.111144
11	0.189000	0.600000	0.000000	0.000000	5.130120	14.996800
12	0.228000	0.620000	0.000000	0.000000	4.769377	3.110900
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	7.890000	6.637402	0.000000	5.350000	11.829598
2	0.118000	7.600000	7.015863	0.000000	5.350000	31.075137
3	0.098000	11.980000	11.438188	0.000000	5.350000	10.021812
4	0.096000	38.620000	23.348000	0.000000	19.822401	0.000000
5	0.092000	86.550000	15.571000	0.000000	89.261280	0.000000
6	0.082000	1.810000	3.811600	0.000000	85.386923	0.000000
7	0.080000	0.970000	15.967900	0.000000	68.616580	0.000000
8	0.094000	1.030000	26.952900	0.000000	41.066204	0.000000
9	0.124000	0.490000	8.851700	0.000000	31.369438	0.000000

10	0.155000	1.310000	22.151700	0.000000	9.184797	0.000000
11	0.189000	1.350000	4.245797	0.000000	5.350000	10.751003
12	0.228000	1.310000	0.315077	0.000000	5.350000	2.795823

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	31.750000	18.467000	0.000000	17.708320	0.000000
2	0.118000	33.260000	38.091000	0.000000	11.766349	0.000000
3	0.098000	51.490000	21.460000	0.000000	40.731807	0.000000
4	0.096000	92.170000	23.348000	0.000000	107.528108	0.000000
5	0.092000	48.160000	15.571000	0.000000	137.322389	0.000000
6	0.082000	7.710000	3.811600	0.000000	138.458372	0.000000
7	0.080000	1.690000	15.967900	0.000000	121.492366	0.000000
8	0.094000	0.550000	26.952900	0.000000	92.486731	0.000000
9	0.124000	0.650000	8.851700	0.000000	81.834971	0.000000
10	0.155000	1.250000	22.151700	0.000000	58.342000	0.000000
11	0.189000	1.070000	14.996800	0.000000	42.078273	0.000000
12	0.228000	2.040000	3.110900	0.000000	38.808257	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	1.920000	18.467000	0.000000	20.831987	0.000000
2	0.118000	61.840000	38.091000	0.000000	43.116267	0.000000

3	0.098000	114.860000	21.460000	0.000000	134.201561	0.000000
4	0.096000	28.960000	23.348000	0.000000	136.662604	0.000000
5	0.092000	22.860000	15.571000	0.000000	140.882990	0.000000
6	0.082000	2.160000	3.811600	0.000000	136.463725	0.000000
7	0.080000	0.530000	15.967900	0.000000	118.383033	0.000000
8	0.094000	1.090000	26.952900	0.000000	89.968841	0.000000
9	0.124000	0.640000	8.851700	0.000000	79.360835	0.000000
10	0.155000	0.470000	22.151700	0.000000	55.155833	0.000000
11	0.189000	0.950000	14.996800	0.000000	38.862444	0.000000
12	0.228000	1.330000	3.110900	0.000000	34.992833	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	1.270000	18.467000	0.000000	16.463649	0.000000
2	0.118000	12.550000	22.786894	0.000000	5.350000	15.304106
3	0.098000	46.130000	21.460000	0.000000	29.136688	0.000000
4	0.096000	56.450000	23.348000	0.000000	60.794893	0.000000
5	0.092000	2.720000	15.571000	0.000000	46.466461	0.000000
6	0.082000	18.110000	3.811600	0.000000	59.486363	0.000000
7	0.080000	2.160000	15.967900	0.000000	44.346473	0.000000
8	0.094000	0.260000	26.952900	0.000000	16.493570	0.000000

9	0.124000	0.150000	8.851700	0.000000	7.005897	0.000000
10	0.155000	0.610000	1.549787	0.000000	5.350000	20.601913
11	0.189000	0.510000	0.000000	0.000000	5.041020	14.996800
12	0.228000	0.720000	0.000000	0.000000	4.782227	3.110900

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	27.570000	18.467000	0.000000	13.016140	0.000000
2	0.118000	81.550000	38.091000	0.000000	54.983607	0.000000
3	0.098000	71.260000	21.460000	0.000000	102.674560	0.000000
4	0.096000	46.710000	23.348000	0.000000	123.290518	0.000000
5	0.092000	8.860000	15.571000	0.000000	113.891719	0.000000
6	0.082000	7.320000	3.811600	0.000000	115.044043	0.000000
7	0.080000	0.360000	15.967900	0.000000	97.159174	0.000000
8	0.094000	0.380000	26.952900	0.000000	68.432677	0.000000
9	0.124000	0.370000	8.851700	0.000000	58.019872	0.000000
10	0.155000	1.840000	22.151700	0.000000	35.694652	0.000000
11	0.189000	2.150000	14.996800	0.000000	21.138624	0.000000
12	0.228000	3.090000	3.110900	0.000000	19.585868	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	24.380000	18.467000	0.000000	24.303905	0.000000

2	0.118000	30.490000	38.091000	0.000000	15.476324	0.000000
3	0.098000	71.680000	21.460000	0.000000	64.356314	0.000000
4	0.096000	27.980000	23.348000	0.000000	67.151433	0.000000
5	0.092000	68.120000	15.571000	0.000000	117.450302	0.000000
6	0.082000	25.160000	3.811600	0.000000	136.202800	0.000000
7	0.080000	0.690000	15.967900	0.000000	118.284921	0.000000
8	0.094000	0.380000	26.952900	0.000000	89.169624	0.000000
9	0.124000	0.370000	8.851700	0.000000	78.311366	0.000000
10	0.155000	1.840000	22.151700	0.000000	55.488219	0.000000
11	0.189000	2.150000	14.996800	0.000000	40.373520	0.000000
12	0.228000	9.000000	3.110900	0.000000	44.048633	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	28.320000	18.467000	0.000000	52.084346	0.000000
2	0.118000	10.640000	38.091000	0.000000	23.008463	0.000000
3	0.098000	56.710000	21.460000	0.000000	56.919306	0.000000
4	0.096000	152.840000	23.348000	36.867779	146.600000	0.000000
5	0.092000	51.150000	15.571000	32.049620	146.600000	0.000000
6	0.082000	10.690000	3.811600	3.928118	146.600000	0.000000
7	0.080000	16.970000	15.967900	0.000000	144.623917	0.000000

8	0.094000	3.220000	26.952900	0.000000	117.841671	0.000000
9	0.124000	2.430000	8.851700	0.000000	108.416600	0.000000
10	0.155000	7.170000	22.151700	0.000000	90.144601	0.000000
11	0.189000	7.780000	14.996800	0.000000	79.646096	0.000000
12	0.228000	7.580000	3.110900	0.000000	80.674313	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	31.160000	18.467000	0.000000	90.667493	0.000000
2	0.118000	45.330000	38.091000	0.000000	95.123469	0.000000
3	0.098000	62.480000	21.460000	0.000000	133.354902	0.000000
4	0.096000	60.660000	23.348000	20.614456	146.600000	0.000000
5	0.092000	11.010000	15.571000	0.000000	138.911020	0.000000
6	0.082000	3.090000	3.811600	0.000000	135.446086	0.000000
7	0.080000	2.860000	15.967900	0.000000	119.689307	0.000000
8	0.094000	3.500000	26.952900	0.000000	93.637123	0.000000
9	0.124000	2.610000	8.851700	0.000000	84.901279	0.000000
10	0.155000	6.440000	22.151700	0.000000	66.471983	0.000000
11	0.189000	7.780000	14.996800	0.000000	56.624716	0.000000
12	0.228000	7.580000	3.110900	0.000000	58.375502	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	28.730000	18.467000	0.000000	66.480396	0.000000
2	0.118000	14.190000	38.091000	0.000000	40.613978	0.000000
3	0.098000	15.100000	21.460000	0.000000	32.985649	0.000000
4	0.096000	18.320000	23.348000	0.000000	26.820392	0.000000
5	0.092000	15.930000	15.571000	0.000000	26.211684	0.000000
6	0.082000	3.520000	3.811600	0.000000	25.152024	0.000000
7	0.080000	2.670000	15.967900	0.000000	11.126323	0.000000
8	0.094000	1.610000	6.852847	0.000000	5.350000	20.100053
9	0.124000	2.350000	1.792526	0.000000	5.350000	7.059174
10	0.155000	5.860000	5.133932	0.000000	5.350000	17.017768
11	0.189000	8.660000	7.759520	0.000000	5.350000	7.237280
12	0.228000	9.650000	3.110900	0.000000	10.810777	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	24.130000	18.467000	0.000000	15.492927	0.000000
2	0.118000	19.830000	29.044535	0.000000	5.350000	9.046465
3	0.098000	30.890000	21.460000	0.000000	14.049088	0.000000
4	0.096000	39.870000	23.348000	0.000000	29.587826	0.000000
5	0.092000	76.790000	15.571000	0.000000	89.177762	0.000000

6	0.082000	3.510000	3.811600	0.000000	86.987866	0.000000
7	0.080000	2.870000	15.967900	0.000000	72.070762	0.000000
8	0.094000	2.570000	26.952900	0.000000	45.980071	0.000000
9	0.124000	2.790000	8.851700	0.000000	38.452262	0.000000
10	0.155000	7.170000	22.151700	0.000000	21.890933	0.000000
11	0.189000	7.970000	14.996800	0.000000	13.491567	0.000000
12	0.228000	8.920000	3.110900	0.000000	17.961066	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	24.300000	18.467000	0.000000	22.638984	0.000000
2	0.118000	12.020000	28.303220	0.000000	5.350000	9.787780
3	0.098000	43.760000	21.460000	0.000000	26.790388	0.000000
4	0.096000	10.760000	23.348000	0.000000	13.261151	0.000000
5	0.092000	40.530000	15.571000	0.000000	37.266171	0.000000
6	0.082000	3.070000	3.811600	0.000000	35.561556	0.000000
7	0.080000	2.180000	15.967900	0.000000	20.864840	0.000000
8	0.094000	3.160000	17.936928	0.000000	5.350000	9.015972
9	0.124000	2.430000	1.871726	0.000000	5.350000	6.979974
10	0.155000	6.450000	5.718032	0.000000	5.350000	16.433668
11	0.189000	6.790000	5.908220	0.000000	5.350000	9.088580

12	0.228000	9.650000	3.110900	0.000000	10.810777	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	16.270000	18.467000	0.000000	7.711527	0.000000
2	0.118000	35.430000	36.877278	0.000000	5.350000	1.213722
3	0.098000	50.390000	21.460000	0.000000	33.354088	0.000000
4	0.096000	24.260000	23.348000	0.000000	33.062283	0.000000
5	0.092000	50.340000	15.571000	0.000000	66.400607	0.000000
6	0.082000	2.510000	3.811600	0.000000	63.621629	0.000000
7	0.080000	2.380000	15.967900	0.000000	48.626906	0.000000
8	0.094000	3.220000	26.952900	0.000000	23.622844	0.000000
9	0.124000	3.110000	8.851700	0.000000	16.906309	0.000000
10	0.155000	7.170000	17.691356	0.000000	5.350000	4.460344
11	0.189000	9.630000	8.719820	0.000000	5.350000	6.276980
12	0.228000	11.050000	3.110900	0.000000	12.196777	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	18.330000	18.467000	0.000000	11.103414	0.000000
2	0.118000	24.320000	29.195991	0.000000	5.350000	8.895009
3	0.098000	70.040000	21.460000	0.000000	52.807588	0.000000
4	0.096000	25.650000	23.348000	0.000000	53.516709	0.000000

5	0.092000	58.280000	15.571000	0.000000	94.329115	0.000000
6	0.082000	3.510000	3.811600	0.000000	92.049207	0.000000
7	0.080000	2.890000	15.967900	0.000000	77.064285	0.000000
8	0.094000	1.600000	26.952900	0.000000	49.919674	0.000000
9	0.124000	2.610000	8.851700	0.000000	42.127301	0.000000
10	0.155000	7.330000	22.151700	0.000000	25.632335	0.000000
11	0.189000	8.820000	14.996800	0.000000	17.967012	0.000000
12	0.228000	9.610000	3.110900	0.000000	22.972774	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	19.930000	18.467000	0.000000	23.203993	0.000000
2	0.118000	45.200000	38.091000	0.000000	28.963168	0.000000
3	0.098000	23.900000	21.460000	0.000000	30.274918	0.000000
4	0.096000	38.240000	23.348000	0.000000	43.883096	0.000000
5	0.092000	30.370000	15.571000	0.000000	57.246073	0.000000
6	0.082000	39.000000	3.811600	0.000000	90.754699	0.000000
7	0.080000	9.080000	15.967900	0.000000	81.920265	0.000000
8	0.094000	1.460000	26.952900	0.000000	54.546267	0.000000
9	0.124000	3.230000	8.851700	0.000000	47.266559	0.000000
10	0.155000	5.510000	22.151700	0.000000	28.841505	0.000000

11	0.189000	7.210000	14.996800	0.000000	19.490368	0.000000
12	0.228000	7.590000	3.110900	0.000000	22.446478	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	7.560000	18.467000	0.000000	10.444021	0.000000
2	0.118000	14.190000	18.522323	0.000000	5.350000	19.568677
3	0.098000	10.940000	10.408588	0.000000	5.350000	11.051412
4	0.096000	93.990000	23.348000	0.000000	74.638701	0.000000
5	0.092000	43.290000	15.571000	0.000000	100.216603	0.000000
6	0.082000	5.610000	3.811600	0.000000	99.913112	0.000000
7	0.080000	1.690000	15.967900	0.000000	83.604505	0.000000
8	0.094000	4.250000	26.952900	0.000000	58.961177	0.000000
9	0.124000	3.410000	8.851700	0.000000	51.763449	0.000000
10	0.155000	1.620000	22.151700	0.000000	29.375440	0.000000
11	0.189000	30.810000	14.996800	0.000000	43.373033	0.000000
12	0.228000	6.150000	3.110900	0.000000	44.130404	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	40.310000	18.467000	0.000000	64.034286	0.000000
2	0.118000	48.430000	38.091000	0.000000	72.117098	0.000000
3	0.098000	45.810000	21.460000	0.000000	94.282833	0.000000

4	0.096000	26.860000	23.348000	0.000000	95.404039	0.000000
5	0.092000	9.810000	15.571000	0.000000	87.453536	0.000000
6	0.082000	9.810000	3.811600	0.000000	91.530822	0.000000
7	0.080000	8.530000	15.967900	0.000000	82.138464	0.000000
8	0.094000	2.670000	26.952900	0.000000	55.958293	0.000000
9	0.124000	2.810000	8.851700	0.000000	48.231980	0.000000
10	0.155000	5.940000	22.151700	0.000000	30.208582	0.000000
11	0.189000	7.990000	14.996800	0.000000	21.590562	0.000000
12	0.228000	39.300000	3.110900	0.000000	55.870950	0.000000
Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	27.580000	18.467000	0.000000	62.895963	0.000000
2	0.118000	16.340000	38.091000	0.000000	39.233730	0.000000
3	0.098000	123.940000	21.460000	0.000000	139.383937	0.000000
4	0.096000	72.620000	23.348000	38.373598	146.600000	0.000000
5	0.092000	175.230000	15.571000	154.888820	146.600000	0.000000
6	0.082000	390.130000	3.811600	379.573718	146.600000	0.000000
7	0.080000	19.420000	15.967900	0.449417	146.600000	0.000000
8	0.094000	7.840000	26.952900	0.000000	124.355920	0.000000
9	0.124000	2.270000	8.851700	0.000000	114.636241	0.000000

10	0.155000	2.570000	22.151700	0.000000	91.662252	0.000000
11	0.189000	2.300000	14.996800	0.000000	75.697200	0.000000
12	0.228000	176.310000	3.110900	97.291081	146.600000	0.000000

Month	Ev_rate	In_flow	Release	Spill	Balance	Deficit
1	0.141000	11.020000	18.467000	0.000000	135.169880	0.000000
2	0.118000	89.240000	38.091000	35.585107	146.600000	0.000000
3	0.098000	7.840000	21.460000	0.000000	129.779021	0.000000
4	0.096000	85.020000	23.348000	41.220560	146.600000	0.000000
5	0.092000	53.080000	15.571000	33.960320	146.600000	0.000000
6	0.082000	17.050000	3.811600	10.224518	146.600000	0.000000
7	0.080000	5.550000	15.967900	0.000000	133.318117	0.000000
8	0.094000	14.730000	26.952900	0.000000	118.135359	0.000000
9	0.124000	6.440000	8.851700	0.000000	112.674035	0.000000
10	0.155000	9.640000	22.151700	0.000000	96.745966	0.000000
11	0.189000	5.800000	14.996800	0.000000	84.107765	0.000000
12	0.228000	3.360000	3.110900	0.000000	80.819732	0.000000