USER MANUAL

UM-46

A MODEL FOR SIMULATION OF MULTIRESERVOIR SYSTEM FOR CONSERVATION OPERATION

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PREFACE

With high time and space variability of rainfall in this country, efficient regulation of reservoirs have become an important aspect of planning and management of water resources. India is bestowed with rich water resources and to harness this water during monsoon, more than 3000 reservoirs have been constructed. A reservoir is constructed to store water for meeting future conservation demands and for moderating flows during the monsoon season. In India, major conservation demands are irrigation, water supply for domestic and industrial use, hydropower generation and minimum flow requirements in the downstream reach.

In the present study, a model has been developed to simulate the operation of a multipurpose multireservoir system for conservation purposes. Rule curves based approach has been adopted for operation. The model operates the system in accordance with the trial policy and carries out the reliability analysis. Using the detailed operation table, the policy can be refined.

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ABSTRACT

Because of high temporal and spatial variability of rainfall in the country, it is essential to utilize the available water resources in the optimal manner. Judicious reservoir operation is an important aspect for this purpose. Reservoirs are constructed to serve for conservation and flood control requirements. In India, reservoirs are operated to serve various conservation purposes like irrigation, hydropower generation, domestic and industrial supply and minimum flow requirements in the downstream reach.

The present report describes a software which has been developed for simulating the operation of a multireservoir system for various conservation purposes for each reservoir. An operation policy in the form of different rule levels in different months is input to the model. The model simuiates the system in accordance with the given rule curves and performs the reliability analysis. Detailed operation tables are also prepared for each structure which can be used to systematically modify the rule curves till the optimum result is achieved.

The report describes the approach used in the software and how to prepare the input data for a particular system. The various variables used in the program are also explained. A listing of a sample input data file for a multireservoir system along with the corresponding output file is included in the report. A listing of the program has also been included.

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CHAPTER - 1
INTRODUCTION

1.1 GENERAL

India is bestowed with rich water resources but more than 80% of the rainfall over this country falls in the four monsoon months from June to September. The average annual rainfall of the country is 119 mm. Because of high temporal and spatial variability of rainfall, many dams have been constructed all over the country for use of the available water resources.

Reservoirs are important components of water resources projects. A reservoir is created by constructing a dam across a stream. The principal function of a reservoir is regulation of natural streamflow. This is achieved by storing surplus water in the high flow season and releasing the stored water in the dry season to supplement the natural stream flow. Moreover, the stored water can be diverted to far away places by means of pipes or canals resulting in spatial changes.

1.2 CLASSIFICATION OF RESERVOIRS

Various classifications of the reservoirs are possible depending upon the purposes of the reservoir, the size of the reservoir and the storage space available in the reservoir. Briefly these are:

a. Classification based upon the purposes

Depending upon the number of purposes that a reservoir serves, a reservoir may be classified as a single purpose reservoir or a multipurpose reservoir.

A single purpose reservoir serves only one purpose. This purpose may be either a conservation purpose like water supply for domestic & industrial purposes, irrigation, navigation, generation of hydroelectric power, and recreation, or flood control which is a nonconservation purpose. A multipurpose reservoir serves a combination of the above purposes. It may also serve the conflicting purposes of conservation and flood control.

b. Classification based upon size

Depending upon the size of a reservoir, reservoirs are classified as major, medium or minor. According to the CWC norms, if the gross capacity and the hydraulic head of the reservoir exceed 60 mcm and 30 m respectively, the reservoir is classified as major reservoir. If gross capacity lies between 10 and 60 mcm and the hydraulic head lies between 12 and 30 m, a reservoir is classified as medium reservoir. Minor reservoirs have gross capacity less than 10 mcm and hydraulic head less than 12 m.

c. Classifications based upon storage

Based on the storage space provided in a reservoir, a reservoir may be classified as a seasonal storage reservoir or overyear storage reservoir.

A seasonal storage reservoir is a reservoir designed to serve conservation purposes for a limited period of low flows. These reservoirs fill and spill frequently and are constructed on small tributaries to serve relatively smaller area. An overyear storage reservoir is designed to serve for periods exceeding more than a water year. The storage in an overyear storage reservoir at the end of a water year is carried over to the next year. These reservoirs may neither fill nor become dry every year.

1.3 RESERVOIR OPERATION PROBLEM

The efficient use of water resources requires not only judicious design but also proper management after construction. Once a reservoir comes into being, the benefits depend, to a large extent, upon how well it is managed. The conservation demands are best served when the reservoir is full at the end of the filling period. The flood control purpose, on the other hand, requires empty storage space so that the incoming floods get absorbed and moderated to permissible limits. The conflict between the storage space requirements is resolved through proper operation of reservoirs.

A reservoir operation policy specifies the releases as a function of the current state of the reservoir, time, the size of current and near-term demands and the likely inflows. The releases must be in conformity with the stated objectives. A full reservoir is needed to maximize returns from conservation uses while an empty reservoir gives maximum benefits from flood control. The operation policy should optimally resolve the conflicts among the various purposes.

1.3.1 Characteristics and Requirements of Water Uses

The complexity of the problem of reservoir operation depends upon the extent to which the various purposes which a reservoir is supposed to serve are compatible. The characteristics of various conservation requirements from a reservoir are briefly described below:

(a) 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 and a small fraction of the water supplied for irrigation is available to the system as return flow. These requirements have direct correlation with the rainfall in the command area.

(b) Hydroelectric Power

The hydroelectric power demands usually vary seasonally and to a lesser extent, daily and hourly too. The degree of fluctuation depends upon the type of load being served, viz., industrial, municipal and agricultural. The hydroelectric power demand is a nonconsumptive use of water.

(c) Municipal and Industrial Water Supply

Generally, the water requirements for municipal and industrial purposes are quite constant throughout the year, more so when compared with the requirements for irrigation and hydroelectric power. The water requirements increase from year to year due to growth and expansion. The seasonal demand peak is observed in summer. The supply system for such purposes is designed for very high level of reliability.

(d) Miscellaneous

Sometimes, storage reservoirs are designed to make a river-reach navigable by maintaining sufficient depth of flow. Navigation demands show marked seasonal variation and depend on the type and volume of traffic. From environmental considerations, it is also sometimes desirable to maintain some minimum flow in the downstream channel.

1.3.2 Conflicts in Reservoir Operation

While operating a reservoir which serves for more than one purpose, conflicts arise among the demands of various purposes. The conflicts that arise in a multipurpose reservoir are: a) conflict in space, b) conflict in time, and c) conflict in discharge.

Conflicts in space occur when a reservoir is required to satisfy divergent purposes like water conservation and flood control. The temporal conflicts occur when the use pattern of water varies with purpose and release for one purpose does not match with the other purpose. Conflicts for discharge are experienced in reservoirs serving for consumptive use and hydropower generation such that release for the two purposes may vary considerably within a day.

1.4 TECHNIQUES OF RESERVOIR OPERATION

A reservoir is operated according to a set of rules for storing and releasing water to achieve the stated objectives. The release decisions in different periods must be according to the water in storage and demands.

For reservoirs designed for multiannual storage, the operation policy is based on long term targets. The estimates of water availability are made using long term data and the various conservation demands are worked out by projecting the demand figures. Water is allocated among various consumptive uses and in the period of drought, based on pre-specified priorities, the supply for some uses is curtailed keeping in view the bare minimum demands of each purpose. The maintenance of essential services should be given due consideration even if it is at the cost of agriculture and industrial production. If power generation is one of the purposes of the reservoir, then releases for consumptive uses are routed through the power house to generate the required energy.

The operation policy for seasonal storage reservoirs is determined based on yearly operation. Reservoir operation study is carried out for long term record considering the demand estimates for various conservation uses. Policy decisions are arrived at introducing the reliability concepts. If necessary, allocation for some purposes can be curtailed, based on priority.

Some of the conventional techniques for reservoir operation are standard linear operation policy, rule curves and storage zoning. All these policies have some advantage and disadvantage. In the present study, the rule curve approach has been adopted for operation of reservoirs for conservation purposes.

A rule curve specifies the storage or empty space to be maintained in a reservoir during different times of the year. The rule curve as such does not give the amount of water to be released from the reservoir. The rule curves reflect the long-term trade-off among the various project objectives. These curves are derived through operation studies using historic or generated flows. Often, different rule curves are followed in different circumstances to provide flexibility in operation.

System engineering is concerned with decision making for the systems on which controls can be applied to best obtain the objectives, subject to social, political, financial and other constraints. Two techniques of system engineering that are most commonly used for solving various reservoir operation problems are simulation and optimization.

Simulation is the process of designing a computerized model of a system and conducting experiments for understanding/evaluating system. The essence of simulation is to reproduce the behaviour of a system. It allows for controlled experimentation on the problem without causing any disturbance to the real system. However, simulation analysis does not yield an immediate optimal answer and requires iterations to arrive at the optimum solution.

In the present study, a model for simulating the operation of a multipurpose multireservoir system has been developed. The reservoir operation is simulated for the specified period using the rule curves. The various conservation purposes which have been considered in the model are: water supply for domestic and industrial purposes, irrigation, hydropower generation, and minimum flow in the river reach downstream of a reservoir. The model can help in finalizing the rule curves for each storage location in a multiple reservoirs/weirs system to optimally use the water resources.

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CHAPTER - 2

METHODOLOGY ADOPTED FOR CONSERVATION OPERATION

2.1 MODELS USED FOR RESERVOIR OPERATION

Since it is not possible to do experiment with the real system, models of a system are developed. Experiments can be conducted using these model to provide insight into the problem. For reservoir operation, the model studies bring into focus certain aspects of operation which serves to improve the manager's ability to manage system wisely. The various categories of models which are used for reservoir management problems are: optimization models and simulation models. The ultimate goal of all such models is to improve the system operation, directly or indirectly.

In the present study, a model to simulate the operation of a multipurpose multireservoir system has been developed. Simulation, in essence is to duplicate the system behaviour under given hydrologic and other input data. Though this approach is not useful for deriving any operation policy directly, it helps in policy evaluation. Much effort is needed to build generalized simulation models. It is a general opinion that simulation is the best approach for analyzing a complex water resources systems. With this view in mind, a generalized computer program for simulation of a multireservoir system, particularly useful in Indian conditions, has been developed. The model allows evaluation of reservoir operation policy through system reliability. Additionally, the model prepares detailed simulation tables which can be used to improve the trial policy. The concept of "Rule Curves" has been adopted in the model which is briefly described in the following section.

2.2 OPERATION OF RESERVOIRS USING RULE CURVES

The reservoirs are frequently operated using the rule curves. A rule curve or a rule level specifies the storage or empty space to be maintained in a reservoir during different times of the year. Here the assumption is that a reservoir can best satisfy its purposes if the storages specified by the rule curve are maintained at different times. The rule curve as such does not give the amount of water to be released from the reservoir. This amount will depend upon the inflows to the reservoir, the storage space available in the reservoir and the demands from the reservoir.

The rule curves are generally derived by operation studies using historic or generated flows. Often, due to various reasons viz. low inflows, minimum requirements for demands etc., it is not possible to maintain the reservoir levels according to the rule curves. However, it is possible to return to the rule levels in several ways. Some possibilities are: a) return to the rule curve by curtailing the release beyond the minimum required if the deviation is negative; b) make release more than the demand but less than the safe carrying capacity, if the deviation is positive. The operation of a reservoir by strictly following rule curves becomes quite rigid. Often, to provide flexibility in operation, different rule curves are followed in different circumstances.

2.3 METHODOLOGY ADOPTED IN THE PRESENT STUDY

In India, the reservoirs are constructed to serve conservation purposes like water supply for domestic and industrial use, irrigation and hydropower generation. Therefore, in the present model, three rule curve levels have been specified, namely the upper rule level, the middle rule level and the lower rule level.

a) Upper Rule Level

The upper rule level specifies the uppermost level up to which a reservoir should be filled if there is sufficient inflow to the reservoir. The upper rule level can be either FRL or a level below FRL. If the reservoir reaches this level then the demands for the remaining duration of that year are likely to be satisfied in full. If the level in the reservoir overtops the upper rule level, then water is spilled from the reservoir in the downstream river. Thus, it is the most desirable level and effort is made to maintain this level.

Though it is always desirable to fill a reservoir up to the maximum available capacity (up to FRL), it is recommended that some spill should be made from the reservoir to keep up the downstream river channel and to avoid encroachment in the river bed. Keeping the upper rule level below FRL can give extra room for flood absorption in the reservoir also. However, lowering the upper rule level below FRL should not affect the performance of the reservoir for conservation demands.

b) Middle Rule Level

The middle and lower rule levels are use in the situation when water is scarce and full supply for the various demands cannot be made. Supply for the various demands can be curtailed to some extent so that the partial demands can be satisfied for longer duration. The underlying assumption is that it would always be better to supply less water for longer duration rather than to meet free demand for some time and then stop the supply..

The middle rule level is critical for irrigation and power generation which are given low priority as compared to water supply and minimum flow requirements. If the water level in the reservoir is above the middle rule level, full supply of water is made for all the demands. However, if the water level in a reservoir falls below the middle rule level, based on relative priority, reduced supply is made either for irrigation or for hydropower generation. The release is made at the reduced rate so that the demands can be met for longer duration.

c) Lower Rule Level

The lower rule level is critical for water supply and minimum flow requirements in the downstream river. If the reservoir level falls below the lower rule level, then supply is made to meet full demands of water supply and minimum flow only. No water is released for irrigation or hydropower generation in this situation. If this water passes through the power plants, then some incidental hydropower may also get generated.

2.3.1 Release of Water for Various Demands

Based on the level of water in the reservoir corresponding to the three rule curve levels specified above, the operation policy adopted for satisfying various demands is described below.

a) Water Supply Demand

The highest priority is given to the water supply demand for domestic and industrial purposes. This demand is met in full as long as the water level in the reservoir is above the minimum drawdown level of water supply outlet.

b) Minimum Flow in Downstream Channel

This requirement is also given top priority along with the water supply demand. Attempt is made to meet this demand in the same manner as the water supply demand.

c) Hydropower Generation Demand

Hydropower generation demand is given in MW. The amount of water required to produce hydropower depends on the head of water available which keeps on changing. The amount of water required to produce desired demand of power is calculated based on the mean elevation of water during a period.

It is assumed that release for maintaining minimum flow will always pass through the power plant. Three ways in which release of water from the reservoir can pass/bypass the plant have been considered. First, all the supply of water from the reservoir is passed through the power plant. Second, only water supply release passes through the power plant and supply for irrigation bypasses the plant. Third, the supply for water supply bypasses the plant and irrigation supply passes through the plant. If the present location serves demand of any downstream location also, then supply for meeting such demand will also pass through the power plant.

At the time of water scarcity, the hydropower generation gets low priority as compared to water supply for domestic and industrial purposes and minimum flow requirements. For reservoir level above the middle rule level, based on the system of supply of water, total demand of water is worked out. Then water is released from the reservoir for meeting all the demands in full. However, for reservoir level below the middle rule level, based on the relative priority, curtailed release either for irrigation or for hydropower generation is made. It may happen that water is not released for power generation but some incidental power is generated if these releases pass through the power plant. At or below the lower rule level, water is supplied only for domestic and industrial purposes and for maintaining minimum flow. Based on the system configuration, some power may get generated in this case also.

d) Irrigation Demand

The demand for irrigation is given low priority as compared to the water supply and minimum flow demand. The priority between hydropower generation or irrigation is user specified and may change from one period to another. Like power, the demand for irrigation is met in full if the reservoir level is above the middle rule level. Below the middle rule level, curtailed supply for irrigation depends on the priority. Below the lower rule level, supply for irrigation is stopped completely.

Based on the methodology described above, a computer program has been developed which is described in the next chapter.

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CHAPTER - 3

DESCRIPTION OF THE SIMULATION MODEL

3.1 PURPOSE OF THE MODEL

The purpose of the model developed here is to simulate a multipurpose multireservoir system for conservation operation. The various conservation purposes considered in the model are water supply for domestic and industrial purposes, irrigation, hydropower generation and minimum flow in the downstream river channel. In a multireservoir system, the model can help in finalizing the optimum rule levels for each storage location.

For each storage location, the model operates the reservoir in accordance with the given trial rule curves (given for each reservoir) and carries out the reliability analysis. Correspondingly, it calculates the time and volume reliability of each reservoir for the given set of rule curve levels and for the given period of operation. Detailed simulation table is also prepared. Based on the observation from the simulation tables, trial rule curves are modified till optimum results are achieved.

3.2 DESCRIPTION OF THE VARIABLES

The description of the input variables used in the program is as follows:

titl	-	Title of the problem
nloc	-	Total number of control locations in the system
imon(1)	-	Initial month of operation
iyr(1)	-	Initial year of operation
nmon	-	Number of months of operation
ifmon	-	A factor for specifying length of a period (= 1 for monthly operation, = 3 for ten-daily operation)
fir	-	A factor for reducing demand of irrigation or hydropower in case of insufficient water
name	-	Name of location in alphanumeric
icp	-	Node Number of the control point

icp1	-	Number of control points immediately upstream of the present control point
icp2	-	Node number of icp1 control points upstream of the present control point
icon	-	A flag to specify the method of supply of water through the power plant
	-	= 0 -- no power plant,
	-	= 1 -- All release pass through plant,
	-	= 2 -- Irr. release bypasses the plant,
	-	= 3 -- WS release bypasses the plant.
etail	-	Tail water elevation (m)
plmin	-	Minimum level for power production (m)
pinst	-	Installed capacity of power plants (MW)
eff	-	Efficiency of the power plants
iprio	-	Priority index for irrigation & power
		= 0 if irrigation has higher priority,
		= 1 if power has higher priority)
pow	-	Hydropower demand for the period in MW
smax	-	Gross capacity up to FRL (m^3)
smin	-	Gross capacity up to intake of WS outlet (m^3)
stor(1)	-	Initial reservoir storage (m^3)
nn	-	Number of points in Elevation-Area-Capacity table, nn = 0 for non-reservoir locations like weirs,
idp	-	A factor controlling simulation table printing
		= 1 gives detailed simulation table in output file &
	-	= 0 detailed simulation table is not printed
elev	-	Elevation in E-A-C table (m)
area	-	Area at corresponding elev. in E-A-C table (sq.m)
cap	-	Capacity at corresponding elev. in E-A-C table (cu.m)
infl	-	A factor for reading/calculating local inflows
		= 1 if inflow data of present location is to be read
		= 2 if inflow data of present location is to be computed from the inflow data of some other location

fac	-	Multiplication factor to convert inflow data in m^3
inod	-	Node Number whose inflow data is to be used for computing inflow at the present location
iddp	-	Node number of downstream location whose partial demands are to be satisfied by present location
demd	-	Total demand for irrigation in Mm^3
wdmd	-	Total demand of water supply for domestic and industrial purposes in Mm^3
amflo	-	Minimum flow demands in downstream channel in Mm^3
rule	-	Upper rule levels (m)
ail	-	Middle rule levels critical for irrigation and hydropower demands (m)
wpl	-	Lower rule levels critical for ws and minimum flow demands (m)
evpd	-	Evaporation depth in meter/month

3.3 DATA REQUIREMENT OF THE MODEL

The data requirement of the model is quite modest and such type of data are generally available with the operating authorities at the dam sites. Some data pertain to the information about each structure viz. full reservoir level, dead storage level, elevation-area-capacity table, various demands from the reservoir like water supply for domestic and industrial purposes, irrigation, hydropower demands and minimum flow requirements in the downstream channel, evaporation depths and local inflow from the intermediate/free catchment area. If the concerned location is to meet some demands of a downstream structure also, then the number of the node whose demands are to be met and the % age of demands is also to be specified in the input data. Some data like defining the configuration of the system and the trial rule curve are specified by the user. Description for defining the configuration of the system is as follows:

3.3.1 Configuration of the System

It is generally a healthy practice to prepare the line diagram of the system under study. Line diagram should highlight the location of reservoir, diversion weirs/barrages and the location and direction of the connecting rivers and streams. For defining the system in the model, node numbers are required to be assigned to each structure starting from the upstream structure. The node numbers are assigned in numeric starting from 1. Take care such that all downstream structures should have node number higher to that of their upstream structures. The model recognizes each structure by its node number. Location of each structure is recognized from the node numbers of control points just upstream of the present location. In this way, the configuration of the system is read by the model. For each location, the model reads the name of the structure, its node number, number of nodes immediately upstream of the present node and their node numbers.

The model can be used for a system having any number of control points. If the number of control points in the system is larger than the dimensional limits specified, the parameter *l1* of the program should be increased.

For defining initial conditions at each location, data in the form such as initial year, initial month and initial storage in each storage location is specified. A factor for reducing irrigation or hydropower demands in case of scarcity of water is also to be specified in the input data.

For structures operated for hydropower generation, details regarding the method of water supply through the power plants, installed capacity of the plants, minimum level for power production, tail level elevation and efficiency of the plants are also to be specified. Three methods of supply of water through the power plant have been considered. In the first case, all the releases from the reservoir including irrigation and water supply for domestic and industrial purposes are routed through the power plant. In the second case, releases for irrigation bypass the power plant and the rest of release is passed through the power plant. In the third case, release for domestic and industrial purpose bypasses the power plant and rest of water supply passes through the plant. It has been assumed that release made for maintaining minimum flow for satisfying demands of any downstream structure always passes through the power plant. In addition, in case of deficiency of water in the reservoir, priority between irrigation or power is also to be specified for each period.

The model has been developed for simulating a system either for monthly operation or for ten-daily operation. In case of monthly operation, the various demands, evaporation depths, trial rule curves and local inflows are given at monthly interval. For ten-daily operation, all these are specified at an interval of ten days for one water year. A variable (IFMON) in the model defines whether operation is to be carried out monthly or ten-daily.

3.4 OUTPUT OF THE MODEL

The model simulates the operation of a system of reservoirs for the specified period. Based on the trial upper, middle and lower rule levels, it calculates the monthly time and volume reliability for each structure. In addition, it also calculates the total number of months of failure, irrigation or power failure and water supply failure. It also calculates the number of months when the release from the reservoir is less then 75 % of the total demands and thus calculates "Critical Failure" months.

In addition to calculating the reliability, a detailed operation table for each structure is optionally prepared. For each period, the table gives the year, month and period of operation, the initial storage, flow from intermediate catchment, evaporation, irrigation, water supply, hydropower and downstream demands, release made, power generated, spill from the structure, end level and middle and upper rule levels. Based on the observations from the tabular presentation, rule curve levels in particular period can be modified till the best operation performance is achieved.

3.4.1 Graphical Presentation

A module for analyzing the operation results in the graphical form has been added in the program. For each control point in the system, four types of graphs can be visualized. reservoir storage vs inflow and plot of demand vs release. Based on the visual inspection of results also (in addition to the tabular form), the trial policy can be revised and rules for better management of the system can be developed.

3.5 STEPS FOR MODEL APPLICATION

The recommended steps to be performed for applying this model to a system and for deriving the optimum rule curves are as follows:

1. Prepare the diagram of the system showing the name of reservoirs and diversion weirs/barrages, their location and the length and direction of the rivers and tributaries.

2. Give node numbers in numeric form to all the control points (storage reservoir, diversion weir, barrage etc.) starting from the upstream node. Take care to see that node number of a particular control point should always be higher than that of all the structures situated upstream.

3. Get general details about the operation like the number of control locations in the system, initial month, initial year, total number of periods of operation, whether operation is to be carried out monthly or ten-daily and reduction factor in case of scarcity of water.

4. Get general details about each location which include whether a location has power plant or not, if yes, then the mode of operation of the plant, tail water elevation, minimum level for power production, installed capacity of power plant, efficiency of the power plant, priority between irrigation and power in all periods of water year, power demands for all periods, maximum capacity up to the full reservoir level, capacity up to the intake of water supply outlet, initial storage, number of points in the elevation-area-capacity table, downstream location whose demand is to be satisfied and the percentage of demands to be satisfied, irrigation demands, water supply demands, minimum flow demands in the downstream channel and the evaporation depths in all the periods of the water year.

5. For each structure, calculate the local flow coming from the free catchment area at that structure for all the periods of operation. If inflow is to be obtained by multiplying the inflow data of some other structure by some number, then the node number whose data are to be used for calculation of local inflow at present structure and the multiplication factor needs to be mentioned in the data file.

6. Derive the initial trial upper, middle and lower rule levels. Prepare the data file, node-by-node for all the locations in the system. The data must be entered in correct units as specified.

7. Keep the upper rule level at FRL and the middle and lower rule level as derived and operate the system. Find the failure months and the months of critical failure. Adjust

the middle rule level such that failure months are reduced without increasing the number of critical failure months. The middle rule levels are modified till the required reliability is achieved without increasing the number of critical failure months.

8. After optimizing the middle rule curve levels, adjust the upper rule levels for all periods to obtain the required results.

3.6 DESCRIPTION OF THE PROGRAM

The present program has been written in the FORTRAN language. The program consists of a main program, one subroutine for simulation of operation of a structure (subroutine *OPER*) for a particular period, one subroutine (subroutine *RESULT*) for tabular presentation of the results and one subroutine for the graphical presentation of the results.

The entire input data are read by the main program. Several checks have been introduced in the read section to detect the likely errors while preparing the input data. Moreover, after reading a group of data items, the program displays a message on the screen showing that the corresponding data items have been read properly. This facility is immensely helpful in locating the possible error as the user knows that for which structure and at which group of data, the error is encountered. It may be mentioned that the program reads in the entire data for a structure at a time.

After reading the input data, the operation subroutine *OPER* is repeatedly called by the main program in a loop, first for each structure and then in another loop for each period. Once the simulation of operation for each structure is over, the subroutine *RESULT* is called by the main program and the results in tabular form are prepared in the output file. In this subroutine, some indices like the reliability for WS demand, irrigation demand and power demand, and the critical failure months for each structure are also calculated. These are presented on the screen after the location number and name of each structure and also in the output file after the simulation table of each structure.

After presenting the reliability of operation for a structure on the screen, the *GRAPHICS* subroutine is evoked by the main program. If the user wishes to visualize graphical presentation of the operation for that structure, he is asked to choose a graph and enter the corresponding code. After the presentation of that graph, another graph can be visualized by selecting the appropriate code. Based on the analysis of the graphical presentation or the simulation table, the rule curves can be revised till optimum performance of the system is achieved.

A function *FINT* has been used in the program for interpolating areas or capacities corresponding to a particular elevation or vice-versa. A listing of the computer program is given in Appendix-1.

3.7 SAMPLE INPUT FILE

A sample input file for the program is shown in appendices. The data for the Sabarmati river system in located in Gujarat has been used to prepare this file. For the convenience of the users, the input file is shown first, in the variable form in Appendix-2 and then, with actual values for the Sabarmati system in Appendix-3. The line diagram of the system has also been presented in Figure-1 and the representation of the system in nodel form is presented in Figure - 2.

The Sabarmati system consists of three dams, two weirs and one barrage in the Gujarat state. The main dam is the Dharoi dam on the river Sabarmati. Upstream of this dam, a tributary named Harnav joins in the submergence area of the dam. One dam, Harnav dam and one weir, Harnav weir have been constructed on this tributary. Downstream of Dharoi dam, Hathmati tributary joins the river Sabarmati. On this tributary, a dam named Hathmati dam and a weir named Hathmati weir have been constructed. Another tributary Guhai, joins the river Hathmati and a dam named Guhai dam has been constructed on this tributary also. Near Ahmedabad, a barrage, namely Wasna barrage has been constructed across the river Sabarmati. These are the major control points in the Sabarmati basin.

3.8 SAMPLE OUTPUT FILE

The output file for the Sabarmati system simulation corresponding to the input data file given in Appendix-3 is shown in the Appendix-4.

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$LARGE
C     SIMULATION OF A MULTIPURPOSE MULTIRESERVOIR SYSTEM FOR CONSERVATION
C     *******************************************************************
      INCLUDE 'FGRAPH.FI'
      INCLUDE 'FGRAPH.FD'
      RECORD / RCCOORD / CURPOS

      CHARACTER NAME*20, TITL*60, FILEI*15
      PARAMETER(L1=6,L2=300)

      COMMON/CONF/ICP(L1), ICP1(L1), ICP2(L1,L1), NAME(L1), ICON(L1),
     1   IPRIO(L1,36)

      COMMON/RES/SMAX(L1), SMIN(L1), NN(L1), ELEV(L1,50), RETF(L1),
     1   AREA(L1,50), CAP(L1,50), FAC(L1), IDDP(L1), DFC(L1), TREL(L1),
     2   TDEMD(L1), FIR, PLMIN(L1), ETAIL(L1), EFF(L1), PINST(L1),
     3   IFAIL(L1), IFAIW(L1), IFAIP(L1), IFAIC(L1), AMFLO(L1)

      COMMON/OP1/RULE(L1,36), EVPD(L1,36), DEMD(L1,36), AIL(L1,36),
     1   WPL(L1,36), WDMD(L1,36), POW(L1,36), TDDM(L1,36)

      COMMON/OP2/FLOW(L1,L2), STOR(L1,L2), REL(L1,L2), ELOS(L1,L2),
     1   RFLO(L1,L2), SPIL(L1,L2), PGEN(L1,L2), TDEM(L1,L2),ENDL(L1,L2),
     2   RELIR(L1,L2), RSPIL(L1,L2)

      COMMON/PRI/IYR(0:L2), IMON(0:L2), IDAY(0:L2), IDP(L1), NLOC,
     1   NMON, IFMON

      CALL CLEARSCREEN($GCLEARSCREEN)
      DUMMY4 = SETBKCOLOR( 2 )
      DUMMY2 = SETTEXTCOLOR( 11 )
      CALL SETTEXTPOSITION( 3, 12, CURPOS )
      CALL OUTTEXT(
     1 ' R E S E R V O I R    S Y S T E M    S I M U L A T I O N ')
      CALL SETTEXTPOSITION( 17, 19, CURPOS )
      CALL OUTTEXT(' NATIONAL INSTITUTE OF HYDROLOGY ')
      CALL SETTEXTPOSITION( 18, 27, CURPOS )
      CALL OUTTEXT(' ROORKEE  247 667 ')
      CALL SETTEXTPOSITION( 21, 26, CURPOS )
      CALL OUTTEXT(' VER 1.0, MARCH 1995 ')
      CALL SETTEXTPOSITION( 24, 3, CURPOS )
      CALL OUTTEXT(' HIT <ENTER> TO CONTINUE .... ')
      READ(*,*)
      DUMMY = SETVIDEOMODE( $DEFAULTMODE )

C***  INPUT AND OUTPUT FILENAMES
      WRITE(*,'(//'' INPUT FILENAME ? '',$)' )
25    READ 1, FILEI
      OPEN(1, FILE = FILEI, STATUS = 'OLD', IOSTAT=IOC)
       IF(IOC.NE.0) THEN
         WRITE(*,84) FILEI
         GO TO 25
       ENDIF
84    FORMAT(//' ** ERROR ACCESSING FILE  'A' RE-ENTER NAME : '$)

      WRITE(*,'(//'' OUTPUT FILENAME ? '',$)' )
      READ 1, FILEI
      OPEN(2, FILE = FILEI)
1       FORMAT(A)

C***  GENERAL INFORMATION OF THE SYSTEM
C***  TITL - TITLE; NLOC - NO. OF LOCATIONS; IMON(1) - INITIAL MONTH
C***  IYR(1) - INITIAL YEAR; NMON - NO. OF PERIODS, IFMON - A FACTOR
C***  (IFMON = 1 FOR MONTHLY AND IFMON = 3 FOR 10-DAILY OPERATION)
      READ (1,1) TITL
      WRITE(2,1) TITL
      READ(1,*) NLOC, IMON(1), IYR(1), NMON, IFMON, FIR
      I12 = 12
      IDAY(1) = 1
```

```
      IF(IFMON.EQ.3) THEN
        NMON = NMON * 3
        I12 = 36
      ENDIF

C***  INFORMATION PERTAINING TO EACH STRUCTURE
C***  NAME - NAME OF LOCATION; ICP(I) - NO. OF THE CONTROL POINT (CP);
C***  ICP1 - NO. OF POINTS U/S OF CP, ICP2 - ALL POINTS U/S OF CP;
C***  ICON - AN INDEX FOR POWER PLANT (ICON = 0 -- NO POWER PLANT;
C***  ICON = 1 -- IRR.+ WS + MIN_FLO THRU PLANT, ICON = 2 -- IRR+MIN_FLO
C***  ONLY THRU PLANT, ICON = 3 -- WS + MIN_FLOW ONLY THRU PLANT,
C***  ETAIL - TAIL WATER ELEVATION (M); PLMIN - MIN LEV FOR POWER
C***  PRODUCTION(M); PINST - INSTALLED CAPACITY (MW), EFF - EFFICIENCY OF
C***  PLANT; IPRIO - A FACTOR FOR PRIORITY (IPRIO = 0 MEANS POWER HIGHER
C***  PRIORITY, IPRIO = 1 MEANS IRR. HIGHER PRIORITY FOR THAT MONTH)
C***  POW - POWER DEMAND IN MW;
C***  SMAX - CAPACITY UPTO FRL (M3);
C***  SMIN - CAPACITY UPTO INTAKE OF WS (M3);
C***  STOR(1) - STARTING STORAGE, NN - POINTS IN EAC TABLE; NN(I) = 0
C***  FOR NON-RESERVOIR LOCATIONS; IDP - A FACTOR (IDP = 1 GIVES DETAILED
C***  TABULATION, IDP = 0 DOES NOT GIVE TABULATION);  ELEV - ELEVATION;
C***  AREA - AREA AT CORRESPONDING ELEVATION; CAP - CAPACITY AT
C***  CORRESPONDING ELEVATIONS;
C***  INFL - A FACTOR FOR
C***  INFLOWS (INFL = 1 MEANS INFLOW DATA FOR THE STRUCTURE IS GIVEN;
C***  INFL = 2 MEANS INFLOW DATA IS TO BE COMPUTED FROM OTHER STRUCTURE
C***  DATA; FAC - MULTIPLICATION FACTOR FOR INFLOWS (LOCAL OR AT LOC J);
C***  INOD - NO. OF LOCATION WHOSE INFLOW DATA IS TO BE USED FOR
C***  DERIVING INFLOW AT PRESENT STRUCTURE.
C***  IDDP-D/S LOCATION WHOSE DEMANDS ALSO TO BE SATISFIED; DFC-A FACTOR
C***  GIVING % DEMANDS OF D/S TO BE SATISFIED; FIR-A FACTOR FOR REDUCING
C***  SUPPLY FOR IRRIGATION IN CASE OF SCARCITY; DEMD - TOTAL DEMAND FOR
C***  IRR. IN MM3; WDMD - WS DEMANDS IN MM3; AMFLO - MIN_FLO
C***  DEMANDS IN MM3; RULE - UPPER RULE LEVELS, AIL - MIDDLE RULE LEVELS
C***  CRITICAL FOR IRR. AND POWER, WPL-LOWER RULE LEVELS CRITICAL FOR WS
C***  AND MIN_FLO; EVPD - EVAPORATION DEPTH IN M/MONTH;

C***  DATA RELATED TO CONFIGURATION
      DO 17 I = 1, NLOC
       READ(1,2) NAME(I)
2        FORMAT(/A)
       READ(1,*) ICP(I), ICP1(I), ICON(I), (ICP2(I,J),J=1,ICP1(I))
       IF(ICON(I).EQ.0) IPRIO(I,J) = 0
       WRITE(*,3) ICP(I), NAME(I)
3        FORMAT(/' LOCATION NO.'I3', ',A)
       WRITE(2,3) ICP(I), NAME(I)
       IF(ICP1(I).GT.0) WRITE(2,5) (ICP2(I,J),J=1,ICP1(I))
5        FORMAT(' UPSTREAM LOCATION NUMBER(S) ='5I3)

C***  DATA RELATED TO HYDROPOWER PLANT
       IF(ICON(I).GT.0) THEN
         READ(1,*)  PINST(I), ETAIL(I), PLMIN(I), EFF(I)
         PINST(I) = PINST(I) * 1000
         READ(1,*) (IPRIO(I,J), J = 1, I12)
         READ(1,*) (POW(I,J), J = 1, I12)
         DO J = 1, I12
           POW(I,J) = POW(I,J) * 1000
         ENDDO
         ENDIF

C***  STORAGE DETAILS OF THE STRUCTURE
       READ(1,*) SMAX(I), SMIN(I), STOR(I,1), NN(I), IDP(I)
       WRITE(*,'(''    STOR OK    '',$)')
       WRITE(2,7) SMAX(I), SMIN(I), STOR(I,1)
7        FORMAT(' MAX. STORAGE     ='E10.3' CUBIC M,'/' DEAD STORAGE
     1    '='E10.3' CUBIC M,'/' INITIAL STORAGE ='E10.3' CUBIC M')
       IF(NN(I).GT.0) THEN
        DO 9 J=1,NN(I)
9          READ(1,*) ELEV(I,J), AREA(I,J), CAP(I,J)
```

```
          WRITE(*,'('' EAC-TABLE  OK    '',$)')
        ENDIF

C***   DATA RELATED TO LOCAL FLOW CALCULATION, DEMANDS AND TRIAL RULE LEVELS
        READ(1,*) INFL, FAC(I), IDDP(I), DFC(I), RETF(I)
        IF(NN(I).GT.0.AND.ICON(I).GT.0) WRITE(2,14) PINST(I)/1000
14      FORMAT(' INSTALLED CAPACITY OF POWER PLANT = 'F7.1' MW')
        IF(INFL.EQ.1) WRITE(2,13) FAC(I)
13        FORMAT(' MULTIPLICATION FACTOR FOR INFLOWS ='E9.3)
        READ(1,*) (DEMD(I,J),J=1,I12)
        WRITE(*,'(''   DEMD OK   '',$)')
        IF(NN(I).GT.0) THEN
         READ(1,*) (WDMD(I,J),J=1,I12)
         READ(1,*) AMFLO(I)
         AMFLO(I) = AMFLO(I) * 1000000
         READ(1,*) (RULE(I,J),J=1,I12)
         READ(1,*) (AIL (I,J),J=1,I12)
         READ(1,*) (WPL (I,J),J=1,I12)
         READ(1,*) (EVPD(I,J),J=1,I12)
         WRITE(*,'('' EVPD  OK   '',$)')
        ENDIF
        DO J = 1, I12
         DEMD(I,J) = DEMD(I,J) * 1000000
         WDMD(I,J) = WDMD(I,J) * 1000000
        ENDDO

C***   CALCULATION OF LOCAL FLOWS
        IF(INFL.EQ.1) THEN
          READ(1,*) (FLOW(I,J), J = 1, NMON)
          DO J = 1, NMON
           FLOW(I,J) = FLOW(I,J) * FAC(I)
          ENDDO
         ELSE
          READ(1,*) INOD
          WRITE(2,15) INOD, FAC(I)
15          FORMAT(' FLOW AT THIS NODE = FLOW AT NODE'I3' * 'F5.2)
          DO J = 1, NMON
           FLOW(I,J) = FLOW(INOD,J) * FAC(I)
          ENDDO
        ENDIF
        IF(IDDP(I).GT.0) WRITE(2,11) DFC(I)*100, IDDP(I)
11        FORMAT(' THIS NODE IS ALSO OPERATED TO MEET ',F5.2' % DEMAND'
     1     ' OF LOCATION'I3)
        WRITE(*,'(''  FLOW  OK '')')
17       CONTINUE

C***   SIMULATE THE SYSTEM OPERATION
       WRITE(*,19)
19       FORMAT(/' SIMULATION BEGINS ***'/)

C***   CALCULATION OF YEAR, MONTH AND PERIOD OF OPERATION
       IMON(0) = IMON(1) - 1
       IYR(0) = IYR(1)
       IDAY(0) = IDAY(1) - 1
       IF(IFMON.EQ.3) IMON(0) = IMON(1)
       DO 21 J = 1, NMON
        IF(IFMON.EQ.3) THEN
          IDAY(J) = IDAY(J-1) + 1
          IMON(J) = IMON(J-1)
          IYR(J) = IYR(J-1)
          IF(IDAY(J).GT.3) THEN
            IMON(J) = IMON(J) + 1
            IDAY(J) = 1
          ENDIF
          IF(IMON(J).GT.12) THEN
            IYR(J) = IYR(J)+1
            IMON(J) = 1
          ENDIF
         ELSE
```

```
          IMON(J) = IMON(J-1) + 1
          IYR (J) = IYR(J-1)
          IF(IMON(J).GT.12) THEN
            IYR(J) = IYR(J) + 1
            IMON(J) = 1
          ENDIF
        ENDIF
        WRITE(*,'(''+   SIMULATING FOR''I5,I7,I5)') J, IYR(J), IMON(J)

C***  SIMULATE LOCATION I FOR PERIOD J
      DO 21 I = 1, NLOC
        CALL OPER(I,J)
21      CONTINUE

C***  OUTPUT OF RESULTS
      CALL RESULT
      WRITE(*,*) ' DO YOU WANT GRAPHICAL PRESENTATION OF RESULTS ?'
      READ(*,1) IY
      IF(IY.EQ.'Y'.OR.IY.EQ.'Y') THEN
121     WRITE(*,' (/'' LOCATION NUMBER ( ENTER 0 TO STOP) ? '')' )
        READ(*,*) I
        IF(I.EQ.0) STOP
        CALL GRAP(I)
        GO TO 121
      ENDIF
      STOP
      END


      SUBROUTINE OPER(I,JM)
      CHARACTER NAME*20
      PARAMETER(L1=6,L2=300)

      COMMON/CONF/ICP(L1), ICP1(L1), ICP2(L1,L1), NAME(L1), ICON(L1),
     1    IPRIO(L1,36)

      COMMON/RES/SMAX(L1), SMIN(L1), NN(L1), ELEV(L1,50), RETF(L1),
     1    AREA(L1,50), CAP(L1,50), FAC(L1), IDDP(L1), DFC(L1), TREL(L1)
     2    TDEMD(L1), FIR, PLMIN(L1), ETAIL(L1), EFF(L1), PINST(L1),
     3    IFAIL(L1), IFAIW(L1), IFAIP(L1), IFAIC(L1), AMFLO(L1)

      COMMON/OP1/RULE(L1,36), EVPD(L1,36), DEMD(L1,36), AIL(L1,36),
     1    WPL(L1,36), WDMD(L1,36), POW(L1,36), TDDM(L1,36)

      COMMON/OP2/FLOW(L1,L2), STOR(L1,L2), REL(L1,L2), ELOS(L1,L2),
     1    RFLO(L1,L2), SPIL(L1,L2), PGEN(L1,L2), TDEM(L1,L2),ENDL(L1,L2),
     2    RELIR(L1,L2), RSPIL(L1,L2)


      COMMON/PRI/IYR(0:L2), IMON(0:L2), IDAY(0:L2), IDP(L1), NLOC,
     1    NMON, IFMON

C***  OPERATE RESERVOIR I FOR MONTH JM
      JC=IMON(JM)
      IF(IFMON.EQ.3) JC = (IMON(JM)-1) * 3 + IDAY(JM)

C***  FLOW FROM UPSTREAM STRUCTURES (RFLO)
      IF(ICP1(I).EQ.0) THEN
        RFLO(I,JM) = 0
       ELSE
        DO K = 1, ICP1(I)
         RFLO(I,JM) = RFLO(I,JM) + RSPIL(ICP2(I,K),JM) +
     1       RETF(I) * RELIR(ICP2(I,K),JM)
        ENDDO
      ENDIF

C***  OPERATION OF THE DIVERSION WEIR
      IF(NN(I).EQ.0) THEN
        TDEM(I,JM) = DEMD(I,JC)
```

```
          TAVFL = FLOW(I,JM) + RFLO(I,JM) + STOR(I,JM)
          REL(I,JM) = AMIN1(TAVFL, DEMD(I,JC))
          RELI = REL(I,JM)
          RELW = 0.0
          STOR(I,JM+1) = AMIN1(SMAX(I), (TAVFL - REL(I,JM)))
          SPIL(I,JM) = AMAX1((TAVFL-REL(I,JM)-SMAX(I)),0.0)
          GO TO 103
        ENDIF

C***    OPERATION FOR STORAGE STRUCTURE
C***    INITIAL ELEVATION, AREA, CAPACITY FOR STRUCTURE I FOR MONTH JM
        IT = 0
        EUPL = RULE(I,JC)
        SUPL = FINT(ELEV,CAP,EUPL,NN(I),I)
        IF(SUPL.GT.SMAX(I)) SUPL = SMAX(I)
          GUPL = AIL(I,JC)
        RUPL = FINT(ELEV,CAP,GUPL,NN(I),I)
        HUPL = WPL(I,JC)
        WUPL = FINT(ELEV,CAP,HUPL,NN(I),I)
        AST = STOR(I,JM)
        ARI = FINT(CAP,AREA,AST,NN(I),I)
        ELI = FINT(CAP,ELEV,AST,NN(I),I)
        ARF = ARI
101     IT = IT + 1
        BRI = ARF
        ELF = FINT(AREA,ELEV,BRI,NN(I),I)

C***    TOTAL DEMAND IN THE MONTH
          IF(IDDP(I).GT.0) THEN
            EFFH = DEMD(IDDP(I),JC) + WDMD(IDDP(I),JC)
            TDDM(I,JC) = EFFH * DFC(I) + AMFLO(I)
           ELSE
            TDDM(I,JC) = AMFLO(I)
          ENDIF
        IF(ICON(I).EQ.0) THEN
            TDEM(I,JM) = DEMD(I,JC) + WDMD(I,JC) + TDDM(I,JC)
         ELSE
          EFFH = ((ELI + ELF)/2. - ETAIL(I)) * 0.99
          PDMD = (POW(I,JC)/(9.817*EFFH*EFF(I))) * 30/IFMON * 86400
          IF(PDMD.LT.TDDM(I,JC).OR.((ELI+ELF)/2).LT.PLMIN(I))
     1        PDMD = TDDM(I,JC)
          IF(ICON(I).EQ.1) TDEM(I,JM) =
     1        AMAX1(PDMD, DEMD(I,JC) + WDMD(I,JC) + TDDM(I,JC))
          IF(ICON(I).EQ.2) THEN
            IF(PDMD.GT.(TDDM(I,JC)+DEMD(I,JC) )) THEN
                TDEM(I,JM) = PDMD + WDMD(I,JC)
             ELSE
                TDEM(I,JM) = TDDM(I,JC) + DEMD(I,JC) + WDMD(I,JC)
            ENDIF
          ENDIF
          IF(ICON(I).EQ.3) THEN
            IF(PDMD.GT.(TDDM(I,JC)+WDMD(I,JC))) THEN
                TDEM(I,JM) = PDMD + DEMD(I,JC)
             ELSE
                TDEM(I,JM) = TDDM(I,JC) + DEMD(I,JC) + WDMD(I,JC)
            ENDIF
          ENDIF
        ENDIF

C***    CONSERVATION OPERATION DURING NORMAL CONDITONS
        AMEAN = (ARI+BRI)/2.0
        ELOS(I,JM) = AMEAN * EVPD(I,JC)
        STINF = STOR(I,JM) + FLOW(I,JM) + RFLO(I,JM)
        STOR(I,JM+1) = STINF - TDEM(I,JM) - ELOS(I,JM)
        REL(I,JM) = TDEM(I,JM)
        RELI = DEMD(I,JC)
        RELW = WDMD(I,JC)
        ELF = FINT(CAP,ELEV,STOR(I,JM+1),NN(I),I)
```

```
C***   CHECK FOR MAXIMUM STORAGE
       IF(STOR(I,JM+1).GT.SUPL) THEN
         STOR(I,JM+1) = SUPL
         REL(I,JM) = STINF - ELOS(I,JM) - STOR(I,JM+1)
       ENDIF

C****  OPERATION FOR IRRIGATION/POWER BELOW MIDDLE RULE LEVEL
       IF(ELF.LT.AIL(I,JC)) THEN
         REL1 = STINF - ELOS(I,JM) - RUPL
         IF(IPRIO(I,JC).EQ.0) THEN            ! IRR. HIGHER PRIO.
           AIRD = DEMD(I,JC)*FIR + WDMD(I,JC) + TDDM(I,JC)
           REL2 = AIRD
           REL(I,JM) = AMAX1(REL1, REL2)
           RELI = REL(I,JM) - WDMD(I,JC) - TDDM(I,JC)
           RELW = WDMD(I,JC)
           STOR(I,JM+1) = STINF - ELOS(I,JM) - REL(I,JM)
           ELF = FINT(CAP,ELEV,STOR(I,JM+1),NN(I),I)
          ELSE                                 ! POWER HIGHER PRIO.
           IF((ICON(I).EQ.1).OR.(ICON(I).EQ.3))
     1          PWD = AMAX1((PDMD*FIR), (WDMD(I,JC) + TDDM(I,JC)))
           IF(ICON(I).EQ.2) PWD =
     1          AMAX1((PDMD*FIR+WDMD(I,JC)),(WDMD(I,JC)+TDDM(I,JC)))
           REL(I,JM) = AMAX1(REL1, PWD)
           IF(ICON(I).EQ.1) RELI =
     1          AMAX1((REL(I,JM)-WDMD(I,JC)-TDDM(I,JC)),0.0)
             IF(RELI.GT.DEMD(I,JC)) RELI = DEMD(I,JC)
           IF(ICON(I).EQ.3) RELI = 0.0
           RELW = WDMD(I,JC)
           STOR(I,JM+1) = STINF - ELOS(I,JM) - REL(I,JM)
           ELF = FINT(CAP,ELEV,STOR(I,JM+1),NN(I),I)
         ENDIF
       ENDIF

C****    ENOUGH WATER ONLY FOR WS DEM
       IF(ELF.LT.WPL(I,JC)) THEN
         REL(I,JM) = WDMD(I,JC) + AMFLO(I)
         RELI = 0.0
         RELW = WDMD(I,JC)
         STOR(I,JM+1) = STINF - ELOS(I,JM) - REL(I,JM)
       ENDIF

C****    CHECK FOR MAINTAINING MINIMUM STORAGE
       IF(STOR(I,JM+1).LT.SMIN(I)) THEN
         STOR(I,JM+1) = SMIN(I)
         IF(ELOS(I,JM).GE.STINF) THEN
           ELOS(I,JM) = STINF
           STOR(I,JM+1) = 0.0
         ENDIF
         REL3 = STINF - ELOS(I,JM) - STOR(I,JM+1)
         IF(REL3.LT.0) REL3 = 0.0
           REL(I,JM) = REL3
         IF(ELF.LT.WPL(I,JC)) THEN
           REL(I,JM) = AMIN1(REL3, (WDMD(I,JC) + AMFLO(I)))
           RELI = 0.0
           RELW = WDMD(I,JC)
         ENDIF
         IF(REL(I,JM).LT.WDMD(I,JC)) RELW = REL(I,JM)
         STOR(I,JM+1) = STINF - REL(I,JM) - ELOS(I,JM)
       ENDIF

C****    CONVERGENCE CHECK
       BST = STOR(I,JM+1)
       ARF = FINT(CAP,AREA,BST,NN(I),I)
       ENDL(I,JM) = FINT(CAP,ELEV,BST,NN(I),I)
       IF(ABS(BRI-ARF).GT.50.AND.IT.LT.30) GO TO 101
       ELOS(I,JM) = (ARI+ARF)/2.0 * EVPD(I,JC)
       STOR(I,JM+1) = STINF - ELOS(I,JM) - REL(I,JM)
       IF(STOR(I,JM+1).LT.0) THEN
         STOR(I,JM+1) = 0.0
```

```
         REL(I,JM) = STINF - ELOS(I,JM)
       ENDIF
103      CONTINUE

C**** CALCULATION OF RELEASE AND SPILL
       IF(NN(I).GT.0) THEN
         RSPIL(I,JM) = 0
         SPIL(I,JM) = 0
         IF(REL(I,JM).GT.(RELI+RELW)) RSPIL(I,JM) =
     1        REL(I,JM) - RELI - RELW
         IF(REL(I,JM).GT.TDEM(I,JM)) THEN
           SPIL(I,JM) = REL(I,JM) - TDEM(I,JM)
           REL (I,JM) = TDEM(I,JM)
         ENDIF
       ENDIF

C****   COMPUTATION OF POWER GENERATED; FLOPL - FLOW THROUGH POWER PLANT
       IF(ICON(I).GT.0.AND.NN(I).GT.0) THEN
         FLOPL=0
         EFFH = ((ELI + ELF)/2.0 - ETAIL(I)) * 0.99
         IF(ICON(I).EQ.1) FLOPL = REL(I,JM)
         IF(ICON(I).EQ.2) FLOPL = REL(I,JM) - RELW
         IF(ICON(I).EQ.3) FLOPL = REL(I,JM) - RELI
         IF(FLOPL.LT.0) FLOPL = 0.
         PGEN(I,JM) = 9.817*EFFH*FLOPL*EFF(I)/30*IFMON/86400
         IF(PGEN(I,JM).GT.PINST(I)) PGEN(I,JM) = PINST(I)
       ENDIF

C**** CALCULATION OF FAILURE MONTHS AND TOTAL RELEASE AND DEMAND
       IF((ICON(I).GE.1.AND.PGEN(I,JM).LT.POW(I,JC)*0.9999))
     1     IFAIP(I) = IFAIP(I) + 1
       IF(IPRIO(I,JC).EQ.0.AND.REL(I,JM).LT.(DEMD(I,JC)+WDMD(I,JC)+
     1     TDDM(I,JC))*0.9999) IFAIL(I) = IFAIL(I) + 1
       IF(REL(I,JM).LT.WDMD(I,JC)) IFAIW(I) = IFAIW(I) + 1
       IF(REL(I,JM).LT.FIR*(DEMD(I,JC)+WDMD(I,JC)+TDDM(I,JC)))
     1     IFAIC(I) = IFAIC(I) + 1
       TREL(I) = TREL(I) + RELI + RELW
       TDEMD(I) = TDEMD(I) + DEMD(I,JC) + WDMD(I,JC)
       RELIR(I,JM) = RELI
       RETURN
       END


       SUBROUTINE RESULT
       CHARACTER NAME*20, IC*1, IP*1
       PARAMETER(L1=6,L2=300)

       COMMON/CONF/ICP(L1), ICP1(L1), ICP2(L1,L1), NAME(L1), ICON(L1),
     1   IPRIO(L1,36)

       COMMON/RES/SMAX(L1), SMIN(L1), NN(L1), ELEV(L1,50), RETF(L1),
     1   AREA(L1,50), CAP(L1,50), FAC(L1), IDDP(L1), DFC(L1), TREL(L1),
     2   TDEMD(L1), FIR, PLMIN(L1), ETAIL(L1), EFF(L1), PINST(L1),
     3   IFAIL(L1), IFAIW(L1), IFAIP(L1), IFAIC(L1), AMFLO(L1)

       COMMON/OP1/RULE(L1,36), EVPD(L1,36), DEMD(L1,36), AIL(L1,36),
     1   WPL(L1,36), WDMD(L1,36), POW(L1,36), TDDM(L1,36)

       COMMON/OP2/FLOW(L1,L2), STOR(L1,L2), REL(L1,L2), ELOS(L1,L2),
     1   RFLO(L1,L2), SPIL(L1,L2), PGEN(L1,L2), TDEM(L1,L2),ENDL(L1,L2),
     2   RELIR(L1,L2), RSPIL(L1,L2)

       COMMON/PRI/IYR(0:L2), IMON(0:L2), IDAY(0:L2), IDP(L1), NLOC,
     1   NMON, IFMON

       WRITE(2,201) NMON/IFMON, IYR(1), IMON(1)
201      FORMAT(/' SYSTEM OPERATION SIMULATED FOR'I4' MONTHS, BEGINNING'
     1   I5,I3/)
       DIV=10**6
```

```
C***  WRITE UP OF GENERAL INFORMATION FOR ALL LOCATIONS
      DO 235 I = 1, NLOC
       WRITE(2,203) I, NAME(I)
       WRITE(*,203) I, NAME(I)
203      FORMAT(//5X,'RESULTS FOR LOCATION NO'I3', 'A/)
       IF(ICP1(I).GT.0) WRITE(2,205) (ICP2(I,J),J=1,ICP1(I))
205      FORMAT('     UPSTREAM LOCATION NUMBER(S) ='5I3)

C***   TABULAR PRESENTATION OF RESULTS
       IF(IDP(I).EQ.1) THEN
         ILIN = 12 * IFMON - 1
         DO 237 J = 1, NMON
          ILIN = ILIN + 1
          IF(IFMON.EQ.3) THEN
            JC = (IMON(J)-1) * 3 + IDAY(J)
            I12 = 36
           ELSE
            JC = IMON(J)
            I12 = 12
            IDAY(J) = 0
          ENDIF
          IC = ' '
          IP = ' '
          IF(IPRIO(I,JC).EQ.0.AND.REL(I,J).LT.(DEMD(I,JC)+WDMD(I,JC)+
     1        TDDM(I,JC))*0.9999) IC = 'F'
          IF(ICON(I).GE.1.AND.PGEN(I,J).LT.POW(I,JC)*0.9999) IP = 'P'
          IF(REL(I,J).LT.FIR*(DEMD(I,JC)+WDMD(I,JC)+TDDM(I,JC)))
     1        IC = 'C'
          IF(REL(I,J).LT.WDMD(I,JC)) IC = 'W'
          IF(NN(I).GT.0) AB=ENDL(I,J-1)
          IF(NN(I).GT.0) CD=ENDL(I,J)

          IF(ILIN.EQ.I12) THEN
            IF(NN(I).GT.0.AND.ICON(I).EQ.0) THEN
              IF(ICP1(I).EQ.0) WRITE(2,209)
              IF(ICP1(I).GT.0) WRITE(2,211)
            ENDIF
            IF(NN(I).GT.0.AND.ICON(I).GT.0) THEN
              IF(ICP1(I).EQ.0) WRITE(2,213)
              IF(ICP1(I).GT.0) WRITE(2,215)
            ENDIF
            IF(NN(I).EQ.0) WRITE(2,217)
          ENDIF
          IF(ILIN.EQ.I12) ILIN = 0

209      FORMAT(94('-')/'YYYY-MN-D  INI_STO LOC_FLO EVAPR TIR'
     1    '_DEM WS_DEM TDS_DEM RELEAS   SPILL END_LEV MDL_RUL UPR_RUL'/
     2    13X,' M M3     M M3',2X,'M M3',4X,'M M3',3X,'M M3',
     3    4X,'M M3',2X,' M M3',3X,' M M3',4X,'M',2(7X,'M')/94('-'))

211      FORMAT(92('-')/'YYYY-MN-D  INI_STO LOC_FLO US_FLO EVAP'
     1    'R TIR_DEM WS_DEM TDS_DEM RELEAS   SPILL END_LEV MDL_RUL'
     2    ' UPR_RUL'/13X,' M M3     M M3    M M3',4X,'M M3  '
     3    'M M3',3X,'M M3    M M3',5X,'M M3    M M3',3(5X,'M')/92('-'))

213      FORMAT(108('-')/'YYYY-MN-D  INI_STO LOC_FLO EVAPR TIR_DEM PW_'
     1    'DEM WS_DEM TDS_DEM RELEAS PW_GEN   SPILL END_LEV MDL_RUL UPR'
     2    '_RUL'/13X,' M M3     M M3  M M3',5X,'M M3  M'
     3    'W',5X,'M M3',4X,'M M3',3X,'M M3',3X,'MW',5X,' M M3',4X,'M',
     4    7X,'M',7X,'M'/108('-'))

215      FORMAT(112('-')/'YYYY-MN-D  INI_STO LOC_FLO US_FLO EVA'
     1    'PR TIR_DEM PW_DEM WS_DEM TDS_DEM  RELEAS PW_GEN  SPILL END_L'
     2    'EV MDL_RUL UPR_RUL'/13X,' M M3     M M3    M M3',2X,
     3    'M M3','     M M3',3X,'MW',5X,'M M3     M M3      M M3',4X,'MW',4X,
     4    'M M3',4X,'M',2(7X,'M')/112('-'))

217      FORMAT(4X,68('-')/4X,'YYYY-MN-D    LOC_FLO    US_FLO   TIR_DEM  D'
     1    'IVERSION      SPILL    STORAGE'/19X,'M M3',5X,'M M3',5X,'M M3',
```

```
     2       7X,'M M3',6X,'M M3',6X,'M M3'/4X,68('-'))

          STOR(I,J) = STOR(I,J)/DIV
          FLOW(I,J) = FLOW(I,J)/DIV
          ELOS(I,J) = ELOS(I,J)/DIV
          TDEM(I,J) = TDEM(I,J)/DIV
          REL (I,J) = REL (I,J)/DIV
          SPIL(I,J) = SPIL(I,J)/DIV
          RFLO(I,J) = RFLO(I,J)/DIV
          PGEN(I,J) = PGEN(I,J)/1000

C***  STORAGE NODE WITHOUT POWER PLANT
          IF(NN(I).NE.0.AND.ICON(I).EQ.0) THEN
            IF(ICP1(I).EQ.0) WRITE(2,219) IYR(J), IMON(J), IDAY(J),
     1         STOR(I,J), FLOW(I,J), ELOS(I,J), DEMD(I,JC)/DIV,
     2         WDMD(I,JC)/DIV, TDDM(I,JC)/DIV, REL(I,J), IC, SPIL(I,J),
     3         CD, AIL(I,JC), RULE(I,JC)

            IF(ICP1(I).GT.0) WRITE(2,221) IYR(J), IMON(J), IDAY(J),
     1         STOR(I,J), FLOW(I,J), RFLO(I,J), ELOS(I,J),
     2         DEMD(I,JC)/DIV, WDMD(I,JC)/DIV, TDDM(I,JC)/DIV, REL(I,J),
     3         IC, SPIL(I,J), CD, AIL(I,JC), RULE(I,JC)
          ENDIF

219         FORMAT(I4,'-',I2.2,'-',I1,F9.2,F8.2,F6.2,F8.2,F7.2,
     1        F8.2,F7.2,A,F7.2,F8.?,F8.2,F8.2)

221         FORMAT(I4,'-',I2.2,'-',I1,F9.2,F8.2,2F6.2,F8.2,F7.2,
     1        F8.2,F7.2,A,F7.2,F8.2,F8.2,F8.2)

C***  STORAGE NODE WITH POWER PLANT
         IF(NN(I).NE.0.AND.ICON(I).GT.0) THEN
           IF(ICP1(I).EQ.0) WRITE(2,223) IYR(J), IMON(J), IDAY(J),
     1        STOR(I,J), FLOW(I,J), ELOS(I,J), DEMD(I,JC)/DIV, POW
     2        (I,JC)/1000, WDMD(I,JC)/DIV, TDDM(I,JC)/DIV, REL(I,J),
     3        IC, PGEN(I,J), IP, SPIL(I,J), CD, AIL(I,JC), RULE(I,JC)

           IF(ICP1(I).GT.0) WRITE(2,225) IYR(J), IMON(J), IDAY(J),
     1        STOR(I,J), FLOW(I,J), RFLO(I,J), ELOS(I,J), DEMD(I,JC)/
     2        DIV, POW(I,JC)/1000, WDMD(I,JC)/DIV, TDDM(I,JC)/DIV, REL(
     3        I,J),IC, PGEN(I,J),IP,SPIL(I,J), CD, AIL(I,JC),RULE(I,JC)
          ENDIF

223         FORMAT(I4,'-',I2.2,'-',I1,F9.1,F8.1,F6.1,F8.1,F7.1,
     1       -F7.1,F8.1,F7.1,A,F6.1,A,F7.1,2F8.2,F8.2)

225         FORMAT(I4,'-',I2.2,'-',I1,F9.1,F8.1,F7.1,F6.1,F8.1,F7.1,
     1        F7.1,F8.1,F8.1,A,F6.1,A,F6.1,2F8.2,F8.2)

C***  NON-STORAGE NODE
          IF(NN(I).EQ.0) WRITE(2,227) IYR(J), IMON(J), IDAY(J),
     1      FLOW(I,J),RFLO(I,J),TDEM(I,J),REL(I,J),IC,
     2      SPIL(I,J), STOR(I,J+1)/DIV

227         FORMAT(4X,I4,'-',I2.2,'-',I1,F10.2,F9.3,F9.3,F11.3,A,
     I        F9.3,F10.3)

237        CONTINUE
         WRITE(2,239)
239        FORMAT(108('-'))
        ENDIF

C***  CALCULATION AND PRESENTATION OF RELIABILITIES
         WRITE(2,229) IFAIW(I), (1.-(IFAIW(I)+0.00001)/NMON)
        WRITE(*,229) IFAIW(I), (1.-(IFAIW(I)+0.00001)/NMON)

        IF(ICON(I).GT.0) WRITE(2,233) IFAIP(I), (1.-(IFAIP(I)+0.00001)
     1      /NMON)
        IF(ICON(I).GT.0) WRITE(*,233) IFAIP(I), (1.-(IFAIP(I)+0.00001)
```

```
     1      /NMON)

        IF(TDEMD(I).GT.0) WRITE(2,231) IFAIL(I),
     1      (1.-(IFAIL(I)+0.00001)/NMON), IFAIC(I), TREL(I)/TDEMD(I)
        IF(TDEMD(I).GT.0) WRITE(*,231) IFAIL(I),
     1      (1.-(IFAIL(I)+0.00001)/NMON), IFAIC(I), TREL(I)/TDEMD(I)

229       FORMAT(/' NO OF FAILURES FOR WS     ='I4', TIME RELIABILITY =',
     1      F6.3)

231       FORMAT(/' NO OF IRR. & WS FAILURES ='I4', TIME RELIABILITY ='
     1     F6.3//' NO OF CRITICAL FAILURES  ='I4//' VOLUME RELIABILITY'
     2     ' FOR IRR & WS ='F6.3)

233       FORMAT(/' NO OF POWER FAILURES      ='I4', TIME RELIABILITY =',
     1      F6.3)
      PAUSE
235     CONTINUE
      RETURN
      END

      FUNCTION FINT(A,B,AVAL,NN,II)
C       FUNCTION SUBPROGRAMME FOR LINEAR INTERPOLATION
      PARAMETER(L1=6,L2=300)
      DIMENSION A(L1,50),B(L1,50)
      IF(AVAL.LT.A(II,1)) THEN
       FINT=B(II,1)
       RETURN
      ENDIF
      IF(AVAL.GT.A(II,NN)) THEN
       FINT=B(II,NN)
       RETURN
      ENDIF
      DO 10 I=2,NN
      IF(AVAL.EQ.A(II,I)) THEN
       FINT=B(II,I)
       RETURN
      ENDIF
      IF(A(II,I-1).LT.AVAL.AND.A(II,I).GT.AVAL) THEN
       FINT=B(II,I-1)+((B(II,I)-B(II,I-1))/(A(II,I)-A(II,I-1)))
     1   *(AVAL-A(II,I-1))
       RETURN
      ENDIF
10      CONTINUE
      END

C  ****     GRAPHICS ROUTINE FOR SYS
      SUBROUTINE GRAP(ID)
      INCLUDE 'FGRAPH.FD'
      PARAMETER(L1=6,L2=300)

      CHARACTER NAME*20
      COMMON/CONF/ICP(L1), ICP1(L1), ICP2(L1,L1), NAME(L1), ICON(L1),
     1   IPRIO(L1,36)

      COMMON/RES/SMAX(L1), SMIN(L1), NN(L1), ELEV(L1,50), RETF(L1),
     1   AREA(L1,50), CAP(L1,50), FAC(L1), IDDP(L1), DFC(L1), TREL(L1),
     2   TDEMD(L1), FIR, PLMIN(L1), ETAIL(L1), EFF(L1), PINST(L1),
     3   IFAIL(L1), IFAIW(L1), IFAIP(L1), IFAIC(L1), AMFLO(L1)

      COMMON/OP1/RULE(L1,36), EVPD(L1,36), DEMD(L1,36), AIL(L1,36),
     1   WPL(L1,36), WDMD(L1,36), POW(L1,36), TDDM(L1,36)

      COMMON/OP2/FLOW(L1,L2), STOR(L1,L2), REL(L1,L2), ELOS(L1,L2),
     1   RFLO(L1,L2), SPIL(L1,L2), PGEN(L1,L2), TDEM(L1,L2),ENDL(L1,L2),
     2   RELIR(L1,L2), RSPIL(L1,L2)

      COMMON/PRI/IYR(0:L2), IMON(0:L2), IDAY(0:L2), IDP(L1), NLOC,
     1   NMON, IFMON
```

```
      COMMON/GR/ XX(L2), YY(3,L2), NP, IOP, NGR
      CHARACTER*1 IYN

      NP = NMON
         DUMMY = SETVIDEOMODE( $DEFAULTMODE )
30    WRITE(*,21)
21    FORMAT(////' THE FOLLOWING TIME-SERIES PLOTS ARE AVAILABLE :'//
     1  '     1.  PLOT OF RESERVOIR INFLOW & RELEASE'/
     2  '     2.  PLOT OF RESERVOIR LEVEL & RULE-LEVEL'/
     3  '     3.  PLOT OF RESERVOIR STORAGE & INFLOW'/
     4  '     4.  PLOT OF DEMAND & RELEASE'//' ENTER OPTION NO. ? '$)
      READ(*,*) IOP
      IF(IOP.LE.0.OR.IOP.GT.4) GO TO 30
      DO I=1,NP
         XX(I) = I
         IF(IOP.EQ.1) YY(1,I) = FLOW(ID,I) + RFLO(ID,I)
         IF(IOP.EQ.1) YY(2,I) = REL (ID,I)
         IF(IOP.EQ.2) YY(1,I) = AIL(ID,IMON(I))
         IF(IOP.EQ.2) YY(2,I) = ENDL(ID,I)
         IF(IOP.EQ.3) YY(1,I) = STOR(ID,I)
         IF(IOP.EQ.3) YY(2,I) = FLOW(ID,I)
         IF(IOP.EQ.4) YY(1,I) = TDEM(ID,I)
         IF(IOP.EQ.4) YY(2,I) = REL (ID,I)
      ENDDO

      CALL GRAPHICSMODE()
      CALL DRAWGRAPH()

      READ (*,*)                                ! WAIT FOR ENTER KEY
      DUMMY = SETVIDEOMODE( $DEFAULTMODE )
      WRITE(*,11)
11    FORMAT(//' DO YOU WANT TO VIEW ANOTHER GRAPH [Y/N] ? '$)
      READ(*,1) IYN
      IF(IYN.EQ.'Y'.OR.IYN.EQ.'Y') GO TO 30
1     FORMAT(A)
      END

      SUBROUTINE DRAWGRAPH()
      PARAMETER(L2=300)

      INCLUDE  'FGRAPH.FD'
      INTEGER*2         DUMMY, MAXX, MAXY, STYL(5)
      RECORD /XYCOORD/ XY
      COMMON/MX/        MAXX, MAXY
      CHARACTER*40 TITLE(2), STR*9, LEG(2,4)*7, YCAP(4)*8
      COMMON/GR/ XX(L2), YY(3,L2), NP, IOP, NGR

      DATA STYL/ #FFFF, #FF00, #F0F0, #DD00, #7E07/
      DATA LEG/'INFLOW', 'RELEASE', 'RES-LEV', 'RUL-LEV',
     1  'STORAGE', 'INFLOW', 'DEMAND', 'RELEASE'/
      DATA YCAP/'M M**3', 'LEVEL(M)', 'M M**3', 'M M**3'/

C     DRAW THE BOX.
C
      CALL CLEARSCREEN($GCLEARSCREEN)
      DUMMY = RECTANGLE( $GBORDER, 0, 0, MAXX, MAXY )
      IF(IOP.EQ.1) TITLE(2) = 'PLOT OF RESERVOIR INFLOW & RELEASE'
      IF(IOP.EQ.2) TITLE(2) = 'PLOT OF RESERVOIR LEVEL & RULE-LEVEL'
      IF(IOP.EQ.3) TITLE(2) = 'PLOT OF RESERVOIR STORAGE & INFLOW'
      IF(IOP.EQ.4) TITLE(2) = 'PLOT OF DEMAND & RELEASE'

C  **** FIND MIN/MAX FOR SCALING
      XMIN=10000000
      XMAX=-999999
      YMIN=XMIN
      YMAX=XMAX
      DO 5 I=1,NP
      IF(XX(I).LT.XMIN) XMIN=XX(I)
      IF(XX(I).GT,XMAX) XMAX=XX(I)
```

```
      IF(YY(1,I).LT.YMIN) YMIN=YY(1,I)
      IF(YY(1,I).GT.YMAX) YMAX=YY(1,I)
      IF(YY(2,I).LT.YMIN) YMIN=YY(2,I)
5     IF(YY(2,I).GT.YMAX) YMAX=YY(2,I)
      IXM=XMIN/10
      XMIN=IXM*10
      IXM=YMIN/10
      YMIN=(IXM-1)*10
      IF(IXM.EQ.0) YMIN=0
      IXM=YMAX/10
      YMAX=(IXM+1)*10

      IXNEW=MAXX*0.15
      IYNEW=MAXY*0.85
      CALL  SETVIEWORG( IXNEW, IYNEW, XY)

C  **** MARK THE TICKS
      CALL  MOVETO( 0, 0, XY )
      IXL = MAXX*0.8
      IXL = IXL/100
      IXL = IXL*100
      DUMMY = LINETO( IXL, 0 )
      CALL  MOVETO( 0, 0, XY )
      IYL = MAXY*0.7
      IYL = IYL/100
      IYL = IYL*100
      DUMMY = LINETO( 0, -IYL )
      ITM = IXL/5
      DO I = 1,5
       CALL  MOVETO( I*ITM, 0, XY)
       DUMMY = LINETO(I*ITM, 5)
      ENDDO
      WRITE(STR,'(F8.0)') XMIN
      CALL SETTEXTPOSITION( 27, 8, XY)
      CALL OUTTEXT(STR)
      CALL SETTEXTPOSITION( 27, 70, XY)
      WRITE(STR,'(F8.0)') XMAX
      CALL OUTTEXT(STR)
      ITM = IYL/5
      DO I = 1,5
       CALL  MOVETO( 0, -I*ITM, XY)
       DUMMY = LINETO(-5, -I*ITM)
       CALL  MOVETO( -20, I*ITM, XY)
      ENDDO
      WRITE(STR,'(F8.0)') YMAX
      CALL SETTEXTPOSITION( 7, 2, XY)
      CALL OUTTEXT(STR)
      CALL SETTEXTPOSITION(26, 2, XY)
      WRITE(STR,'(F8.0)') YMIN
      CALL OUTTEXT(STR)
      CALL SETTEXTPOSITION(14, 2, XY)
      CALL OUTTEXT(LEG(1,IOP) )
      CALL SETTEXTPOSITION(16, 2, XY)
      CALL OUTTEXT(LEG(2,IOP) )

C ***** DRAW THE LINES.
      XR = IXL/(XMAX-XMIN)
      YR = IYL/(YMAX-YMIN)

      CALL  SETLINESTYLE( STYL(1) )
      CALL  MOVETO( 0, 0, XY )
      DO 10 I=1,NP
      IXN = XR * ( XX(I) - XMIN)
      IYN = YR * ( YY(1,I) - YMIN)
10    DUMMY = LINETO( IXN, -IYN)
      CALL  MOVETO( IXL-80, -IYL-20, XY )          ! LEGEND
      DUMMY = LINETO( IXL-50, -IYL-20)
      CALL SETTEXTPOSITION( 6, 70, XY)
      CALL OUTTEXT(LEG(1,IOP))
```

```
      CALL   SETLINESTYLE( STYL(2) )
      CALL   MOVETO( 0, 0, XY )
      DO 11 I=1,NP
      IXN = XR * ( XX(I) - XMIN)
      IYN = YR * ( YY(2,I) - YMIN)
11    DUMMY = LINETO( IXN, -IYN)
      CALL   MOVETO( IXL-80, -IYL-2, XY )
      DUMMY = LINETO( IXL-50, -IYL-2)
      CALL SETTEXTPOSITION( 7, 70, XY)
      CALL OUTTEXT(LEG(2,IOP))

      CALL   SETTEXTPOSITION( 2, 25, XY)
      CALL   OUTTEXT(TITLE(1))
      CALL   SETTEXTPOSITION( 4, 25, XY)
      CALL   OUTTEXT(TITLE(2))
      CALL   SETTEXTPOSITION( 29, 35, XY)
      CALL   OUTTEXT('MONTH --->')
      CALL   SETTEXTPOSITION( 6, 5, XY)
      CALL   OUTTEXT(YCAP(IOP))
      RETURN
      END


      SUBROUTINE GRAPHICSMODE()
      INCLUDE  'FGRAPH.FD'
      INTEGER*2               MAXX, MAXY
      RECORD /VIDEOCONFIG/ MYSCREEN
      COMMON/MX/              MAXX, MAXY

C ****  SET GRAPHICS MODE.

      IF( SETVIDEOMODE( $MAXRESMODE ) .EQ. 0 )
     +     STOP 'ERROR:  CANNOT SET GRAPHICS MODE'

C  **** DETERMINE THE MINIMUM AND MAXIMUM DIMENSIONS.
      CALL GETVIDEOCONFIG( MYSCREEN )
      MAXX = MYSCREEN.NUMXPIXELS - 1
      MAXY = MYSCREEN.NUMYPIXELS - 1
      END
```

INPUT DATA FILE IN VARIABLE FORM

Titl

nloc imon(1) iyr(1) nmon ifmon fir .

name(i)

icp(i) icp1(i) icon(i) icp2(i,j)

pinst(i) etail(i) plmin(i) eff(i` {Only if icon(i).gt.0}

iprio(i,j) {Only if icon(i).gt.0}

pow(i,j) {Only if icon(i).gt.0}

smax(i) smin(i) stor(i,1) nn(i) idp(i)

elev(i,j) area(i,j) cap(i,j) {Only if nn(i).gt.0}

infl fac(i) iddp(i) dfc(i) retf(i)

demd(i,j)

wdmd(i,j)

mflo(i)

rule(i,j)

ail(i,j)

wpl(i,j)

evpd(i,j)

flow(i,j) {if infl.ne.1, then inod instead of flow(i,j)}

Note: Entire data for each structure is entered at a time.

Before entering the name of a subsequent structure, a blank line is a must.

For each variable except for flow(i,j), elev(i,j), area(i,j) and cap(i,j), the index i refers to the structure while the index j refers to the period of operation of a water year. For the variable flow(i,j), i represents the same as above but the index j refers to the total period of operation and is equal to nmon*ifmon. Similarly for varibles elev(i,j), area(i,j) and cap(i,j), j is equal to nn(i).

***

MONTHLY OPERATION SIMULATION OF SABARMATI SYSTEM

6 6 1976 12 3 0.75

Harnav Dam

1 0 0 0

21.667E+06 1.7E+06 5.00E+06 10 1

311.00	0.097E+06	0.0892E+06
314.00	0.200E+06	0.5257E+06
317.00	0.389E+06	1.3957E+06
320.00	0.728E+06	3.0459E+06
323.00	1.066E+06	5.7196E+06
326.00	1.499E+06	9.5496E+06
329.00	1.989E+06	14.7676E+06
332.00	2.626E+06	21.6676E+06
335.00	3.802E+06	31.2556E+06
340.00	5.366E+06	54.0516E+06

1 1000000 0 0 0

0.787 0.787 0.787 0.460 0.460 0.460 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.925 0.925 0.925
1.064 1.064 1.064 0.574 0.574 0.574 0.660 0.660 0.660 0.927 0.927 0.927 Total Demand

0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 Ws Demand

0.0003 Mf Demand

327.25 327.25 327.25 326.50 326.50 326.50 326.00 326.00 326.00 325.75 325.75 325.75
325.25 325.25 325.25 330.00 330.00 330.00 331.00 331.00 331.00 332.00 332.00 332.00
332.00 332.00 332.00 331.25 331.25 331.25 330.25 330.25 330.25 328.75 328.75 328.75 OPL

322.50 322.50 322.50 320.00 320.00 320.00 318.20 318.20 318.20 318.00 318.00 318.00
317.80 317.80 317.80 328.00 328.00 328.00 328.50 328.50 328.50 329.00 329.00 329.00
328.25 328.25 328.25 327.00 327.00 327.00 325.50 325.50 325.50 324.25 324.25 324.25 AIL

317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55
317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55
317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 317.55 WPL

0.047 0.047 0.047 0.047 0.047 0.047 0.063 0.063 0.063 0.080 0.080 0.080
0.102 0.102 0.102 0.072 0.072 0.072 0.051 0.051 0.051 0.051 0.051 0.051
0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 EVAP

0.000 0.000 0.000 1.950 1.950 1.950 3.567 3.567 3.567 2.927 2.927 2.927
0.603 0.603 0.603 0.173 0.173 0.173 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

Dharoi Dam

2 1 3 1

1.4 158.00 171.91 0.75

```
0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0

0.5 0.5 0.5 0.6 0.6 0.6 0.9 0.9 0.9 1.1 1.1 1.1 1.0 1.0 1.0 0.8 0.8 0.8
0.9 0.9 0.9 1.2 1.2 1.2 0.7 0.7 0.7 0.6 0.6 0.6 0.5 0.5 0.5 0.4 0.4 0.4 Pow Dem

829.415E+06   89.941E+06   375.0E+06   15   1

163.07     0.195E+06     0.024E+06
164.59     1.282E+06     0.156E+06
166.12     3.159E+06     4.890E+06
167.64     4.724E+06     9.681E+06
170.69     8.043E+06     29.078E+06
173.74     11.929E+06    58.898E+06
176.78     18.525E+06    103.203E+06
179.83     32.189E+06    180.844E+06
182.88     50.640E+06    304.596E+06
185.93     73.358E+06    497.225E+06
188.98     100.133E+06   763.135E+06
189.59     105.621E+06   829.415E+06
190.50     113.314E+06   926.847E+06
192.02     125.047E+06   1108.144E+06
193.55     137.673E+06   1309.163E+06

1  1000000  6  0.5  0.0

20.326 20.326 20.326 18.946 18.946 18.946 8.870 8.870 8.870 8.563 8.563 8.563
8.848 8.848 8.848 9.632 9.632 9.632 6.821 6.821 6.821 1.380 1.380 1.380
6.595 6.595 6.595 10.365 10.365 10.365 20.151 20.151 20.151 16.398 16.398 16.398 Tt_Dm

6.320 6.320 6.320 6.850 6.850 6.850 8.848 8.848 8.848 8.563 8.563 8.563
8.848 8.848 8.848 7.339 7.339 7.339 6.320 6.320 6.320 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 6.116 6.116 6.116 6.320 6.320 6.320 Ws_Dm

0.003 Mf Demand

187.10 187.10 187.10 186.30 186.30 186.30 185.80 185.80 185.80 185.25 185.25 185.25
184.50 184.50 184.50 187.50 187.50 187.50 188.50 188.50 188.50 189.59 189.59 189.59
189.59 189.59 189.59 189.30 189.30 189.30 188.60 188.60 188.60 188.00 188.00 188.00 OPL

182.25 182.25 182.25 181.00 181.00 181.00 179.50 179.50 179.50 178.70 178.70 178.70
177.50 177.50 177.50 180.00 180.00 180.00 181.00 181.00 181.00 183.25 183.25 183.25
185.00 185.00 185.00 184.75 184.75 184.75 184.00 184.00 184.00 183.00 183.00 183.00 AIL

181.00 181.00 181.00 180.50 180.50 180.50 179.50 179.50 179.50 178.70 178.70 178.70
177.50 177.50 177.50 179.00 179.00 179.00 180.25 180.25 180.25 181.25 181.25 181.25
182.60 182.60 182.60 182.50 182.50 182.50 182.25 182.25 182.25 181.50 181.50 181.50 WPL

0.047 0.047 0.047 0.047 0.047 0.047 0.063 0.063 0.063 0.080 0.080 0.080
0.102 0.102 0.102 0.072 0.072 0.072 0.051 0.051 0.051 0.051 0.051 0.051
0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051 EVAP

 4.10   4.10   4.10  29.13  29.13  29.13  77.18  77.18  77.18  119.54  119.54  119.54
28.83  28.83  28.83   8.52   8.52   8.52   1.82   1.82   1.82    1.10    1.10    1.10
 2.81   2.81   2.81   2.17   2.17   2.17   1.50   1.50   1.50    4.42    4.42    4.42
```

Guhai Dam

3 0 0 0

62.34E+06 5.3E+06 33.00E+06 12 1

160.00	0.1272E+06	0.1761E+06
162.00	0.5191E+06	0.8001E+06
164.00	1.5889E+06	2.8391E+06
166.00	3.9176E+06	7.5301E+06
168.00	5.6954E+06	16.3221E+06
170.00	8.2984E+06	30.2521E+06
172.00	11.8072E+06	50.3121E+06
173.00	14.1000E+06	62.3460E+06
174.00	16.2820E+06	78.4571E+06
176.00	21.4608E+06	116.6600E+06
178.00	27.2646E+06	169.6000E+06
180.00	32.7246E+06	224.4971E+06

1 1000000 0 0 0

2.637 2.637 2.637 0.855 0.855 0.855 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.016 0.016 0.016 0.322 0.322 0.322 0.345 0.345 0.345
2.622 2.622 2.622 3.194 3.194 3.194 2.826 2.826 2.826 2.084 2.084 2.084 Total Demand

0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 Ws Demand

0.0003 Mf Demand

171.00 171.00 171.00 170.50 170.50 170.50 170.25 170.25 170.25 170.00 170.00 170.00
169.75 169.75 169.75 171.00 171.00 171.00 172.00 172.00 172.00 173.00 173.00 173.00
173.00 173.00 173.00 172.50 172.50 172.50 172.00 172.00 172.00 171.50 171.50 171.50 OPL

167.40 167.40 167.40 166.10 166.10 166.10 165.75 165.75 165.75 165.50 165.50 165.50
165.25 165.25 165.25 167.50 167.50 167.50 169.00 169.00 169.00 170.50 170.50 170.50
171.35 171.35 171.35 170.75 170.75 170.75 169.75 169.75 169.75 168.75 168.75 168.75 AIL

165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05
165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05
165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 165.05 WPL

0.038 0.038 0.038 0.042 0.042 0.042 0.067 0.067 0.067 0.092 0.092 0.092
0.100 0.100 0.100 0.092 0.092 0.092 0.065 0.065 0.065 0.063 0.063 0.063
0.054 0.054 0.054 0.050 0.050 0.050 0.038 0.038 0.038 0.039 0.039 0.039 Evap

0.000 0.000 0.000 12.230 12.230 12.230 13.953 13.953 13.953 11.617 11.617 11.617
2.333 2.333 2.333 1.380 1.380 1.380 0.860 0.860 0.860 0.387 0.387 0.387
0.123 0.123 0.123 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

Hathmati Dam.

4 0 0 0

152.20E+06 3.512E+06 80.0E+06 22 1

169.16	1.110E+06	1.216E+06
169.77	1.440E+06	1.883E+06
170.38	1.950E+06	2.812E+06

170.69 2.378E+06 3.512E+06
170.99 2.787E+06 4.374E+06
171.60 3.950E+06 6.132E+06
172.21 5.295E+06 8.273E+06
172.82 6.689E+06 11.599E+06
173.43 7.989E+06 15.723E+06
174.04 9.104E+06 20.460E+06
174.65 10.544E+06 26.878E+06
175.26 11.799E+06 32.760E+06
175.87 13.750E+06 40.631E+06
176.48 16.072E+06 49.958E+06
177.09 18.023E+06 61.060E+06
177.70 20.160E+06 71.950E+06
178.31 22.297E+06 85.006E+06
178.61 23.133E+06 92.236E+06
178.92 24.434E+06 99.688E+06
179.53 27.732E+06 115.931E+06
180.14 30.054E+06 133.357E+06
180.75 32.144E+06 152.513E+06

1 1000000 5 0.7 0

1.570 1.570 1.570 0.673 0.673 0.673 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.453 0.453 0.453 0.177 0.177 0.177 0.547 0.547 0.547
1.737 1.737 1.737 1.863 1.863 1.863 1.587 1.587 1.587 1.793 1.793 1.793 Total Demand

0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 Ws Demand

0.0003 Mf Demand

180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74
180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74
180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 180.74 OPL

174.00 174.00 174.00 173.25 173.25 173.25 172.75 172.75 172.75 172.50 172.50 172.50
172.25 172.25 172.25 177.50 177.50 177.50 178.25 178.25 178.25 179.00 179.00 179.00
179.35 179.35 179.35 177.75 177.75 177.75 176.50 176.50 176.50 175.25 175.25 175.25 AIL

173.00 173.00 173.00 172.00 172.00 172.00 171.20 171.20 171.20 171.00 171.00 171.00
170.90 170.90 170.90 174.00 174.00 174.00 175.25 175.25 175.25 176.00 176.00 176.00
175.75 175.75 175.75 175.25 175.25 175.25 174.50 174.50 174.50 173.75 173.75 173.75 WPL

0.038 0.038 0.038 0.042 0.042 0.042 0.067 0.067 0.067 0.092 0.092 0.092
0.100 0.100 0.100 0.092 0.092 0.092 0.065 0.065 0.065 0.063 0.063 0.063
0.054 0.054 0.054 0.050 0.050 0.050 0.038 0.038 0.038 0.039 0.039 0.039 Evap

1.390 1.390 1.390 12.320 12.320 12.320 26.293 26.293 26.293 16.117 16.117 16.117
3.563 3.563 3.563 1.790 1.790 1.790 1.820 1.820 1.820 0.053 0.053 0.053
4.977 4.977 4.977 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

Himatnagar Weir

5 2 0 3 4

17.783E+06 0.0 10.000E+06 0 1

2 0.571428 0 0.0 0

2.82 2.82 2.82 1.18 1.18 1.18 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 2.89 2.89 2.89 1.77 1.77 1.77 5.36 5.36 5.36
12.55 12.55 12.55 15.03 15.03 15.03 7.82 7.82 7.82 3.27 3.27 3.27 Demand

4

Wasna Barrage

6 2 0 2 5

5.35E+06 0.0 2.5E+06 0 1

2 0.67184 0 0.0 0

0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.11 0.11 0.11 10.12 10.12 10.12 17.98 17.98 17.98
23.37 23.37 23.37 14.28 14.28 14.28 0.00 0.00 0.00 0.00 0.00 0.00 Demand

2

MONTHLY OPERATION SIMULATION OF SABARMATI SYSTEM

Location No. 1, Harnav Dam
Max. Storage = .217E+08 Cubic m,
Dead Storage = .170E+07 Cubic m,
Initial Storage = .500E+07 Cubic m
Multiplication factor for inflows = .100E+07

Location No. 2, Dharoi Dam
Upstream Location Number(s) = 1
Max. Storage = .829E+09 Cubic m,
Dead Storage = .899E+08 Cubic m,
Initial Storage = .375E+09 Cubic m
Installed Capacity of Power Plant = 1.4 MW
Multiplication factor for inflows = .100E+07
This node is also operated to meet 50.00 % demand of location 6

Location No. 3, Guhai Dam
Max. Storage = .623E+08 Cubic m,
Dead Storage = .530E+07 Cubic m,
Initial Storage = .330E+08 Cubic m
Multiplication factor for inflows = .100E+07

Location No. 4, Hathmati Dam
Max. Storage = .152E+09 Cubic m,
Dead Storage = .351E+07 Cubic m,
Initial Storage = .800E+08 Cubic m
Multiplication factor for inflows = .100E+07
This node is also operated to meet 70.00 % demand of location 5

Location No. 5, Himatnagar Weir
Upstream Location Number(s) = 3 4
Max. Storage = .178E+08 Cubic m,
Dead Storage = .000E+00 Cubic m,
Initial Storage = .100E+08 Cubic m
Flow at this node = Flow at node 4 * .57

Location No. 6, Wasna Barrage
Upstream Location Number(s) = 2 5
Max. Storage = .535E+07 Cubic m,
Dead Storage = .000E+00 Cubic m,
Initial Storage = .250E+07 Cubic m
Flow at this node = Flow at node 2 * .67

System Operation Simulated for 12 Months, Beginning 1976 6

Results for Location No 1, Harnav Dam

YYYY-Mn-D	Ini_Sto m m3	Loc_Flo m m3	Evapr m m3	Tir_Dem m m3	Ws_Dem m m3	Tds_Dem m m3	Releas m m3	Spill m m3	End_Lev m	Mdl_Rul m	Upr_Rul m
1976-06-1	5.00	.00	.07	.00	.00	.00	.00	.00	322.11	328.00	330.00
1976-06-2	4.93	.00	.07	.00	.00	.00	.00	.00	322.04	328.00	330.00
1976-06-3	4.86	.00	.07	.00	.00	.00	.00	.00	321.96	328.00	330.00
1976-07-1	4.79	1.95	.05	.00	.00	.00	.00	.00	323.76	328.50	331.00
1976-07-2	6.69	1.95	.07	.00	.00	.00	.00	.00	325.23	328.50	331.00
1976-07-3	8.57	1.95	.08	.00	.00	.00	.00	.00	326.51	328.50	331.00
1976-08-1	10.45	3.57	.09	.93	.00	.00	.69F	.00	328.12	329.00	332.00
1976-08-2	13.23	3.57	.10	.93	.00	.00	.93	.00	329.44	329.00	332.00
1976-08-3	15.77	3.57	.11	.93	.00	.00	.93	.00	330.54	329.00	332.00
1976-09-1	18.30	2.93	.12	1.06	.00	.00	1.06	.00	331.29	328.25	332.00
1976-09-2	20.04	2.93	.13	1.06	.00	.00	1.06	.11	332.00	328.25	332.00
1976-09-3	21.67	2.93	.13	1.06	.00	.00	1.06	1.73	332.00	328.25	332.00
1976-10-1	21.67	.60	.13	.57	.00	.00	.57	1.62	331.25	327.00	331.25
1976-10-2	19.94	.60	.13	.57	.00	.00	.57	.00	331.21	327.00	331.25
1976-10-3	19.85	.60	.13	.57	.00	.00	.57	.00	331.17	327.00	331.25
1976-11-1	19.75	.17	.12	.66	.00	.00	.66	1.50	330.25	325.50	330.25
1976-11-2	17.64	.17	.11	.66	.00	.00	.66	.00	329.99	325.50	330.25
1976-11-3	17.04	.17	.11	.66	.00	.00	.66	.00	329.73	325.50	330.25
1976-12-1	16.44	.00	.10	.93	.00	.00	.93	1.08	328.75	324.25	328.75
1976-12-2	14.33	.00	.10	.93	.00	.00	.93	.00	328.16	324.25	328.75
1976-12-3	13.31	.00	.09	.93	.00	.00	.93	.00	327.58	324.25	328.75
1977-01-1	12.29	.00	.08	.79	.00	.00	.79	.00	327.08	322.50	327.25
1977-01-2	11.42	.00	.08	.79	.00	.00	.79	.00	326.58	322.50	327.25
1977-01-3	10.56	.00	.07	.79	.00	.00	.79	.00	326.08	322.50	327.25
1977-02-1	9.70	.00	.07	.46	.00	.00	.46	.00	325.70	320.00	326.50
1977-02-2	9.17	.00	.07	.46	.00	.00	.46	.00	325.29	320.00	326.50
1977-02-3	8.64	.00	.06	.46	.00	.00	.46	.00	324.88	320.00	326.50
1977-03-1	8.12	.00	.08	.00	.00	.00	.00	.00	324.81	318.20	326.00
1977-03-2	8.03	.00	.08	.00	.00	.00	.00	.00	324.74	318.20	326.00
1977-03-3	7.95	.00	.08	.00	.00	.00	.00	.00	324.68	318.20	326.00
1977-04-1	7.86	.00	.10	.00	.00	.00	.00	.00	324.60	318.00	325.75
1977-04-2	7.76	.00	.10	.00	.00	.00	.00	.00	324.52	318.00	325.75
1977-04-3	7.66	.00	.10	.00	.00	.00	.00	.00	324.44	318.00	325.75
1977-05-1	7.55	.00	.13	.00	.00	.00	.00	.00	324.34	317.80	325.25
1977-05-2	7.42	.00	.13	.00	.00	.00	.00	.00	324.23	317.80	325.25
1977-05-3	7.30	.00	.13	.00	.00	.00	.00	.00	324.14	317.80	325.25

No of failures for WS = 0, Time Reliability = 1.000

No of Irr. & WS failures = 1, Time Reliability = .972

No of Critical failures = 0

Volume Reliability for Irr & WS = .986

Results for Location No 2, Dharoi Dam

Upstream Location Number(s) = 1

YYYY-Mn-D	Ini_Sto m m3	Loc_Flo m m3	Us_Flo m m3	Evapr m m3	Tir_Dem m m3	Pw_Dem mw	Ws_Dem m m3	Tds_Dem m m3	Releas m m3	PW_Gen mw	Spill m m3	End_Lev m	Mdl_Rul m	Upr_Rul m
1976-06-1	375.0	4.1	.0	4.2	9.6	.8	7.3	.1	17.0	1.4	.0	183.72	180.00	187.50
1976-06-2	357.9	4.1	.0	4.0	9.6	.8	7.3	.1	17.0	1.4	.0	183.46	180.00	187.50
1976-06-3	340.9	4.1	.0	3.9	9.6	.8	7.3	.1	17.0	1.4	.0	183.19	180.00	187.50
1976-07-1	324.1	29.1	.0	2.7	6.8	.9	6.3	5.1	18.2	1.4	.0	183.32	181.00	188.50
1976-07-2	332.3	29.1	.0	2.8	6.8	.9	6.3	5.1	18.2	1.4	.0	183.45	181.00	188.50
1976-07-3	340.5	29.1	.0	2.8	6.8	.9	6.3	5.1	18.2	1.4	.0	183.58	181.00	188.50
1976-08-1	348.6	77.2	.0	3.0	1.4	1.2	.0	9.0	10.4	1.4	.0	184.59	183.25	189.59
1976-08-2	412.4	77.2	.0	3.4	1.4	1.2	.0	9.0	10.4	1.4	.0	185.59	183.25	189.59
1976-08-3	475.7	77.2	.0	3.8	1.4	1.2	.0	9.0	10.4	1.4	.0	186.41	183.25	189.59
1976-09-1	538.8	119.5	.0	4.2	6.6	.7	.0	11.7	18.3	1.4	.0	187.52	185.00	189.59
1976-09-2	635.8	119.5	.1	4.7	6.6	.7	.0	11.7	18.3	1.4	.0	188.63	185.00	189.59
1976-09-3	732.5	119.5	1.7	5.2	6.6	.7	.0	11.7	18.3	1.4	.9	189.59	185.00	189.59
1976-10-1	829.4	28.8	1.6	5.3	10.4	.6	.0	7.1	17.5	1.4	39.1	189.30	184.75	189.30
1976-10-2	797.9	28.8	.0	5.3	10.4	.6	.0	7.1	17.5	1.4	6.1	189.30	184.75	189.30
1976-10-3	797.9	28.8	.0	5.3	10.4	.6	.0	7.1	17.5	1.4	6.1	189.30	184.75	189.30
1976-11-1	797.9	8.5	1.5	5.1	20.2	.5	6.1	.0	26.3	1.4	46.6	188.60	184.00	188.60
1976-11-2	730.0	8.5	.0	4.9	20.2	.5	6.1	.0	26.3	1.4	.0	188.34	184.00	188.60
1976-11-3	707.4	8.5	.0	4.8	20.2	.5	6.1	.0	26.3	1.4	.0	188.08	184.00	188.60
1976-12-1	684.9	1.8	1.1	4.6	16.4	.4	6.3	.0	22.7	1.4	.0	187.80	183.00	188.00
1976-12-2	660.4	1.8	.0	4.5	16.4	.4	6.3	.0	22.7	1.4	.0	187.51	183.00	188.00
1976-12-3	635.0	1.8	.0	4.4	16.4	.4	6.3	.0	22.7	1.4	.0	187.22	183.00	188.00
1977-01-1	609.7	1.1	.0	3.9	20.3	.5	6.3	.0	26.6	1.4	.0	186.88	182.25	187.10
1977-01-2	580.2	1.1	.0	3.8	20.3	.5	6.3	.0	26.6	1.4	.0	186.55	182.25	187.10
1977-01-3	550.9	1.1	.0	3.6	20.3	.5	6.3	.0	26.6	1.4	.0	186.21	182.25	187.10
1977-02-1	521.7	2.8	.0	3.5	18.9	.6	6.8	.0	25.8	1.4	.0	185.90	181.00	186.30
1977-02-2	495.3	2.8	.0	3.4	18.9	.6	6.8	.0	25.8	1.4	.0	185.48	181.00	186.30
1977-02-3	468.9	2.8	.0	3.2	18.9	.6	6.8	.0	25.8	1.4	.0	185.07	181.00	186.30
1977-03-1	442.7	2.2	.0	4.1	8.9	.9	8.8	.0	17.7	1.4	.0	184.75	179.50	185.80
1977-03-2	423.0	2.2	.0	4.0	8.9	.9	8.8	.0	17.7	1.4	.0	184.45	179.50	185.80
1977-03-3	403.5	2.2	.0	3.9	8.9	.9	8.8	.0	17.7	1.4	.0	184.14	179.50	185.80
1977-04-1	384.0	1.5	.0	4.7	8.6	1.1	8.6	.0	17.1	1.4	.0	183.82	178.70	185.25
1977-04-2	363.7	1.5	.0	4.5	8.6	1.1	8.6	.0	17.1	1.4	.0	183.50	178.70	185.25
1977-04-3	343.6	1.5	.0	4.3	8.6	1.1	8.6	.0	17.1	1.4	.0	183.18	178.70	185.25

1977-05-1	323.6	4.4	.0	5.3	8.8	1.0	8.8	.0	17.7	1.4	.0	182.89	177.50	184.50
1977-05-2	305.1	4.4	.0	5.0	8.8	1.0	8.8	.0	17.7	1.4	.0	182.44	177.50	184.50
1977-05-3	286.7	4.4	.0	4.8	8.8	1.0	8.8	.0	17.7	1.4	.0	182.00	177.50	184.50

No of failures for WS = 0, Time Reliability = 1.000

No of Power failures = 0, Time Reliability = 1.000

No of Irr. & WS failures = 0, Time Reliability = 1.000

No of Critical failures = 0

Volume Reliability for Irr & WS = 1.000

Results for Location No 3, Guhai Dam

YYYY-Mn-D	Ini_Sto m m3	Loc_Flo m m3	Evapr m m3	Tir_Dem m m3	Ws_Dem m m3	Tds_Dem m m3	Releas m m3	Spill m m3	End_Lev m	Mdl_Rul m	Upr_Rul m
1976-06-1	33.00	.00	.80	.02	.00	.00	.02	.00	170.19	167.50	171.00
1976-06-2	32.18	.00	.79	.02	.00	.00	.02	.00	170.11	167.50	171.00
1976-06-3	31.38	.00	.78	.02	.00	.00	.02	.00	170.03	167.50	171.00
1976-07-1	30.59	12.23	.61	.32	.00	.00	.32	.00	171.16	169.00	172.00
1976-07-2	41.89	12.23	.72	.32	.00	.00	.32	2.76	172.00	169.00	172.00
1976-07-3	50.31	12.23	.77	.32	.00	.00	.32	11.14	172.00	169.00	172.00
1976-08-1	50.31	13.95	.82	.34	.00	.00	.35	.76	173.00	170.50	173.00
1976-08-2	62.34	13.95	.89	.34	.00	.00	.35	12.72	173.00	170.50	173.00
1976-08-3	62.34	13.95	.89	.34	.00	.00	.35	12.72	173.00	170.50	173.00
1976-09-1	62.34	11.62	.76	2.62	.00	.00	2.62	8.23	173.00	171.35	173.00
1976-09-2	62.34	11.62	.76	2.62	.00	.00	2.62	8.23	173.00	171.35	173.00
1976-09-3	62.34	11.62	.76	2.62	.00	.00	2.62	8.23	173.00	171.35	173.00
1976-10-1	62.34	2.33	.68	3.19	.00	.00	3.19	4.47	172.50	170.75	172.50
1976-10-2	56.33	2.33	.64	3.19	.00	.00	3.19	.00	172.38	170.75	172.50
1976-10-3	54.83	2.33	.63	3.19	.00	.00	3.19	.00	172.25	170.75	172.50
1976-11-1	53.34	1.38	.46	2.83	.00	.00	2.83	1.12	172.00	169.75	172.00
1976-11-2	50.31	1.38	.44	2.83	.00	.00	2.83	.00	171.81	169.75	172.00
1976-11-3	48.42	1.38	.43	2.83	.00	.00	2.83	.00	171.62	169.75	172.00
1976-12-1	46.55	.86	.43	2.08	.00	.00	2.08	.00	171.46	168.75	171.50
1976-12-2	44.89	.86	.42	2.08	.00	.00	2.08	.00	171.30	168.75	171.50
1976-12-3	43.25	.86	.41	2.08	.00	.00	2.08	.00	171.13	168.75	171.50
1977-01-1	41.62	.39	.38	2.64	.00	.00	2.64	.00	170.87	167.40	171.00
1977-01-2	38.99	.39	.36	2.64	.00	.00	2.64	.00	170.61	167.40	171.00
1977-01-3	36.37	.39	.35	2.64	.00	.00	2.64	.00	170.35	167.40	171.00
1977-02-1	33.78	.12	.37	.86	.00	.00	.86	.00	170.24	166.10	170.50
1977-02-2	32.67	.12	.36	.86	.00	.00	.86	.00	170.13	166.10	170.50
1977-02-3	31.58	.12	.35	.86	.00	.00	.86	.00	170.02	166.10	170.50
1977-03-1	30.49	.00	.56	.00	.00	.00	.00	.00	169.95	165.75	170.25
1977-03-2	29.94	.00	.55	.00	.00	.00	.00	.00	169.88	165.75	170.25
1977-03-3	29.39	.00	.54	.00	.00	.00	.00	.00	169.80	165.75	170.25
1977-04-1	28.84	.00	.73	.00	.00	.00	.00	.00	169.69	165.50	170.00
1977-04-2	28.11	.00	.72	.00	.00	.00	.00	.00	169.59	165.50	170.00
1977-04-3	27.39	.00	.71	.00	.00	.00	.00	.00	169.49	165.50	170.00
1977-05-1	26.68	.00	.76	.00	.00	.00	.00	.00	169.38	165.25	169.75
1977-05-2	25.93	.00	.74	.00	.00	.00	.00	.00	169.27	165.25	169.75
1977-05-3	25.18	.00	.73	.00	.00	.00	.00	.00	169.17	165.25	169.75

No of failures for WS = 0, Time Reliability = 1.000

No of Irr. & WS failures = 0, Time Reliability = 1.000

No of Critical failures = 0

Volume Reliability for Irr & WS = 1.000

Results for Location No 4, Hathmati Dam

YYYY-Mn-D	Ini_Sto m m3	Loc_Flo m m3	Evapr m m3	Tir_Dem m m3	Ws_Dem m m3	Tds_Dem m m3	Releas m m3	Spill m m3	End_Lev m	Mdl_Rul m	Upr_Rul m
1976-06-1	80.00	1.39	1.95	.45	.00	2.02	2.48	.00	177.93	177.50	180.74
1976-06-2	76.96	1.39	1.91	.45	.00	2.02	2.48	.00	177.79	177.50	180.74
1976-06-3	73.97	1.39	1.86	.45	.00	2.02	2.48	.00	177.65	177.50	180.74
1976-07-1	71.02	12.32	1.35	.18	.00	1.24	1.37F	.00	178.10	178.25	180.74
1976-07-2	80.62	12.32	1.45	.18	.00	1.24	1.42	.00	178.52	178.25	180.74
1976-07-3	90.07	12.32	1.54	.18	.00	1.24	1.42	.00	178.91	178.25	180.74
1976-08-1	99.44	26.29	1.66	.55	.00	3.75	4.30	.00	179.66	179.00	180.74
1976-08-2	119.78	26.29	1.86	.55	.00	3.75	4.30	.00	180.35	179.00	180.74
1976-08-3	139.91	26.29	1.98	.55	.00	3.75	4.30	7.73	180.74	179.00	180.74
1976-09-1	152.20	16.12	1.73	1.74	.00	8.79	10.52	3.86	180.74	179.35	180.74
1976-09-2	152.20	16.12	1.73	1.74	.00	8.79	10.52	3.86	180.74	179.35	180.74
1976-09-3	152.20	16.12	1.73	1.74	.00	8.79	10.52	3.86	180.74	179.35	180.74
1976-10-1	152.20	3.56	1.58	1.86	.00	10.52	12.38	.00	180.41	177.75	180.74

1976-10-2	141.80	3.56	1.52	1.86	.00	10.52	12.38	.00	180.07	177.75	180.74
1976-10-3	131.46	3.56	1.46	1.86	.00	10.52	12.38	.00	179.71	177.75	180.74
1976-11-1	121.18	1.79	1.06	1.59	.00	5.47	7.06	.00	179.49	176.50	180.74
1976-11-2	114.85	1.79	1.02	1.59	.00	5.47	7.06	.00	179.25	176.50	180.74
1976-11-3	108.56	1.79	.97	1.59	.00	5.47	7.06	.00	179.02	176.50	180.74
1976-12-1	102.31	1.82	.96	1.79	.00	2.29	4.08	.00	178.90	175.25	180.74
1976-12-2	99.09	1.82	.94	1.79	.00	2.29	4.08	.00	178.76	175.25	180.74
1976-12-3	95.89	1.82	.92	1.79	.00	2.29	4.08	.00	178.63	175.25	180.74
1977-01-1	92.71	.05	.87	1.57	.00	1.97	3.54	.00	178.45	174.00	180.74
1977-01-2	88.35	.05	.85	1.57	.00	1.97	3.54	.00	178.26	174.00	180.74
1977-01-3	84.00	.05	.83	1.57	.00	1.97	3.54	.00	178.06	174.00	180.74
1977-02-1	79.68	4.98	.91	.67	.00	.83	1.50	.00	178.18	173.25	180.74
1977-02-2	82.25	4.98	.93	.67	.00	.83	1.50	.00	178.30	173.25	180.74
1977-02-3	84.80	4.98	.94	.67	.00	.83	1.50	.00	178.41	173.25	180.74
1977-03-1	87.34	.00	1.51	.00	.00	.00	.00	.00	178.34	172.75	180.74
1977-03-2	85.83	.00	1.49	.00	.00	.00	.00	.00	178.28	172.75	180.74
1977-03-3	84.34	.00	1.48	.00	.00	.00	.00	.00	178.21	172.75	180.74
1977-04-1	82.86	.00	2.00	.00	.00	.00	.00	.00	178.12	172.50	180.74
1977-04-2	80.86	.00	1.97	.00	.00	.00	.00	.00	178.02	172.50	180.74
1977-04-3	78.88	.00	1.94	.00	.00	.00	.00	.00	177.93	172.50	180.74
1977-05-1	76.94	.00	2.08	.00	.00	.00	.00	.00	177.84	172.25	180.74
1977-05-2	74.86	.00	2.05	.00	.00	.00	.00	.00	177.74	172.25	180.74
1977-05-3	72.81	.00	2.01	.00	.00	.00	.00	.00	177.64	172.25	180.74

No of failures for WS = 0, Time Reliability = 1.000

No of Irr. & WS failures = 1, Time Reliability = .972

No of Critical failures = 0

Volume Reliability for Irr & WS = .999

Results for Location No 5, Himatnagar Weir

Upstream Location Number(s) = 3 4

YYYY-Mn-D	Loc_Flo m m3	US_Flo m m3	Tir_Dem m m3	Diversion m m3	Spill m m3	Storage m m3
1976-06-1	.79	2.024	2.890	2.890	.000	9.928
1976-06-2	.79	2.024	2.890	2.890	.000	9.856
1976-06-3	.79	2.024	2.890	2.890	.000	9.784
1976-07-1	7.04	1.240	1.770	1.770	.000	16.293
1976-07-2	7.04	4.003	1.770	1.770	7.783	17.783
1976-07-3	7.04	12.380	1.770	1.770	17.650	17.783
1976-08-1	15.02	4.516	5.360	5.360	14.181	17.783
1976-08-2	15.02	16.472	5.360	5.360	26.137	17.783
1976-08-3	15.02	24.199	5.360	5.360	33.863	17.783
1976-09-1	9.21	20.880	12.550	12.550	17.539	17.783
1976-09-2	9.21	20.880	12.550	12.550	17.539	17.783
1976-09-3	9.21	20.880	12.550	12.550	17.539	17.783
1976-10-1	2.04	14.995	15.030	15.030	2.001	17.783
1976-10-2	2.04	10.522	15.030	15.030	.000	15.311
1976-10-3	2.04	10.522	15.030	15.030	.000	12.838
1976-11-1	1.02	6.596	7.820	7.820	.000	12.637
1976-11-2	1.02	5.475	7.820	7.820	.000	11.315
1976-11-3	1.02	5.475	7.820	7.820	.000	9.992
1976-12-1	1.04	2.290	3.270	3.270	.000	10.052
1976-12-2	1.04	2.290	3.270	3.270	.000	10.111
1976-12-3	1.04	2.290	3.270	3.270	.000	10.171
1977-01-1	.03	1.975	2.820	2.820	.000	9.356
1977-01-2	.03	1.975	2.820	2.820	.000	8.541
1977-01-3	.03	1.975	2.820	2.820	.000	7.726
1977-02-1	2.84	.827	1.180	1.180	.000	10.216
1977-02-2	2.84	.827	1.180	1.180	.000	12.707
1977-02-3	2.84	.827	1.180	1.180	.000	15.197
1977-03-1	.00	.001	.000	.000	.000	15.199
1977-03-2	.00	.001	.000	.000	.000	15.199
1977-03-3	.00	.001	.000	.000	.000	15.199
1977-04-1	.00	.001	.000	.000	.000	15.200
1977-04-2	.00	.001	.000	.000	.000	15.200
1977-04-3	.00	.001	.000	.000	.000	15.201
1977-05-1	.00	.001	.000	.000	.000	15.202
1977-05-2	.00	.001	.000	.000	.000	15.202
1977-05-3	.00	.001	.000	.000	.000	15.203

No of failures for WS = 0, Time Reliability = 1.000

No of Irr. & WS failures = 0, Time Reliability = 1.000

No of Critical failures = 0

Volume Reliability for Irr & WS = 1.000

Results for Location No 6, Wasna Barrage

Upstream Location Number(s) = 2 5

YYYY-Mn-D	Loc_Flo m m3	US_Flo m m3	Tir_Dem m m3	Diversion m m3	Spill m m3	Storage m m3
1976-06-1	2.75	.058	.110	.110	.000	5.203
1976-06-2	2.75	.058	.110	.110	2.555	5.350
1976-06-3	2.75	.058	.110	.110	2.703	5.350
1976-07-1	19.57	5.063	10.120	10.120	14.514	5.350
1976-07-2	19.57	5.063	10.120	10.120	14.514	5.350
1976-07-3	19.57	5.063	10.120	10.120	14.514	5.350
1976-08-1	51.85	8.993	17.980	17.980	42.866	5.350
1976-08-2	51.85	8.993	17.980	17.980	42.866	5.350
1976-08-3	51.85	8.993	17.980	17.980	42.866	5.350
1976-09-1	80.31	11.688	23.370	23.370	68.630	5.350
1976-09-2	80.31	11.688	23.370	23.370	68.630	5.350
1976-09-3	80.31	12.576	23.370	23.370	69.518	5.350
1976-10-1	19.37	46.278	14.280	14.280	51.367	5.350
1976-10-2	19.37	13.212	14.280	14.280	18.301	5.350
1976-10-3	19.37	13.212	14.280	14.280	18.301	5.350
1976-11-1	5.72	46.557	.000	.000	52.281	5.350
1976-11-2	5.72	.003	.000	.000	5.727	5.350
1976-11-3	5.72	.003	.000	.000	5.727	5.350
1976-12-1	1.22	.003	.000	.000	1.226	5.350
1976-12-2	1.22	.003	.000	.000	1.226	5.350
1976-12-3	1.22	.003	.000	.000	1.226	5.350
1977-01-1	.74	.003	.000	.000	.742	5.350
1977-01-2	.74	.003	.000	.000	.742	5.350
1977-01-3	.74	.003	.000	.000	.742	5.350
1977-02-1	1.89	.003	.000	.000	1.891	5.350
1977-02-2	1.89	.003	.000	.000	1.891	5.350
1977-02-3	1.89	.003	.000	.000	1.891	5.350
1977-03-1	1.46	.003	.000	.000	1.461	5.350
1977-03-2	1.46	.003	.000	.000	1.461	5.350
1977-03-3	1.46	.003	.000	.000	1.461	5.350
1977-04-1	1.01	.003	.000	.000	1.011	5.350
1977-04-2	1.01	.003	.000	.000	1.011	5.350
1977-04-3	1.01	.003	.000	.000	1.011	5.350
1977-05-1	2.97	.003	.000	.000	2.973	5.350
1977-05-2	2.97	.003	.000	.000	2.973	5.350
1977-05-3	2.97	.003	.000	.000	2.973	5.350

No of failures for WS = 0, Time Reliability = 1.000

No of Irr. & WS failures = 0, Time Reliability = 1.000

No of Critical failures = 0

Volume Reliability for Irr & WS = 1.000

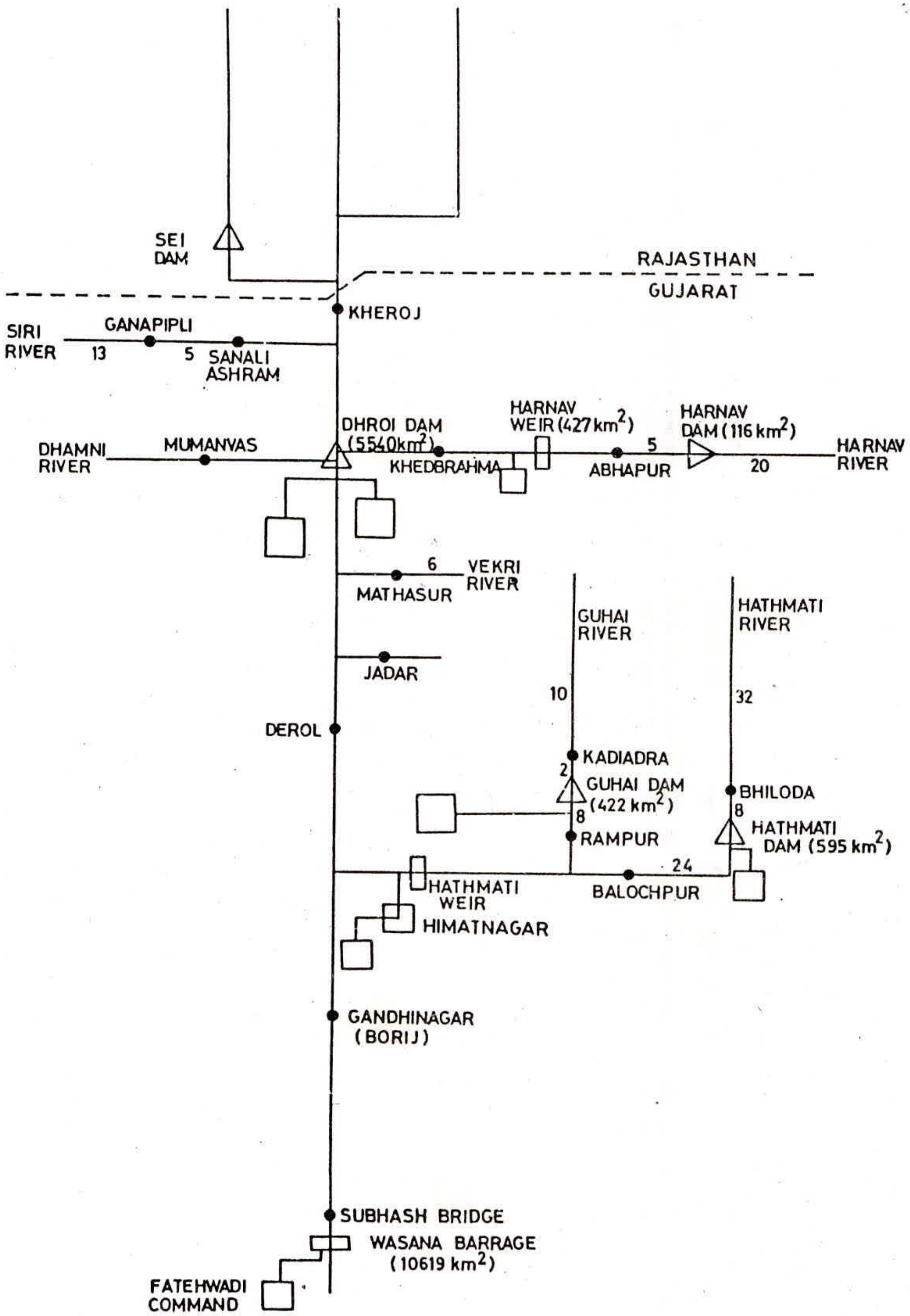

FIG.1 LINE DIAGRAM – SABARMATI BASIN UPTO WASNA BARRAGE (AHMEDABAD)

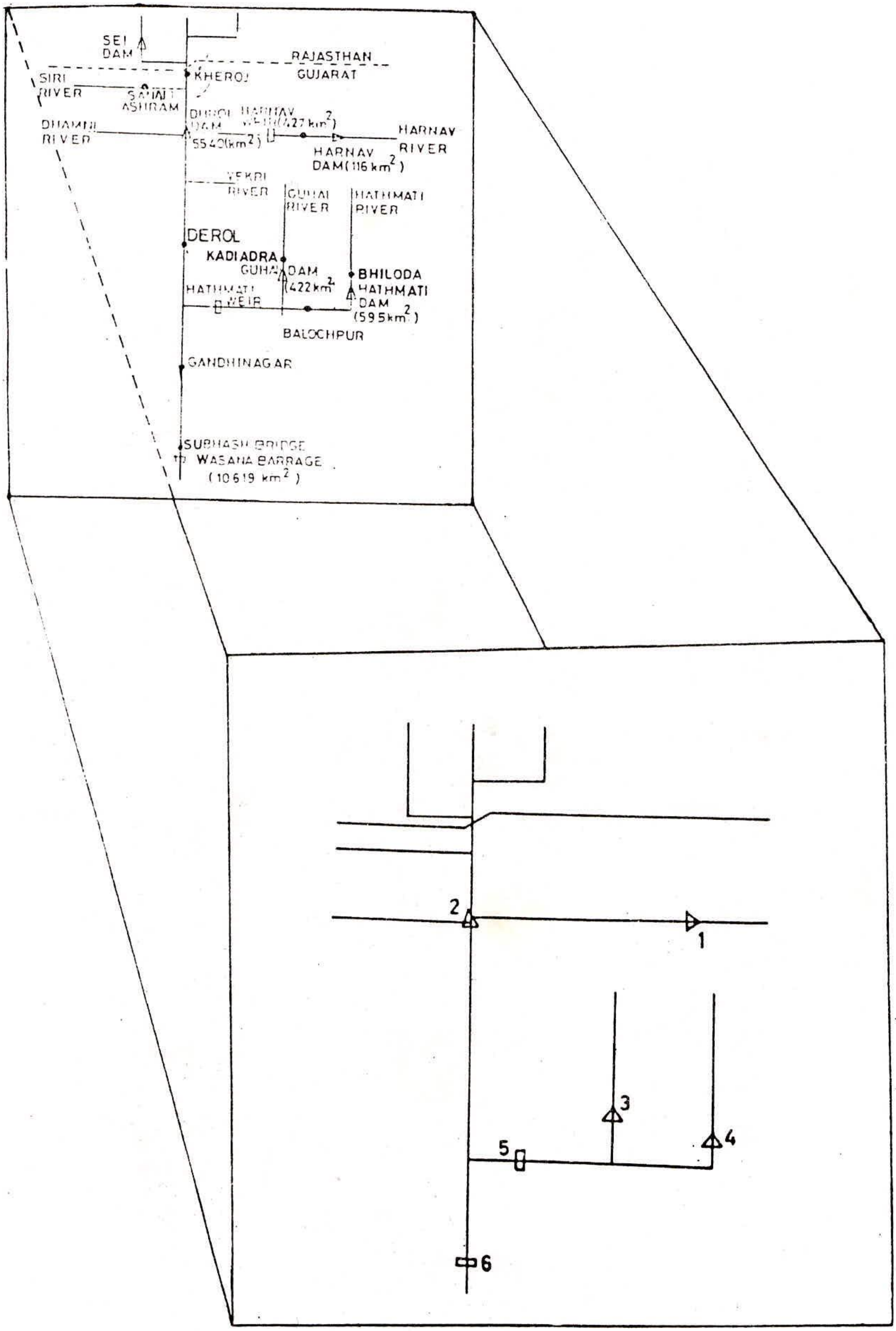

FIG. 2 - NODAL REPRESENTATION OF DHAROI SYSTEM

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