CONTRATO

IICA / INDRHI / CSU

INSTITUTO INTERAMERICANO
DE COOPERACION PARA LA
AGRICULTURA (IICA)

INSTITUTO NACIONAL DE RECURSOS
HIDRAULICOS (INDRHI)

UNIVERSIDAD DEL
ESTADO DE COLORADO
(CSU)

ESTUDIOS SOBRE LA OPERACION Y SEGURIDAD DEL SISTEMA DE EMBALSES DE VALDESIA

DOCUMENTO No.

INSTITUTO INTERAMERICANO DE COOPERACION PARA LA AGRICULTURA (IICA)

CONTRATO
IICA / INDRHI / CSU

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

UNIVERSIDAD DEL ESTADO DE COLORADO (CSU)

SECOND TECHNICAL REPORT 1/

VOLUME II

NORMAL OPERATION

26
June
1986

1/ Additional comments to this report are included in Addendum (Document No. 32).

Technical Report on the Project

OPERATIONAL AND SAFETY STUDIES OF THE VALDESIA RESERVOIR

for

Contract IICA/INDRHI/CSU
(Loan 1655-DO from World Bank)

VOLUME II

NORMAL OPERATION

by

John W. Labadie
Vinio Floris
Nine-Fang Chou
Darrell G. Fontane

VOLUME II.

NORMAL OPERATION

TABLE OF CONTENTS

2.1. Introduction

The Valdesia Reservoir system is a multipurpose and multiobjective system that releases water for irrigation and hydropower and possibly, in the future, for water supply. The key to substantial improvement in the system performance is in operating it in a comprehensive and integrated fashion so we can optimize the benefits. Unfortunately, cohesive and fully integrated system operations confront managers with a difficult task. These systems are subject to multiple and conflicting objectives as well as complex constraints and interrelationships. Optimal integration of many facets of such a system and detailed analysis of trade-offs between conflicting objectives, requires the assistance of analytical tools to provide information on which to base management decisions.

2.1.1. Description of the study area.

a. Reservoir subsystem.

The reservoir subsystem has two reservoirs: Valdesia Reservoir which is located in the upper part of the irrigation zone north of the city of Santo Domingo (see Figure 2.1.1) and in the bed of the Nizao River. It has a concrete dam that allows a maximum storage of 153.088 $10^6 m^3$ at level 150 m.a.s.l. The spillway is at the top of the dam and the spills can be regulated with 5 radial gates. There is a tunnel that allows the passage of water to the hydroelectric power plant that has 2 Francis turbines.

The other reservoir is a small one (6.05 $10^6 m^3$ of maximum capacity at level 80 m.a.s.l.) called Las Barias. The purpose of this structure is to reregulate the inflows already regulated by Valdesia and provide water for irrigation.

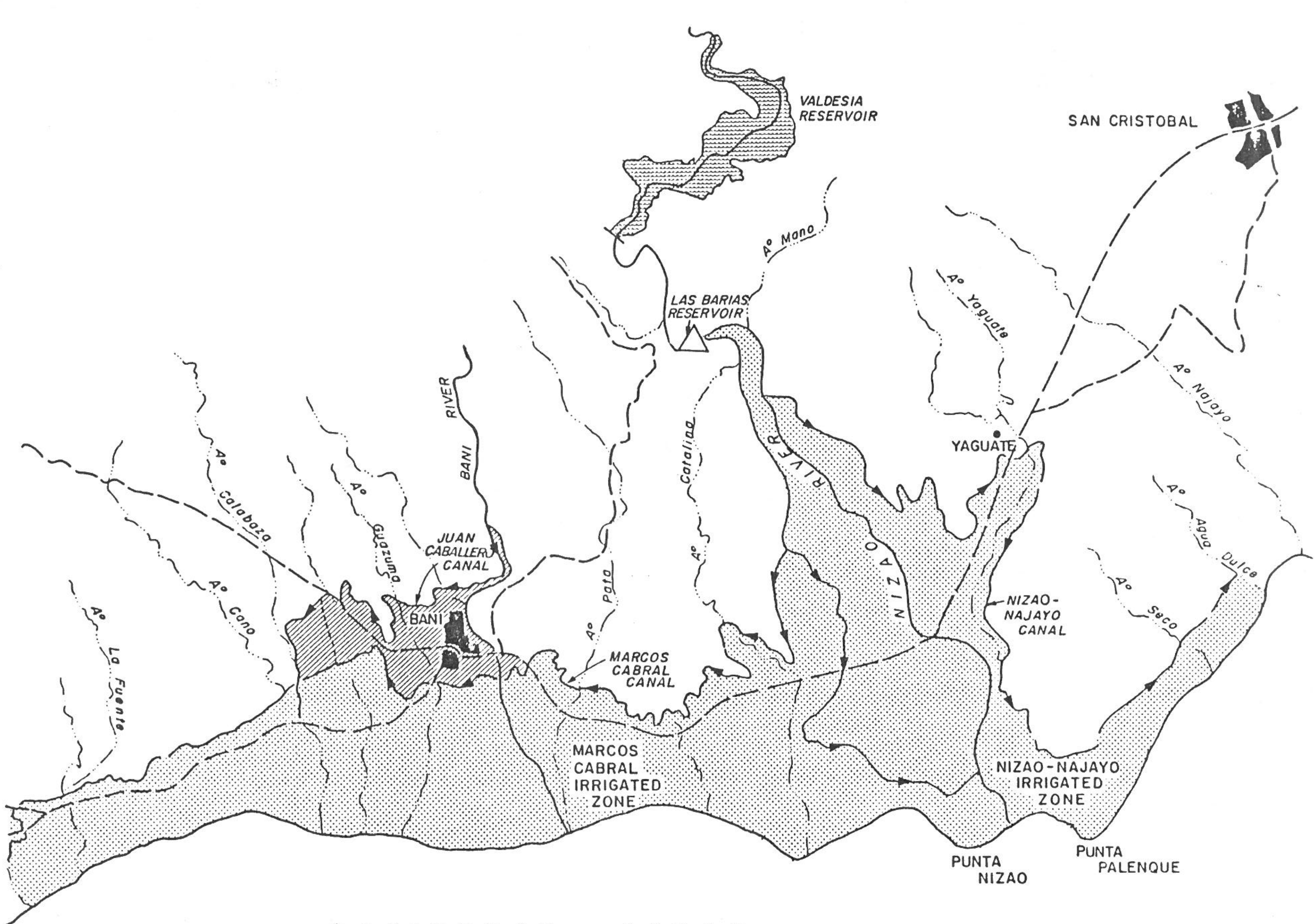


Figure 2.1.1 Valdesia Reservoir System

The construction of the other major reservoirs upstream of Las Barias (Jiguey and Aguacate) has been planned for better regulation of the Nizao River and better use of the energy potential and water supply to the city of Santo Domingo, capital of the Dominican Republic.

b. Irrigation subsystem.

Irrigation water collected by the Valdesia Reservoir System is distributed through two major canals to allow farmers in the Nizao Basin to grow many important crops. The two canals are:

b.1. Marcos A. Cabral: flows to the right of the Nizao's river (looking from upstream to downstream) and has at this time two other laterals:

b.1.1. Juan Caballero: length of 14 Km, irrigates 353 Ha.

b.1.2. Marcos A. Cabral: 47 Km of length, irrigates 8707 Ha.

Both distribute water over an area of 9060 Ha.

b.2. Nizao-Najayo: this flows on the other side of the river (left hand side). Has a length of 34 Km and irrigates 1636 Ha. (see map No. 2.2).

Tropical and subtropical crops such as rice, sugarcane, small vegetables, and fruit (large banana production) are grown in an average yearly temperature of 27^{o}C with average annual rainfall of 800 mm. Meteorological data has been collected in limited time intervals at the stations near or in the irrigation zone; the most complete data was collected at station San Cristobal approximately 10 km from the area.

2.1.2. Need for improved operational strategies.

Computer models of the Valdesia Reservoir system are needed to efficiently predict the impacts of alternative normal operations stragegties under a variety of future scenarios for water-energy supply and demand.

Advances in computer technology, both hardware and software, have been dramatic in recent years and a wide array of tools are available. Computer simulation models are currently being used for a number of river basin systems in the U.S. for generating weekly, monthly, and annual operational guidelines. Many are customized for the particular system, but there is also substantial usage of generalized models such as HEC 5 (Hydrologic Engineering Center, 1979). Computer simulation models are particularly attractive for answering "what if" questions regarding the performance of alternative regulation strategies. However, they are not well suited for finding the best or optimum strategies when flexibility exists in coordinated reservoir system operation.

Optimizing models offer an expanded capability to systematically select optimum solutions or families of solutions, under agreed upon objectives and constraints. In addition, if properly constrained, an optimizing model can act as a simplified simulation model. However, simulation models are generally able to simulate a system with a higher degree of accuracy and are useful for risk analysis in examining the long term performance of proposed operating strategies.

The best approach is to combine simulation and optimization together so as to accentuate their respective strengths. Optimizing models should first be used for generating operational policies which can then be tested and refined with a more detailed simulation model. Therefore, two types of models are needed: one for simulation and one for optimization.

2.1.3. Objectives of this study.

The objectives associated with this research were as follows:

1. To identify a procedure, including methods of operation of the Valdesia and Las Barias Reservoirs that will optimize their

ability -via a dynamic programming computer model- to respond to energy and irrigation needs in the target area.

2. Develop a generalized river basin computer model that can serve as a tool in solving comprehensive problems of integrated river basin management.
3. Demonstrate the use of these models by applying these models to a historical period for comparison.
4. Engage in technology transfer efforts to prepare Dominican engineers for application of this technology.

2.2. Description of the models to be used.

The many challenging complexities associated with integrated river basin management have prompted the development and application of computer models to assist water resources managers in their task. The need for computer models of river basins is particularly great when the system is large-scale, when there are several potentially conflicting objectives, and when there are many complicating operational restrictions, including political and institutional factors. Especially today, when funds for new development are in short supply, it is important that management of existing projects be optimized.

A particularly important problem faced by water resource managers is the need to optimize the benefits from the often conflicting objectives of irrigation supply and hydropower generation. This is the case of the Valdesia Reservoir system in the Nizao River basin in the Dominican Republic. As a solution to this problem we present two models: a generalized river system simulation computer model called MODSIM that analyzes complex water management issues, develops trade-offs among varying management alternatives and allocates water among several demand nodes; and, a general purpose dynamic programming code model called CSUDP which will be used for screening alternative operational strategies for the Valdesia Reservoir System.

These two programs work together: CSUDP gives optimal operation rules which can be input to MODSIM to improve system performance. The idea is that simulation and optimization should be used together. The former can more accurately depict the operation of the entire system, whereas the latter can be useful in helping find optimal operating guidelines for the simulation.

2.2.1. Optimization model for monthly operational targets: CSUDP

There are a wide variety of optimization techniques available today, including linear programming, nonlinear programming, dynamic programming, integer programming, network flow theory, optimal control theory, stochastic optimization, large-scale optimization methods, and multiobjective techniques. The Tennessee Valley authority (Shane and Gilbert, 1982) has implemented a linear programming model to schedule weekly releases from their 42 reservoir system. The optimization is performed on a week by week basis, rather than in a fully dynamic sense in anticipation of forecasted conditions. A nonlinear search technique is used to tradeoff current energy production with future potential energy. Before the 1976-1977 drought, dynamic programming was being used to operate a portion of the Central Valley Project in northern California (Sheer and Meredith, 1984). A 10% increase in hydropower production revenues during the period the algorithm was used was documented, with the qualification that some of this benefit may not have been due solely to use of the optimization model.

For this study, the optimization technique selected was dynamic programming. The reader is referred to Labadie (1980) and Yakowitz (1982) for applications of dynamic programming to water resources. The advantages of dynamic programming (DP) include:

a. particular suitability to solving sequential decision problems over many time periods or stages. With DP, computer time requirements increase linearly with the number of stages. With other methods, except for optimal control theory, computer time requirements tend to increase geometrically.

b. Ease of considering nonlinear aspects of reservoir modeling including hydropower production functions and evaporation calculations. The former introduce a high degree of nonconvexity into the optimization problem which can cause severe difficulties with other methods.

c. Determination of "feedback" operating rules for a wide range of conditions or states of the system, rather than just one "open loop" optimal solution that would be obtained with other methods.

d. Solution efficiency actually increases when a large number of operational constraints are included, whereas the opposite occurs with other methods.

e. Particular attractiveness for solving stochastic optimization problems with inclusion of conditional risk constraints defining limits of probability of failure to meet certain operational constraints and criteria (Sneidovich, 1979).

The primary disadvantages are:

a. The so-called "curse of dimensionality," which asserts itself with a vengeance as the number of reservoirs considered surpasses three.

Computer costs and rapid access storage requirements increase dramatically with each added reservoir.

b. Lack of available, generalized dynamic programming computer software. The usual approach is to write a specialized DP code for each new application. This requires both good programming skills and a thorough understanding of the theory and numerical aspects of DP.

The second disadvantage is overcome by the availability of Program CSUDP developed at Colorado State University (Labadie, 1980). The first disadvantage is not a problem for this study since there are a limited number of reservoirs.

2.2.2. Simulation model for weekly real-time operation: MODSIM.

For development of operational guidelines under normal operations for the Valdesia Reservoir System, we propose use of Program MODSIM developed at Colorado State University.

The underlying principle of the operation of MODSIM is that most physical water resource systems can be represented as capacitated flow networks. The term "capacitated" refers to the existance of strict bounds on each link and satisfaction of mass balance at each node. The components of the system are represented in the network as nodes, both storage (i.e., reservoirs) and nonstorage (i.e., river confluences, diversion points, points of inflow, and demand locations) and links or arcs (i.e., canals, pipelines, and natural river reaches). In order to consider demands, inflow, and desired reservoir operating rules, several artificial nodes and links must be constructed in such a way as to insure that mass balance is satisfied throughout the networks. These artificial nodes and links are created automatically by MODSIM, so that the user need only to be concerned with the actual system and links.

MODSIM allows the use of "costs" that, in other words, assign priorities for nodes and links to satisfy their demands (nonstorage nodes), levels (storage nodes) or storage rights priorities (in links). These cost terms can vary from 1 to 99 (a lower number represents a higher priority) and also it is possible to use negative costs "benefits" from -1 to -99.

The "costs" in this case need not be true costs, but can be priority or weighting factors that serve to rank operational alternatives. Most other available general purpose river basin models do not have this capability, such as HEC 5 (Hydrologic Engineering Center, 1979), MITSIM (Lenton and Strzepek, 1977) and SSARR model (U.S. Army Corps of Engineers, (1972). With these models, various demands and operating priorities cannot be ranked by the user.

MODSIM is a network flow linear programming model that uses the out-of-kilter (OKM) algorithm that solves the network flow problem iteratively, in a sequential fashion over time.

Network flow algorithms have several advantages over other optimization techniques for river basin modeling. One advantage is that the general network form allows different configurations of water resource systems to be represented without reprogramming the model. Also, since the network represents the actual components of the physical system, it is easy to conceptualize the system morphology. Another advantage is that, unlike other network programming-type algorithms, the user need not provide an initial feasible solution when using the OKM. This is essentially a primal-dual linear programming algorithm which is specifically designed for efficient solution of minimum cost flow network problems.

Another important advantage is that this algorithm has a high computational efficiency which has been quite attractive for solving moderately large network problems and enables modeling of systems that otherwise would be impracticable due to computer storage and computation requirements.

Both the irrigation and power demand models (we used a stochastic analysis program) are attached to MODSIM for real-time development of operation rules for the system. The target storage levels and other operational characteristics needed for MODSIM have been defined through use of dynamic programming (Program CSUDP) to obtain optimality of the system operation rules. Stream-aquifer interaction and hydropower production are included in the model structure. The model is particularly well suited to water supply problems where institutional factors governing water allocation are important.

The current version of Program MODSIM is primarily intended for obtaining weekly or monthly management guidelines over an entire river basin or selected subbasin. The model is therefore not well suited to short term flood control operations requiring streamflow routing. Therefore, it is best suited to normal operations. The model is capable of generating operational plans that satisfy specified targets, priorities, and constraints. It also can be used to evaluate tradeoffs between conflicting uses during periods of deficient water availability. This information can provide a rational, documentable basis for making difficult water allocation decisions.

One of the most important features of the model is its "user friendly" design. The model input has been structured in an interactive, conversational format which encourages use by water control personnel with little computer experience. The version used in this study was designed primarily for the IBM PC microcomputer and compatible machines operating under PC DOS 2.0 with a minimum of 320K memory. The source code is written in FORTRAN 77.

MODSIM is designed to be a tool only. The results are only as valid as the data input, but the model can be useful as a means of pinpointing data needs. Models can, and have been, abused, and model usage must always be tempered with sound judgment and experience. The user should have a good understanding of the assumptions and approximations associated with the model.

2.2.3. Irrigation demands

In order to calculate the monthly and weekly net irrigation requirements, two computer programs were created:

- MODPEN: estimates the crop evapotranspiration using the Modified Penman equation.
- EFEC: calculates the effective rainfall that is available in the rootzone of the crops. The methodology recommended by Hubert J. Morel-Seytoux and Jorge I. Restrepo (1985) has been used.

a. Modified Penman method

The effect of climate on crop water requirements is most satisfactorily obtained by the Modified Penman Method. Guidelines for predictions by this method were taken from an FAO publication entitled "Crop Water Requirements". The procedure involves calculation of the evapotranspiration based on the location of the station, the temperature, humidity, wind speed, and bright sunshine hours as measured each day. This evapotranspiration term is multiplied by a crop coefficient to determine the water required by each type of crop.

The Penman equation has two terms: an energy term which considers incoming radiation, and an aerodynamic term based on wind and humidity. The

Modified Penman Method involves a revised wind function term and a correction for day and night-time weather conditions the original wind term does not consider. As a function of the water vapour pressure, the evapotranspiration considers humidity and additional factors of wind speed, average termperature, and altitude. The radiation term is based on the amount of bright sunshine, and the relative position of the sun and the station (month, latitude).

The crop coefficients modify the predicted evapotranspiration assuming that crops are grown under optimum conditions producing optimum yields. We categorized crops into ten groups based on similar characteristics: time of planting or sowing, rate of crop development and length of growing season, climatic conditions, and frequency of rain or irrigation required. Similarities in plant structure were also used to group major crops. Some plants resist transpiration well; size, roughness, reflectivity, and ground cover have an effect that was also considered. Yet, many inaccuracies still reside because the problem is so complex and irregular, and the area so large. Each crop could be studied using a lysimeter to determine water requirements more confidently. Then, inefficiencies in the water transport could be identified and improved.

b. Estimation of effective precipitation.

Effective precipitation is the portion of rainfall that contributes to meet the evapotranspiration requirement of a crop. The computer program takes the daily rainfall and subtracts the amount that is intercepted and returned to the atmosphere. What remains is the depth of water that reaches the ground that does not evaporate. From this amount we need to subtract again the surface drainage depth and what remains is the infiltration depth due to precipitation which is set equal to the hydraulic conductivity at natural saturation assuming a steady infiltration rate.

The infiltrated fraction of the precipitation is either consumed by crops, stored in the soil, evaporated and/or it serves as recharge to the aquifer by deep percolation. Unless the soil is initially saturated, some of the infiltrating water gradually fills available storage. Considering the average soil water field capacity, water content prevailing at the beginnng of the day, the thickness of the root zone and the recharge parameter for the precipitation process, we can get the daily effective infiltration depth due to precipation. This methodology uses the principles stated by Konikow and Bredehoeft (1974).

2.2.4 Microcomputer implementation of models.

Two major models, CSUDP and MODSIM, are written in Fortran 77 language and implemented with IBM PC. Both models are compiled by Microsoft MS-FORTRAN Compiler V3.20 and linked by MS-FORTRAN Linker V2.41 under PC DOS 2.00. Size of required memory to run these two packages in shown in Table 2.2.1.

A general instruction and remark file, named READ.ME!, is enclosed in each package to describe the origin, characteristics and implementation of the model. Two example problems with data file and which are solved by the packages are also enclosed for debugging purpose. For CSUDP, another documentation file named CSUDPIBM.DOC is enclosed to explain detailed usage of that package.

Since integer variable calculation is used in the Out-of-Kilter method, MODSIM is linked with standard math library MATH.LIB of MS-FORTRAN V3.20. With this option, both system units installed with or without an 8087 math coprocessor can run MODSIM successfully. In addition, MODSIM uses many integer variables with 32-bit precision. If the user needs to modify the program, he should use INTEGER*2 data type or $STORAGE metacommand with caution. To increase the execution speed of CSUDP, an 8087 math coprocessor is utilized. The option of metacommand $NOFLOATCALLS in compiling and real math library 8087.LIB for linking are both used to get an executable file with faster execution speed.

The PC version of MODSIM is a user-friendly package. It is designed for the purpose of interactive use and easily being implemented by beginners. A batch command file MODSIMX.BAT is provided to connect different procedures of MODSIM package together. Typing in MODSIMX after DOS prompt to start the package, the user can follow and answer different questions to create a data file or to execute MODSIM for operational analysis. Once the user is familiar with all different procedures of this package, he can just go to each specific part to perform his particular job.

CSUDP is a general dynamic programming package. The user needs to prepare his own subroutines STATE, OBJECT, and READIN for describing a particular problem. After these three subroutines are successfully compiled, they should be linked with the other two main program object files CSUDP087.OBJ and DPSUB087.OBJ to get the executable file. Here the 8087.LIB and MS Linker V2.40 or V2.41 should be used for linking. If a PC system unit is installed without an 8087 coprocessor, the user can use the other two object files CSUDP086.OBJ and DPSUB086.OBJ or create his own with the source codes provided to link with real math library ALTMATH.LIB. A batch file DPLINK.BAT used for linking is enclosed in the package. The user may also study this file to find out what object files should be linked to get an executable file.

Table 2.2.1 Minimum Required Memory for Executing CSUDP and MODSIM in IBM PC with Executable Files Compiled by MS-FORTRAN V3.20

	CSUDP	MODSIM
Source Code	36,110	72,378
Code of Libraries Real Math Library	32,306 (8087.LIB)	40,214 (MATH.LIB)
Constants, Static Variables, and Stack Segment	11,824	17,472
Common Blocks	46,736	113,873
Total	126,976	243,937
Suggested System Memory	192K bytes	320K bytes

Note: 1. Memory is in Bytes and counted by decimal numbers.
2. 512 bytes of stack segment is temporarily assumed.

Hints about implementing a floppy disk driver are given in file READ.ME!. Both models can be executed with floppy diskette, but it's only available for small problems because up to five direct access files in MODSIM and up to three in CSUDP will be created during execution. Some nonimmediate data will be stored in a disk file to save memory. For problems which have many stages and finer discretizations in CSUDP or many nodes with different characteristics in MODSIM, the corresponding direct access file will be huge. In either case, the only way to run the model is to use a fixed disk. For details of the size of those direct access files, the user can also refer to the READ.ME! file.

Because of the same reason described above, the total number of files that can be opened concurrently by DOS should be four to eight. For users who run MODSIM in a PC AT or compatible machines with DOS V3.00 or higher, FILE=15 is suggested to be specified in the system configuration file CONFIG.SYS for allowing more files to be accessed at the same time.

2.3. Data Collection

The historical data has a very important role in the normal operation study of a system, especially in the calibration of the simulation and optimization models and in the estimation of water demands (irrigation demands in this special case).

Several limitations have been found on data quality and quantity in time and at specific locations, but this situation was solved by filling missing data by statistical procedures and by using the mass balance equations.

All the data available for the normal operation part has been received in computer printouts or just simple record papers. We keypunched it and loaded it on tapes or diskettes for further data manipulation.

Table 2.3.1
Summary of the data available for the normal operation study of the Valdesia Reservoir System

Purpose	Location	Time Intervals	Data Used
MODSIM calibration	Station Valdesia	Weekly basis 1976-1984	- Evaporation - Rainfall - Inflows - Irrigation deliveries for the M. Cabral and N. Najayo canals - Historical water levels in the reservoir - Historical turbines operating hours
		General data	- Turbines efficiencies as a function of the head and releases - Curves area-capacity-head for Valdesia and Las Barias Reservoirs (before and after hurrican David)
CSUDP calibration	Station Valdesia	Monthly basis	- Precipitation - Evaporation - Inflows - Valdesia Reservoir levels - Water power release - Energy generated
Irrigation demands	Station San Cristobal	Daily basis 1983-1984	- Evaporation - Rainfall - Temperature - Relative humidity - Wind speed - Cloud cover
	Valdesia irrigation zone	Monthly basis	- Cropping area - Crop coefficients - Cropping patterns (10 groups)

2.3.1. Available hydrological and meteorological data at selected locations and time intervals

As we can see in Table 2.3.1, hydrological and meteorological data have been used at daily, weekly and monthly time bases for different locations.

2.3.2. Irrigation cropping area, crop patterns and crop coefficients.

The total irrigation cropping area has been divided in 8 sectors. The 35 or so various crops were combined into 10 groups, considering their similar life time period, and then a specific crop coefficient for a certain growing period was estimated.

The groups of crops are the following:

No.	Name of the group	Crops in their respective group
1	rice	rice
2	corn	corn, sorghum, sunflower, peanuts, red beans, molondron
3	bananas	bananas, guineo, rulo
4	papaya	papaya (lechoza)
5	yuca	yuca
6	onions	onions
7	sugarcane	sugarcane
8	small vegetables (hortalizas)	tomatoes, pepinos, green beans (vainita), sugarbeets, berenjena, green pepper, cebollin, cabbage, name, melon, auyama, sweet potatoes, potatoes, cucumbers, watermelon
9	pastures	natural pastures, pangola, guinea
10	perennial	citrics, coconuts, mango, avocados, figs, mispero

In Table 2.3.3 the monthly crop coefficients for the Valdesia irrigation zone are shown.

2.3.3. Characteristics of hydropower systems

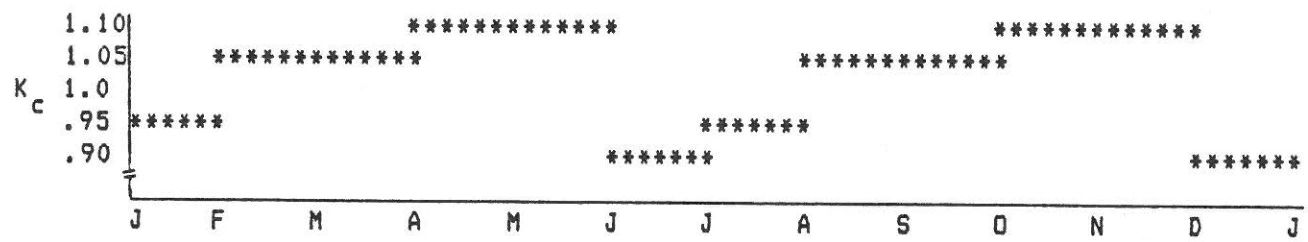
The two turbines located in the Valdesia Hydropower plant are Francis type and can generate different levels of power as a function of the head in Valdesia reservoir, the discharge released (up to 90 m^3/s) and the turbines efficiencies.

Table 2.3.2 Turbines Efficiencies

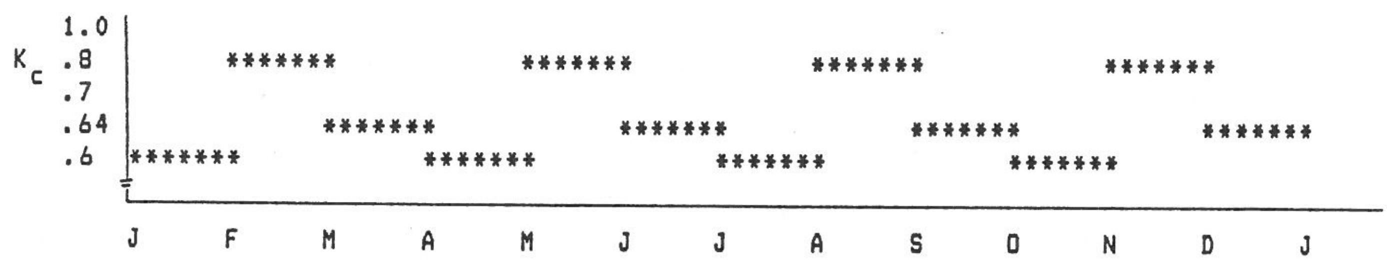
Head (m)	Discharge (m^3/s) 0	40	50	60	65	70	75	80	90
60	.0	.6442	.6893	.7085	.7190	.7131	.7133	.7046	.6797
64	.0	.6346	.6854	.7190	.7344	.7334	.7296	.7219	.6970
67	.0	.6346	.6893	.7258	.7373	.7430	.7440	.7411	.7430
71	.0	.6202	.6893	.7354	.7507	.7565	.7498	.7478	.7248
74	.0	.6144	.6874	.7402	.7526	.7632	.7613	.7574	.7315
77	.0	.6288	.6912	.7373	.7507	.7584	.7594	.7565	.7373
80	.0	.6422	.7037	.7421	.7526	.7622	.7670	.7613	.7334

Table 2.3.3 Crop coefficients for different groups of crops.

Group 1: Rice



Group 2: Corn



Group 3: Bananas

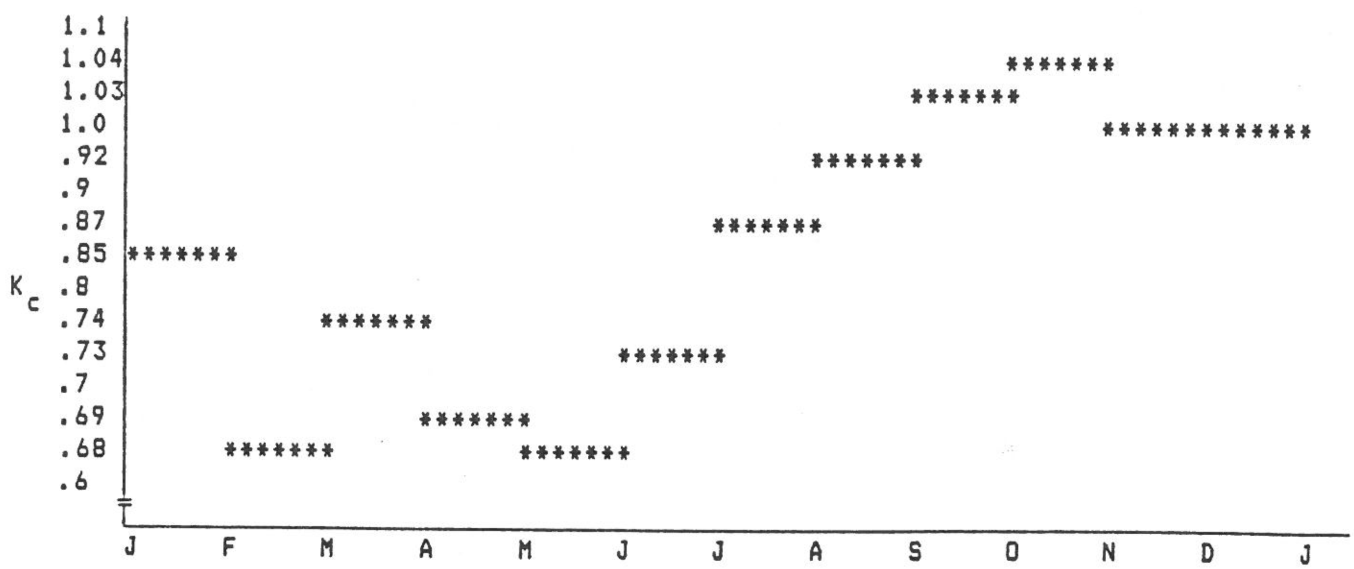
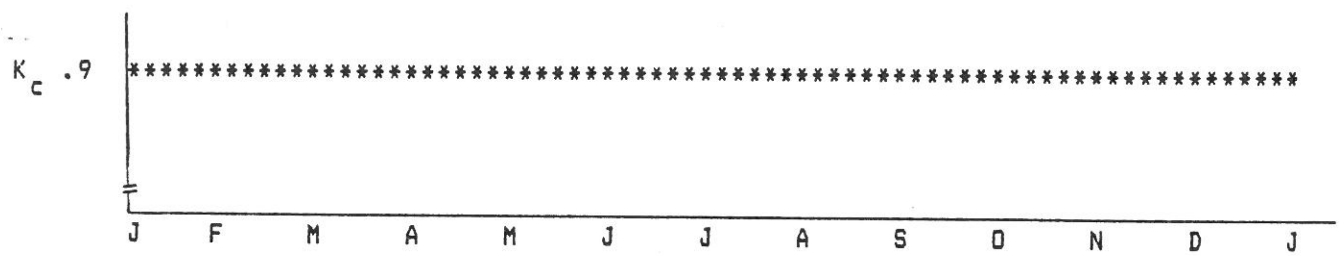
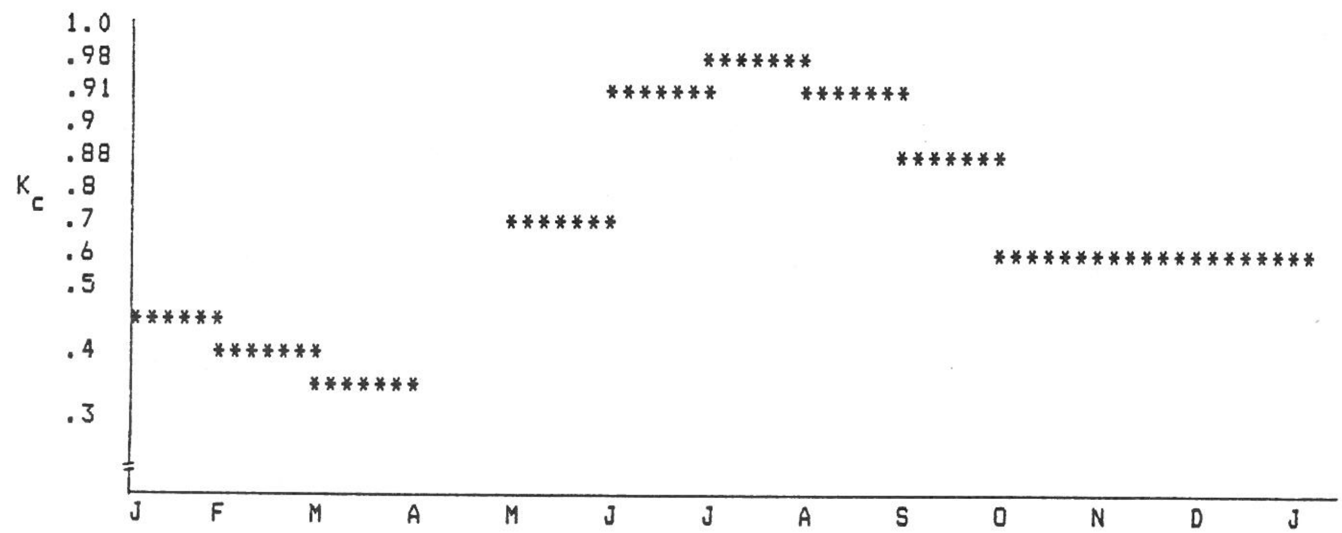


Table 2.3.3 Crop coefficients for different groups of crops. (continued)

Group 4: Papaya



Group 5: Yuca



Group 6: Onions

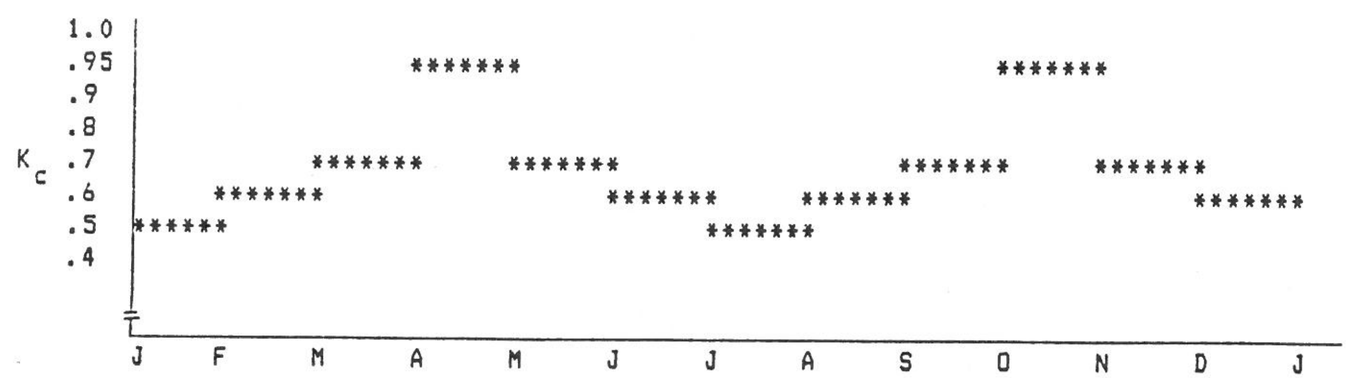
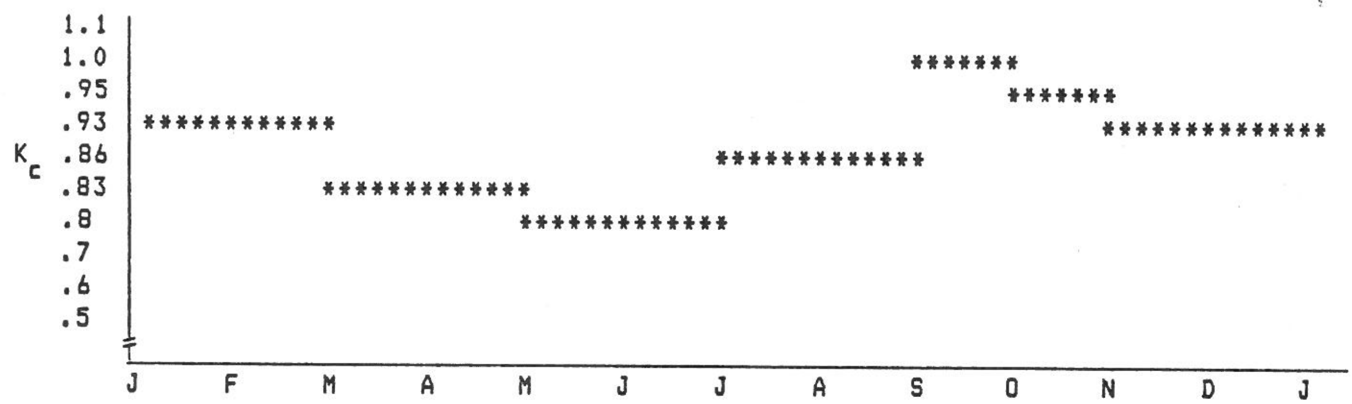
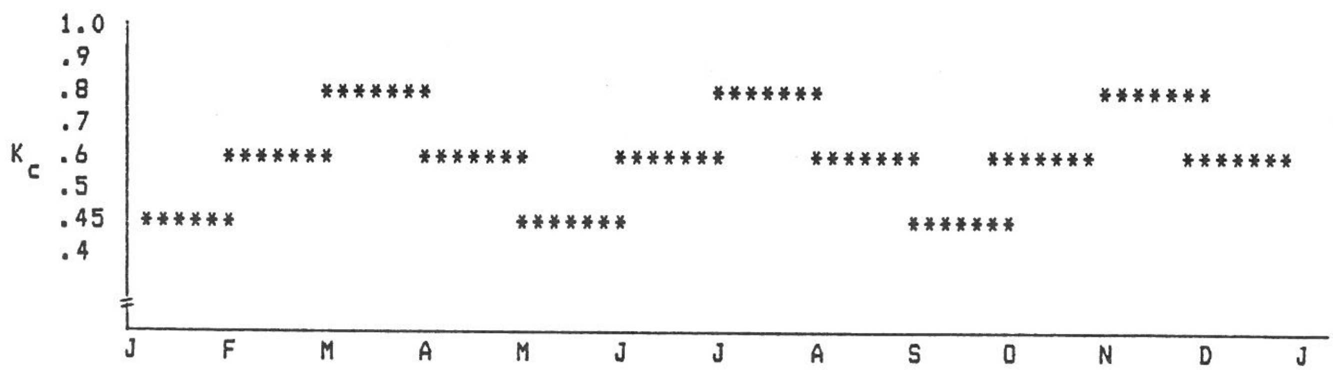


Table 2.3.3 Crop coefficients for different groups of crops. (continued)

Group 7: Sugarcane



Group 8: Small vegetables and not perennial crops



Group 9: Pastures

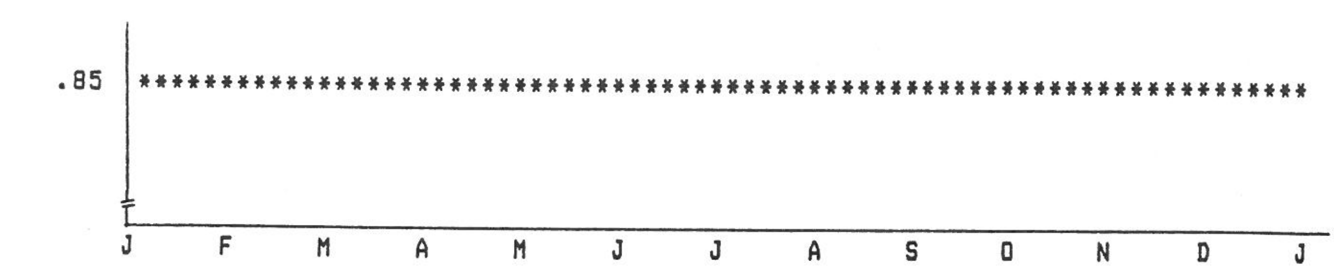
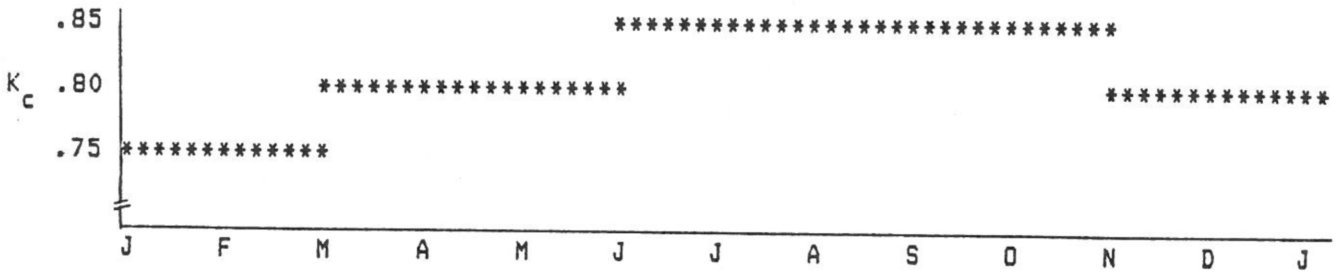


Table 2.3.3 Crop coefficients for different groups of crops. (continued)

Group 10: Perennial crops



We slightly modified the table of efficiencies (Table 2.3.2) after doing the MODSIM calibration because we felt that the values were a little high.

2.3.4. Historical system operation

The historical system behavior can be analyzed under two situations:

a. Operation of the hydroelectric power plant and Valdesia reservoir: the most important variables are water levels, releases and power generation (see Figures 2.3.1, 2.3.2, and 2.3.3). As we can see in these figures the operation of the reservoir does not follow a precise operation rule generating conflicts in the power generation and water irrigation demands, especially in the dry season.

b. Water delivered to the irrigation canals M. Cabral and Nizao-Najayo (see Figures 2.4.3, 2.4.4 and 2.4.5 in Chapter 2.4). These releases are dependent on the hydrology of the Nizao River and the pattern of water releases of Valdesia and Las Barias Reservoirs.

2.4 Model calibration from historical data.

The normal operation studies basically require two computer programs. The first one is a dynamic programming model called CSUDP which will be used for screening alternative operational strategies for the Valdesia Reservoir System. The second program is a river system simulation model named MODSIM which is being used for detailed operational analysis of the system and allocation of water among the several demand nodes. These two programs work together: CSUDP gives optimal operation rules which can be input to MODSIM to improve system performance. The idea is that simulation and optimization

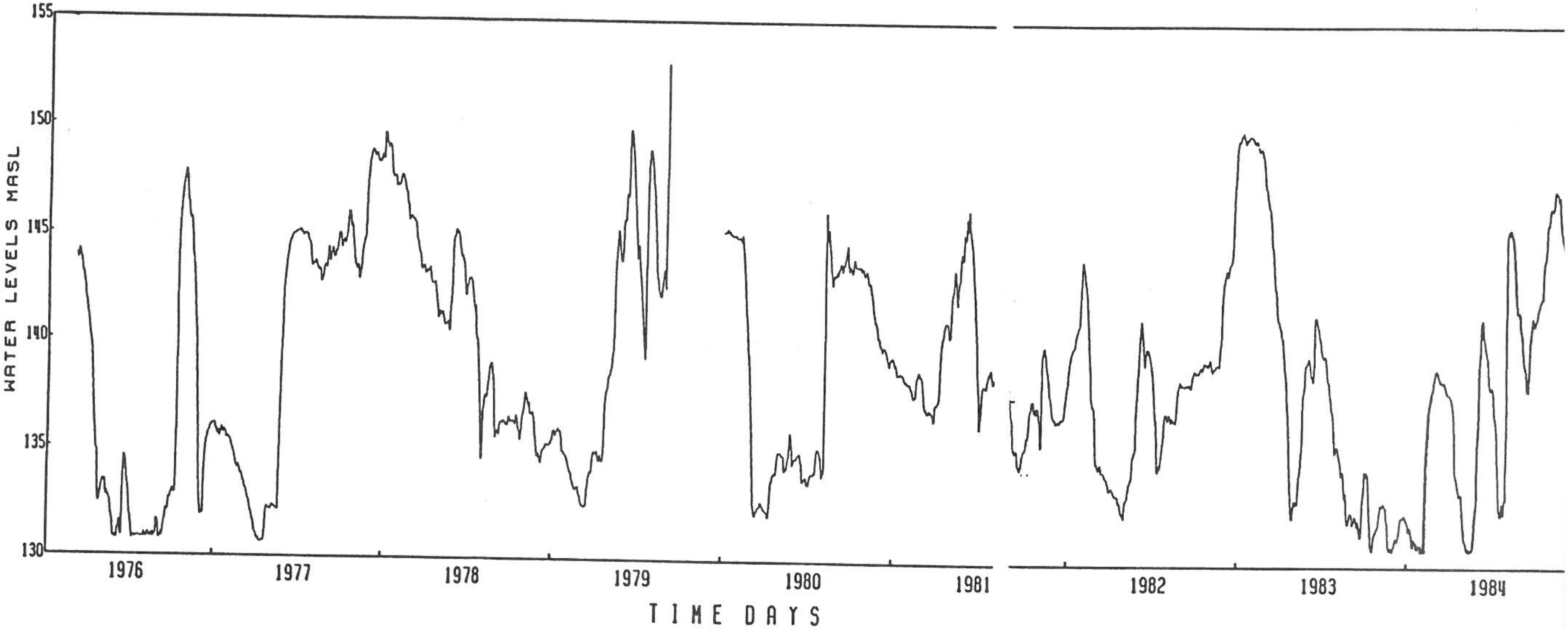


FIGURE 2.3.1 DAILY WATER LEVELS (18:00 HRS) AT VALDESIA R SERVOIR

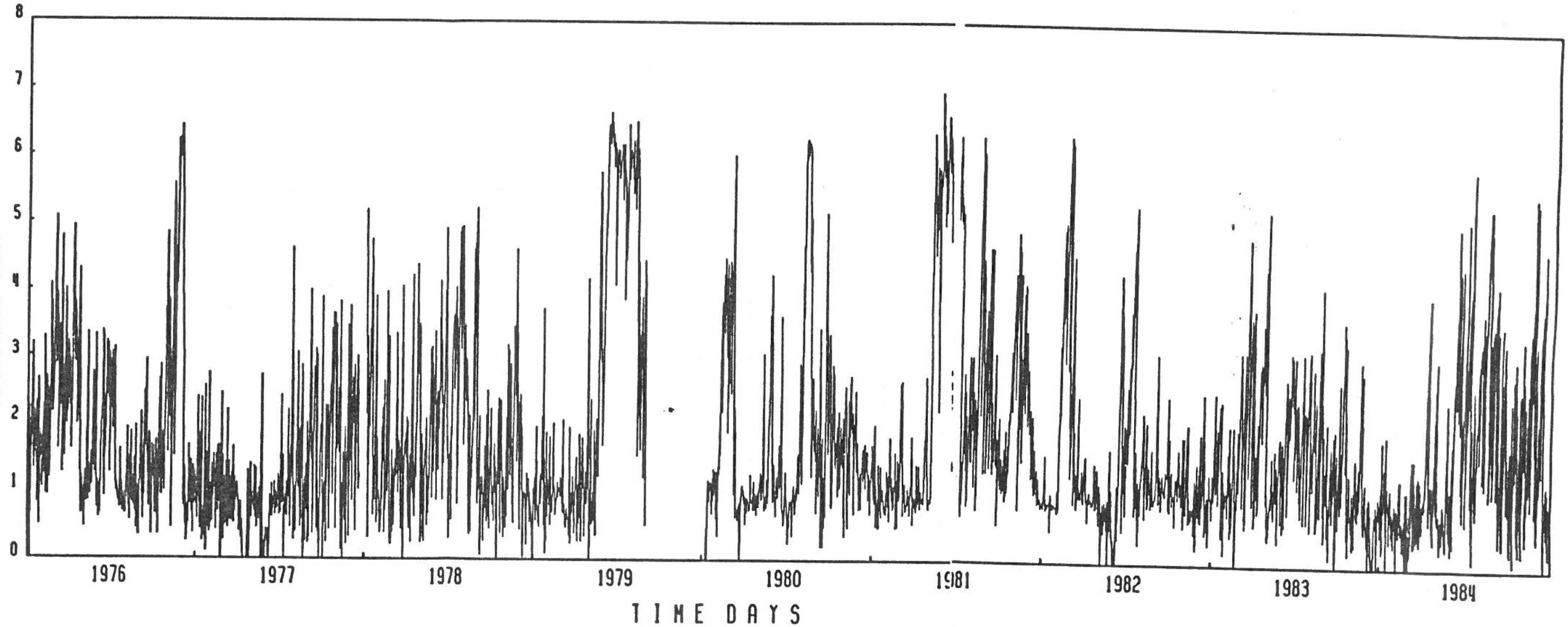


FIGURE 2.3.2 DAILY ENERGY RELEASES FOR VALDESIA RESERVOIR

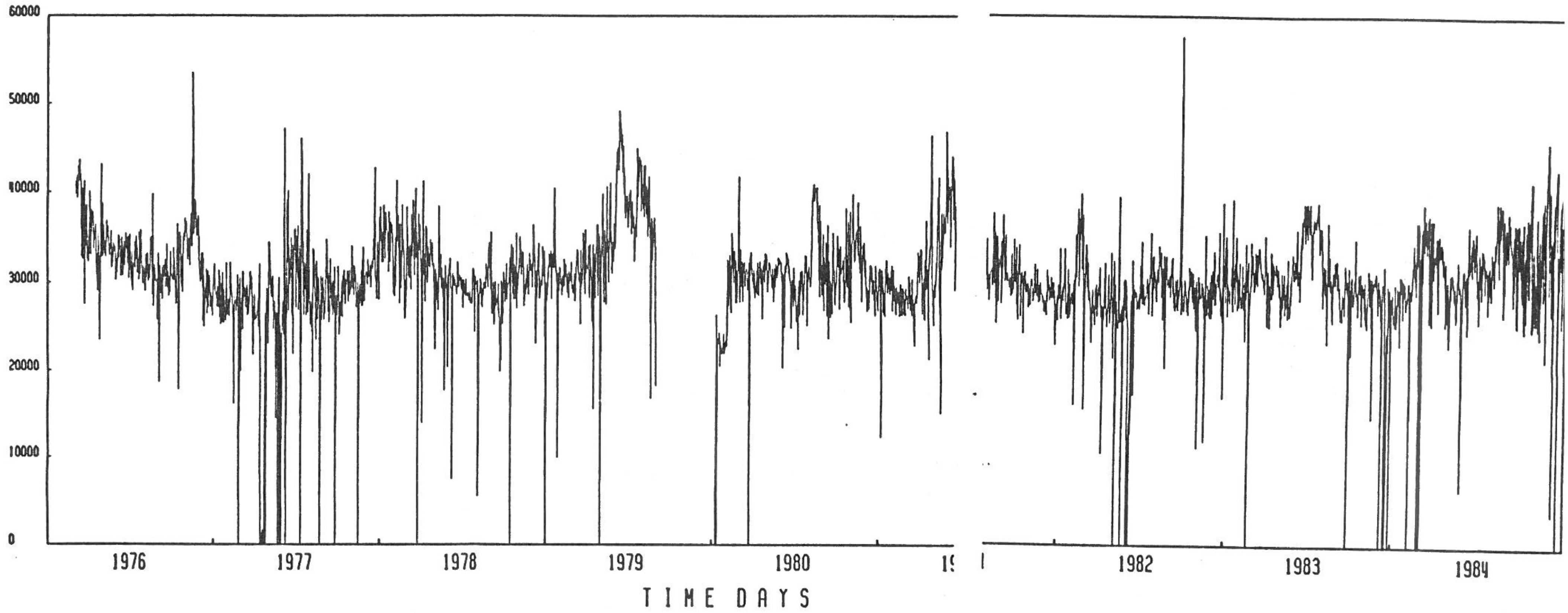


FIGURE 2.3.3 DAILY POWER GENERATED AT VALDESIA RESER OIR

should be used together. The former can more accurately depict the operation of the entire system, whereas the latter can be useful in helping find optimal operating guidelines for the simulation. The objective of the calibration phase is to develop a computer model that, based on successful reproduction of the historical values, can reproduce the system behavior for future optimal operation of the integrated system.

2.4.1. Calibration runs of the CSUDP Program

a. Program setup and data input

The calibration of CSUDP is initially based on monthly data as shown in Table 2.4.1. The results from the CSUDP runs will then be input into MODSIM as dynamic operating rules.

The elevation-area-volume relations for Valdesia reservoir are shown in Table 2.4.2 and those for Las Barias are given in Table 2.4.3. Table 2.4.4 gives the power that can be generated for different amounts of discharge and elevations.

CSUDP runs require three user-supplied subroutines and one input data file. Subroutine STATE, for this particular case, includes data for the elevation-area-volume curve (CEAV), the net precipitation over the reservoir (PME) and the Nizao river inflows (AP). It calculates the releases (U) based on given initial (X) and final (X1) levels of the reservoir in a current period. The model actually optimizes target end-of-period storage levels (X1) directly, rather than releases. This is considered more reasonable for weekly or monthly time intervals.

Subroutine OBJECT includes data for the number of energy hours per month (XNH), the power table based on reservoir level and discharge (CEPQ), the historical energy generated (EQ), and the water released for power (AGT). Based on interpolations of power for different levels of releases

TABLE 2.4.1 MONTHLY DATA FOR VALDESIA RESERVOIR (Source CDE)

Year	Month	Precipitation - Evaporation (mm) PME	Inflows ($10^6 m^3$) AP	Reservoir Levels (M.O.S.L)	Hour of Gen. (Hrs) XNH	Water Power Release	Energy Generated (GW-h) EG
1982	January	- 75.80	48.31	137.72	257.15	26.14	3.65
	February	- 69.30	75.17	141.19	837.75	98.14	14.57
	March	-160.10	27.42	137.12	398.05	47.78	6.33
	April	- 45.40	23.20	133.59	267.70	28.93	3.73
	May	193.30	45.49	132.42	208.17	22.37	2.90
	June	243.20	57.08	137.30	441.32	44.53	6.36
	July	- 96.60	48.31	139.45	579.90	61.89	8.53
	August	-106.70	45.91	136.85	341.27	37.62	5.18
	September	40.10	39.24	138.77	350.12	37.38	5.23
	October	- 23.60	34.19	138.70	302.10	31.02	4.34
	November	- 49.00	35.23	139.25	265.50	26.76	3.75
	December	-125.70	82.67	140.85	301.95	30.09	4.54
							69.11
1983	Janurary	-124.50	56.53	148.11	384.12	41.59	6.61
	February	- 65.20	22.30	149.84	342.95	32.10	5.15
	March	- 18.70	22.52	148.61	725.70	74.11	11.47
	April	17.70	17.84	141.18	566.97	62.64	8.64
	May	246.70	68.25	132.57	299.58	32.65	4.40
	June	97.50	65.43	139.28	512.02	60.43	8.87
	July	- 83.00	34.07	140.34	461.73	57.87	8.27
	August	116.90	36.33	135.48	433.87	50.13	6.60
	September	15.00	34.68	132.49	265.13	29.98	3.82
	October	- 28.70	39.14	133.60	410.22	47.14	6.05
	November	-116.20	28.48	131.79	281.95	32.64	4.15
	December	-111.50	21.82	130.59	140.45	15.66	1.97
							76.00
					TOTAL		145.11

Table 2.4.2 Elevation-Area-Volume for Valdesia Reservoir.
(Source: CDE)

ELEVATION (M.A.S.L.)	AREA ($10^3 m^2$)	Volume $10^3 m^3$ ORIGINAL	SINCE MAY 1981
95	38	38	0
100	150	508	0
105	324	1693	0
110	871	4680	600
115	1572	10788	1173
120	2310	20493	6182
125	3406	34808	16214
130	4537	54669	32163
135	5664	80168	53736
140	6677	111021	80145
145	7492	146443	113465
150	8357	186066	153688
155	9000	229458	196487
160	9776	276398	243421

Table 2.4.3 Elevation-Area-Volume Relations for Las Barias Reservoir. (Source: CDE)

ELEVATION (M.A.S.L.)	AREA $10^3 m^2$)	VOLUME $(10^3 m^3)$
69	0	0
70	52	50
72	190	240
73	310	450
74	460	800
75	640	1400
76	805	2100
77	910	3000
78	1000	4000
80	1140	6050

TABLE 2.4.4 POWER (Mw) FOR DIFFERENT VALUES OF ELEVATION AND DISCHARGE.

Discharge (m^3/s)	Elevation (M.O.S.L.)						
0	130.75	134	137	141	144	147	150
20	8.0	8.3	8.7	9.0	9.3	9.9	10.5
25	10.7	11.2	11.8	12.5	13.0	13.6	14.4
30	13.2	14.1	14.9	16.0	16.8	17.4	18.2
32.5	14.5	15.6	16.4	17.7	18.5	19.2	20.0
35	15.6	16.8	17.8	19.2	20.2	20.9	21.8
37.5	16.6	17.9	19.1	20.4	21.6	22.4	23.5
40	17.5	18.9	20.3	21.7	22.9	23.8	24.9
42.5	18.4	19.8	21.3	22.7	24.0	25.1	26.0
45	19.0	20.5	22.0	23.5	24.9	26.1	27.0

and reservoir heads, OBJECT calculates the theoretical generated energy. It also minimizes the square error of the theoretical and historical releases (run #1) and minimizes the square error of the theoretical and historical generated power (run #2) for calibration purposes. This has been done also with two more runs with the CSUDP model with the idea to maximize the total energy qeneration (run #3) and maximize the minimum generation in any month (run #4) for firm energy considerations.

Subroutine READIN has not been used, but the main program calls it at the beginning of each stage, so in the future it can be useful for data input or other calculations.

b. Results

Typical samples of Subroutines OBJECT, STATE, and input data file, are shown in Figures 2.4.1, 2.4.2, and 2.4.3. All the runs were made with the new version of the program named CSUDPIBM for the IBM PC microcomputer.

Figure 2.4.4 gives the results of the calibration model for minimizing the difference between the observed and calculated releases (run #1). A sample CSUDP output for this run is given in Figure 2.4.5. In all these runs, a splicing option was used where initial coarse increments on storage are used and then successively spliced to more accurate levels. Figure 2.4.6 presents results of minimizing the deviation between the historical and calculated power releases (run #2).

Figure 2.4.7 shows the water levels resulting from run #1, and Figure 2.4.8 displays the water levels from run #2. Figures 2.4.9 and 2.4.10, 2.4.11, and 2.4.12 show the water releases and levels of Valdesia reservoir for runs #3 and #4: maximization of energy and max(min) of monthly energy.

Figure 2.4.1 Subroutine STATE for CSUDP Run #1

```
      SUBROUTINE STATE
C
C     THIS SUBROUTINE CALCULATES THE MONTHLY WATER POWER RELEASES
C
C     CEAV : DATA FOR THE CURVES ELEVATION-AREA-VOLUME
C     PME  : NET PRECIPITATION (PRECIP-EVAPOR) IN MM
C     AP   : INFLOW IN MCM
C     X    : WATER LEVEL AT THE INITIAL OF THE MONTH IN M.O.S.L.
C     X1   : WATER LEVEL AT THE END OF THE MONTH IN M.O.S.L.
C     U    : WATER POWER RELEASES (MCM)
C
      COMMON/ONEDM/X,X1,U,F,I,J,K,L,R,PNALTY
      DIMENSION CEAV(14,3),PME(24),AP(24)
      DATA CEAV/95.,100.,105.,110.,115.,120.,125.,130.,135.,140.,145.,
     *150.,155.,160.,38.,150.,324.,871.,1572.,2310.,3406.,4537.,5664.,
     *6677.,7492.,8357.,9000.,9776.,0.,0.,0.,600.,1173.,6182.,16214.,
     *32163.,53736.,80145.,113465.,153088.,196481.,243421./
      DATA PME/-75.80,-69.30,-160.1,-45.4,193.3,243.2,-96.6,-106.7,40.1,
     *-23.6,-40.9,-125.7,-124.5,-65.2,-18.7,17.7,246.7,97.5,-83.0,116.9,
     *15.0,-28.7,-116.2,-111.5/
      DATA AP/48.31,75.17,27.42,23.2,45.49,57.08,48.31,45.91,
     *39.24,34.19,35.23,82.67,56.53,22.30,22.52,17.84,68.25,65.43,
     *34.07,36.33,34.68,39.14,28.48,21.82/
      DO 1 I10=1,14
      IF(X.GT.CEAV(I10,1))GO TO 1
      K10=I10
      GO TO 2
    1 CONTINUE
      K10=14
    2 DO 3 I10=1,14
      IF(X1.GT.CEAV(I10,1))GO TO 3
      K11=I10
      GO TO 4
    3 CONTINUE
      K11=14
    4 A0=CEAV(K10-1,2)+(CEAV(K10,2)-CEAV(K10-1,2))*(X-CEAV(K10-1,1))/
     *(CEAV(K10,1)-CEAV(K10-1,1))
      S0=CEAV(K10-1,3)+(CEAV(K10,3)-CEAV(K10-1,3))*(X-CEAV(K10-1,1))/
     * (CEAV(K10,1)-CEAV(K10-1,1))
      A1=CEAV(K11-1,2)+(CEAV(K11,2)-CEAV(K11-1,2))*(X1-CEAV(K11-1,1))/
     *( CEAV(K11,1)-CEAV(K11-1,1))
      S1=CEAV(K11-1,3)+(CEAV(K11,3)-CEAV(K11-1,3))*(X1-CEAV(K11-1,1))/
     *(CEAV(K10,1)-CEAV(K10-1,1))
      U=(S0-S1)/1000.+AP(I)+PME(I)*(A0+A1)*.5E-6
C     WRITE(IN,101)X,X1,A0,S0,S1,U
C 101 FORMAT('X=',F8.1,'X1=',F8.1,'A0=',F8.1,'S0=',F8.1,
C    * 'S1=',F8.1,'U=',F8.1)
      RETURN
      END
```

Figure 2.4.2 Subroutine OBJECT for CSUDP Run #1

```
      SUBROUTINE OBJECT
C
C     THIS SUBROUTINE CALCULATES THE SQUARE DIFFERENCE BETWEEN THE
C     HISTORICAL AND CALCULATED VALUES OF RELEASES AND POWER
C
C     XNH  : POWER GENERATION HOURS PER MONTH
C     CEPQ : DATA FROM THE ELEVATION-AREA-VOLUME TABLE
C     EG   : HISTORICAL POWER GENERATED PER MONTH (GWH)
C     EG1  : CALCULATED POWER PER MONTH (GWH)
C     AQT  : HISTORICAL WATER POWER RELEASE PER MONTH (MCM)
C     U    : CALCULATED WATER POWER RELEASE PER MONTH (MCM)
C
      COMMON/ONEDM/X,X1,U,F,I,J,K,L,R,PNALTY
      DIMENSION XNH(24),CEPQ(10,8),EG(24),AGT(24)
      DATA XNH,CEPQ,EG/257.15,873.75,398.05,267.70,208.17,441.32,
     1579.90,341.27,350.12,302.10,265.50,301.95,384.12,342.95,725.70,
     2566.97,299.58,512.02,461.73,433.87,265.13,410.22,281.95,140.45,
     30.0,20.0,25.0,30.0,32.5,35.0,37.5,40.0,42.5,45.0,
     4130.75,8.0,10.7,13.2,14.5,15.6,16.6,17.5,17.7,19.0,
     5134.0,8.3,11.2,14.1,15.6,16.8,17.9,18.9,19.8,20.5,
     6137.0,8.7,11.8,14.9,16.4,17.8,19.1,20.3,21.3,22.0,
     7141.0,9.0,12.5,16.0,17.7,19.2,20.4,21.7,22.7,23.5,
     8144.0,9.3,13.0,16.8,18.5,20.2,21.6,22.9,24.0,24.9,
     9147.0,9.9,13.6,17.4,19.2,20.9,22.4,23.8,25.1,26.1,
     1150.0,10.5,14.4,18.2,20.0,21.8,23.5,24.9,26.0,27.0,
     23.65,14.57,6.33,3.73,2.90,6.36,8.53,5.18,5.23,4.34,3.75,4.54,
     36.61,5.15,11.47,8.64,4.4,8.87,8.27,6.6,3.82,6.05,4.15,1.97/
      DATA AGT/26.14,98.14,47.78,28.93,22.37,44.53,61.89,37.62,
     *37.38,31.02,26.76,30.09,41.59,32.10,74.11,62.64,32.65,
     *60.43,57.87,50.13,29.98,47.14,32.64,15.66/
      XPROM=(X+X1)/2.
      Q=U/XNH(I)*1E6/3600
      IF(Q.GT.CEPQ(2,1))GO TO 5
      IQ=3
      GO TO 21
    5 DO 1 I10=2,10
      IF(Q.GT.CEPQ(I10,1))GO TO 1
      IQ=I10
      GO TO 21
    1 CONTINUE
      IQ=10
   21 IF(XPROM.GT.CEPQ(1,2))GO TO 2
      IX=3
    2 DO 3 I10=2,8
      IF(XPROM.GT.CEPQ(1,I10))GO TO 3
      IX=I10
      GO TO 4
    3 CONTINUE
      IX=8
    4 PP=CEPQ(IQ-1,IX-1)+(CEPQ(IQ-1,IX)-CEPQ(IQ-1,IX-1))*(XPROM-CEPQ(1,
     *IX-1))/(CEPQ(1,IX)-CEPQ(1,IX-1))
```

```
      PP1=CEPQ(IQ,IX-1)+(CEPQ(IQ,IX)-CEPQ(IQ,IX-1))*(XPROM-CEPQ(1,
     *IX-1))/(CEPQ(1,IX)-CEPQ(1,IX-1))
      POT=(PP1-PP)*(Q-CEPQ(IQ-1,1))/(CEPQ(IQ,1)-CEPQ(IQ-1,1))+PP
      EG1=POT*XNH(I)*1E-3
      EDIFF=EG1-EG(I)
C     F=(EG1-EG(I))**2
      F=(U-AGT(I))**2
C     F=EG1
      RETURN
      END
```

Figure 2.4.3 CSUDP INPUT DATA FILE (FILE5)

```
CSUDP CALIBRATION FOR VALDESIA RESERVOIR. RUN #1
  1    1   24    1    1    1
  1    0    0    1    0    1
     2.7       .05       .1       .0      3.0      3.0
  3
  1      137.7     137.7
  2      130.0     150.0
 25      132.1     132.1
  1
  1         0.       100.
```

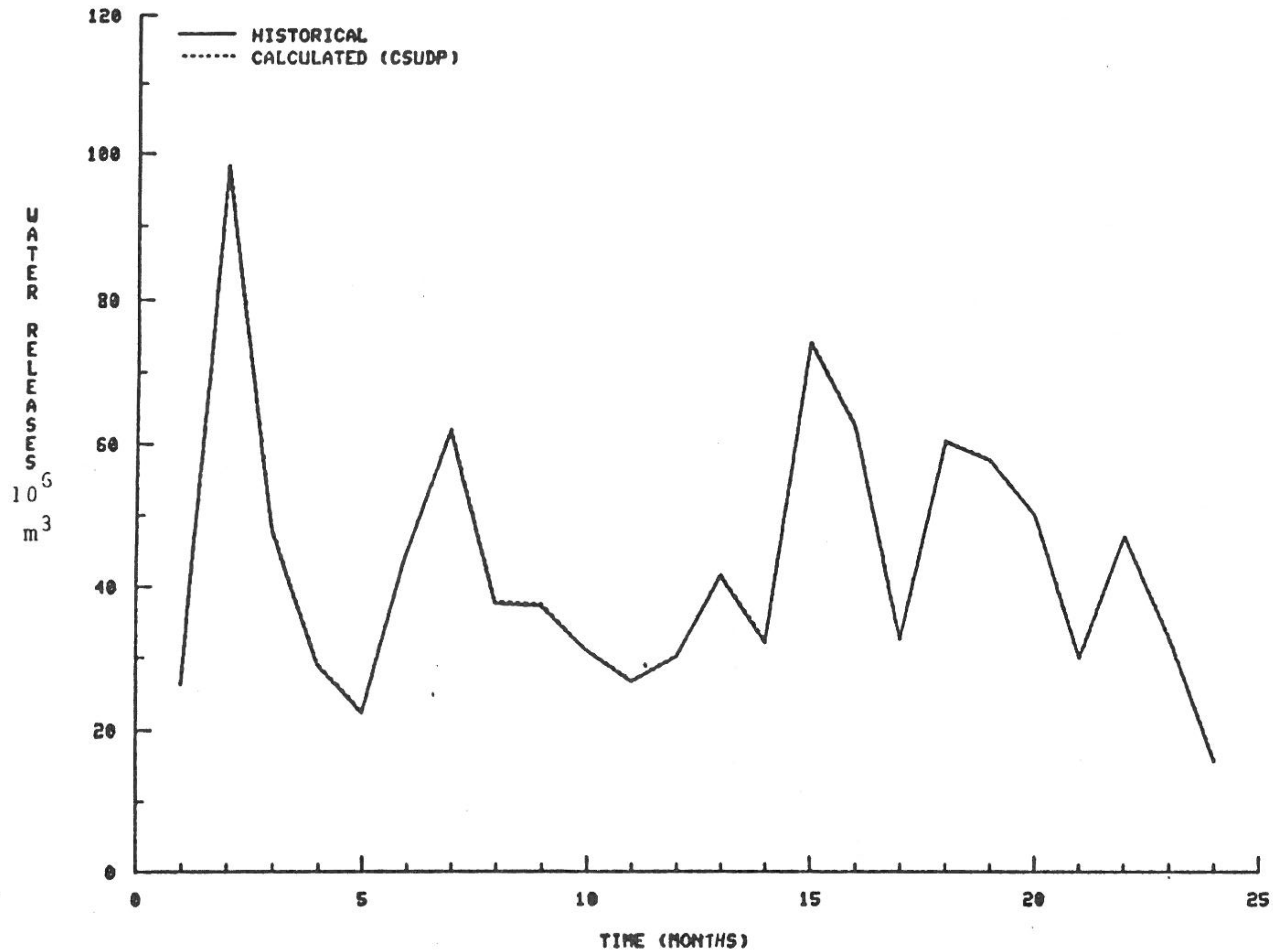


FIG. 2.4.4 MONTHLY POWER RELEASES FOR VALDESIA RES. (1982-83). RUN 1

FIGURE 2.4.5

```
TITLE     CSUDP CALIBRATION FOR VALDESIA RESERVOIR. RUN #1
-----
***************************************
*                                     *
*        1 DIMENSIONAL PROBLEM        *
*                                     *
*         MINIMIZATION PROBLEM        *
*                                     *
*     OBJECTIVE IS SUMMATION TYPE     *
*                                     *
*      DETERMINISTIC OPTIMIZATION     *
*                                     *
*      PROBLEM ASSUMED INVERTIBLE     *
*                                     *
*         LAST TIE VALUE TAKEN        *
*                                     *
*       SPLICING WILL OCCUR ON X      *
*         SPLICE =  3.000             *
*         XMULT =   3.000             *
*                                     *
*        NUMBER OF STAGES = 24        *
*                                     *
*                                     *
***************************************

INTERVAL FOR X =  2.700
INTERVAL FOR U =  .1000
TOLERANCE =  .0000
```

UPPER AND LOWER BOUNDS ON X(I+1) AND U(I)

I	XMIN(I)	XMAX(I)	UMIN(I)	UMAX(I)
1	137.7	137.7	.0000	100.0
2	130.0	150.0	.0000	100.0
3	130.0	150.0	.0000	100.0
4	130.0	150.0	.0000	100.0
5	130.0	150.0	.0000	100.0
6	130.0	150.0	.0000	100.0
7	130.0	150.0	.0000	100.0
8	130.0	150.0	.0000	100.0
9	130.0	150.0	.0000	100.0
10	130.0	150.0	.0000	100.0
11	130.0	150.0	.0000	100.0
12	130.0	150.0	.0000	100.0
13	130.0	150.0	.0000	100.0
14	130.0	150.0	.0000	100.0
15	130.0	150.0	.0000	100.0
16	130.0	150.0	.0000	100.0
17	130.0	150.0	.0000	100.0
18	130.0	150.0	.0000	100.0

19	130.0	150.0	.0000	100.0
20	130.0	150.0	.0000	100.0
21	130.0	150.0	.0000	100.0
22	130.0	150.0	.0000	100.0
23	130.0	150.0	.0000	100.0
24	130.0	150.0	.0000	100.0
25	132.1	132.1		

OPTIMAL SOLUTION FOR X(1) = 137.700

I	X*	U*
1	137.7000	30.30000
2	140.8000	90.10000
3	138.1000	52.80000
4	132.7000	34.60000
5	130.0000	22.80000
6	135.4000	44.30000
7	138.1000	62.00000
8	135.4000	45.30000
9	135.4000	39.50000
10	135.4000	34.10000
11	135.4000	20.70000
12	138.1000	28.90000
13	146.2000	34.10000
14	148.9000	43.20000
15	146.2000	75.30000
16	138.1000	55.90000
17	130.0000	31.60000
18	138.1000	66.00000
19	138.1000	59.90000
20	132.7000	48.50000
21	130.0000	23.10000
22	132.7000	50.70000
23	130.0000	28.00000
24	130.0000	12.20000
25	132.1000	

MINIMUM OBJECTIVE VALUE = 609.2175

.
.
.

CONTINUE THE ITERATIONS UNTIL FINAL RESULTS ARE OBTAINED

.
.
.

I	X*	U*
1	137.7000	26.30000
2	141.4000	98.30000
3	137.3000	47.90000
4	132.8500	29.00000
5	131.4500	22.50000
6	136.6500	44.60000
7	139.3000	62.20000
8	136.5500	37.90000
9	137.9500	37.60000
10	138.3000	31.10000
11	138.8500	26.90000
12	140.3000	30.20000
13	147.5500	41.70000
14	149.3000	32.50000
15	147.9500	74.40000
16	140.7000	62.80000
17	131.8000	32.90000
18	139.3500	60.60000
19	140.3000	58.00000
20	135.7500	50.20000
21	132.8500	30.20000
22	133.9000	47.20000
23	132.0000	32.90000
24	130.8500	15.90000
25	132.1000	

MINIMUM OBJECTIVE VALUE = .9255104

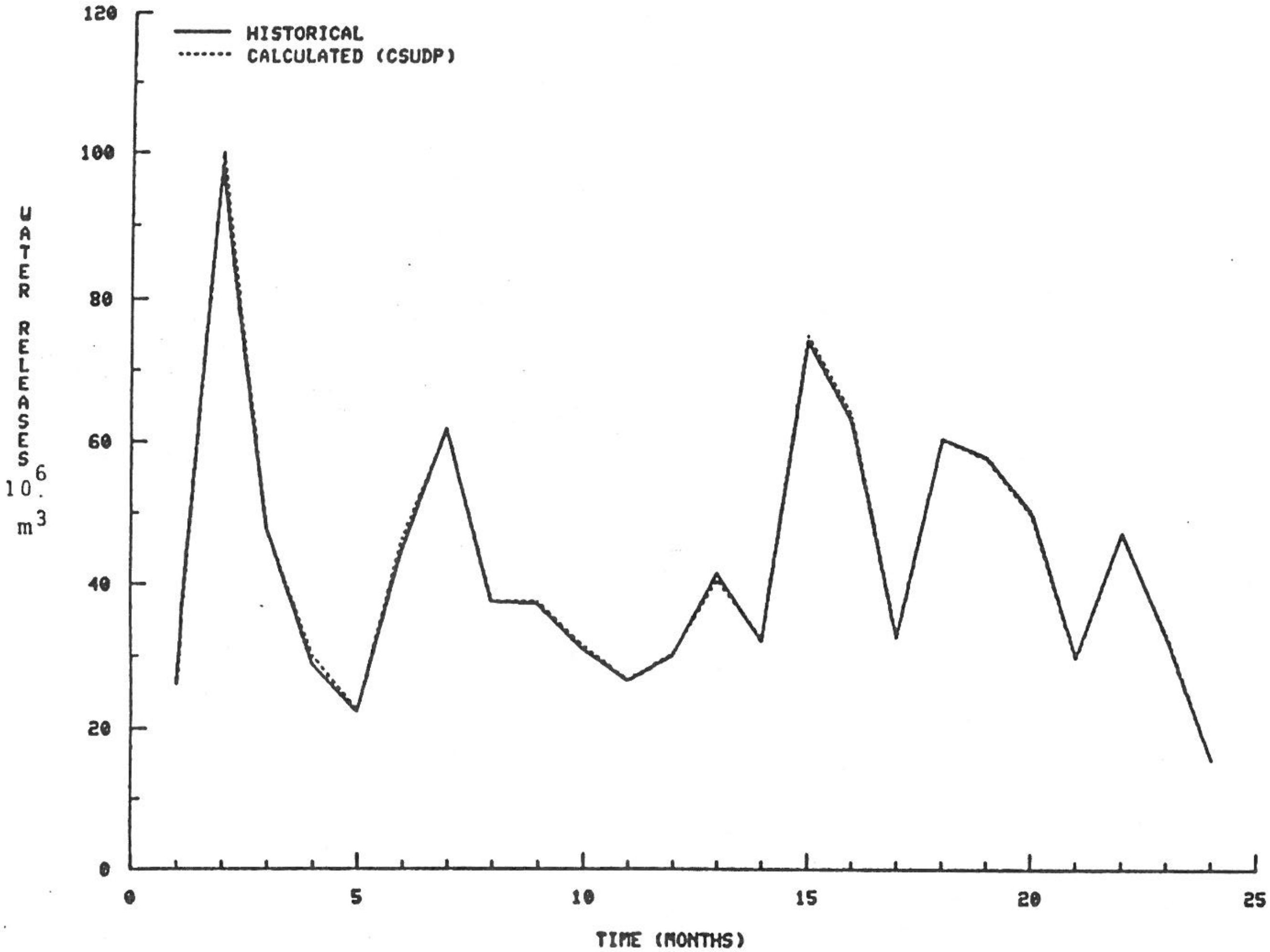


FIG. 2.4.6 MONTHLY POWER RELEASES FOR VALDESIA RES.(1982-83). RUN 2

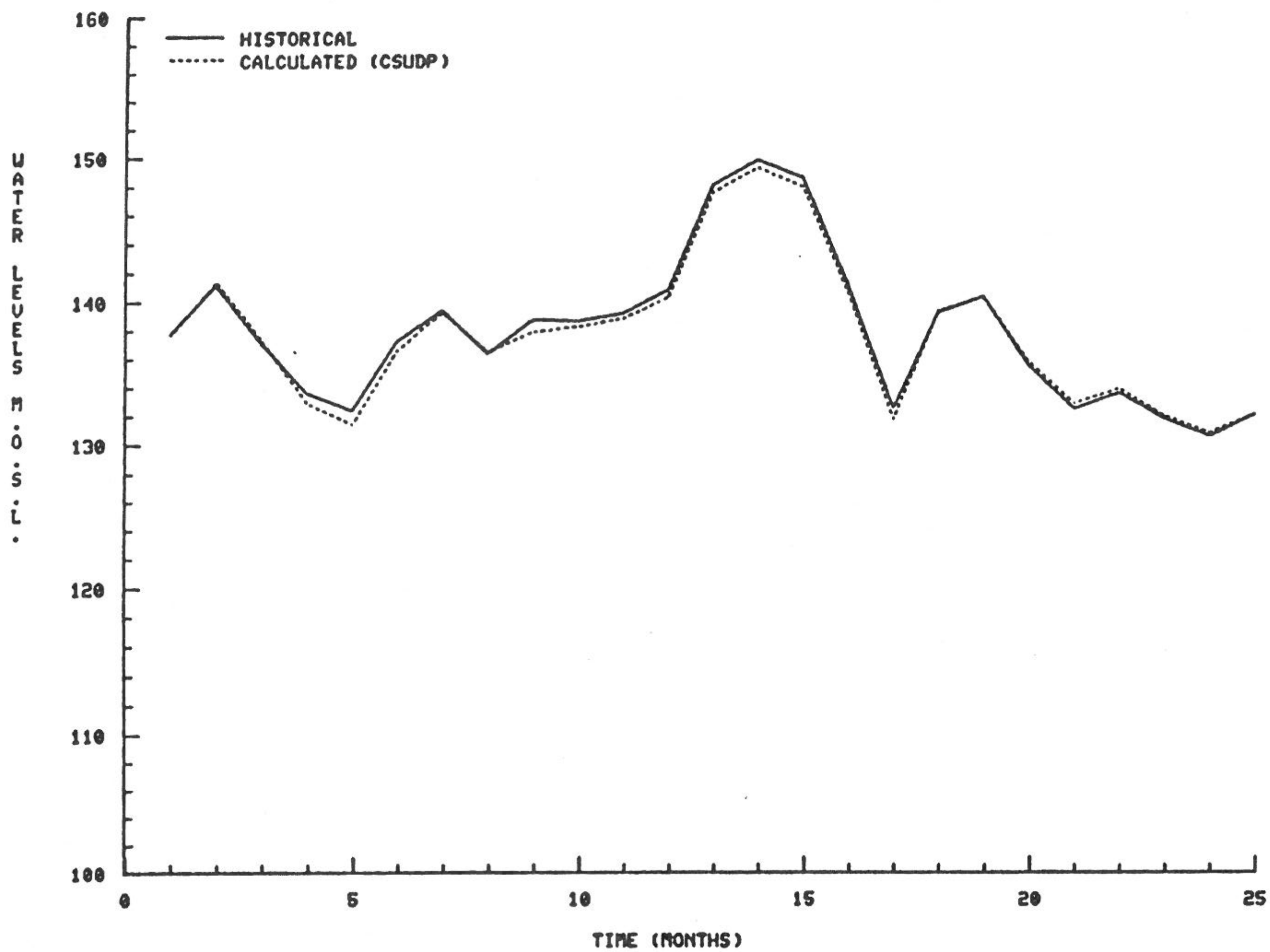


FIG. 2.4.7 MONTHLY RESERVOIR LEVELS FOR VALDESIA (1982-83). RUN 1

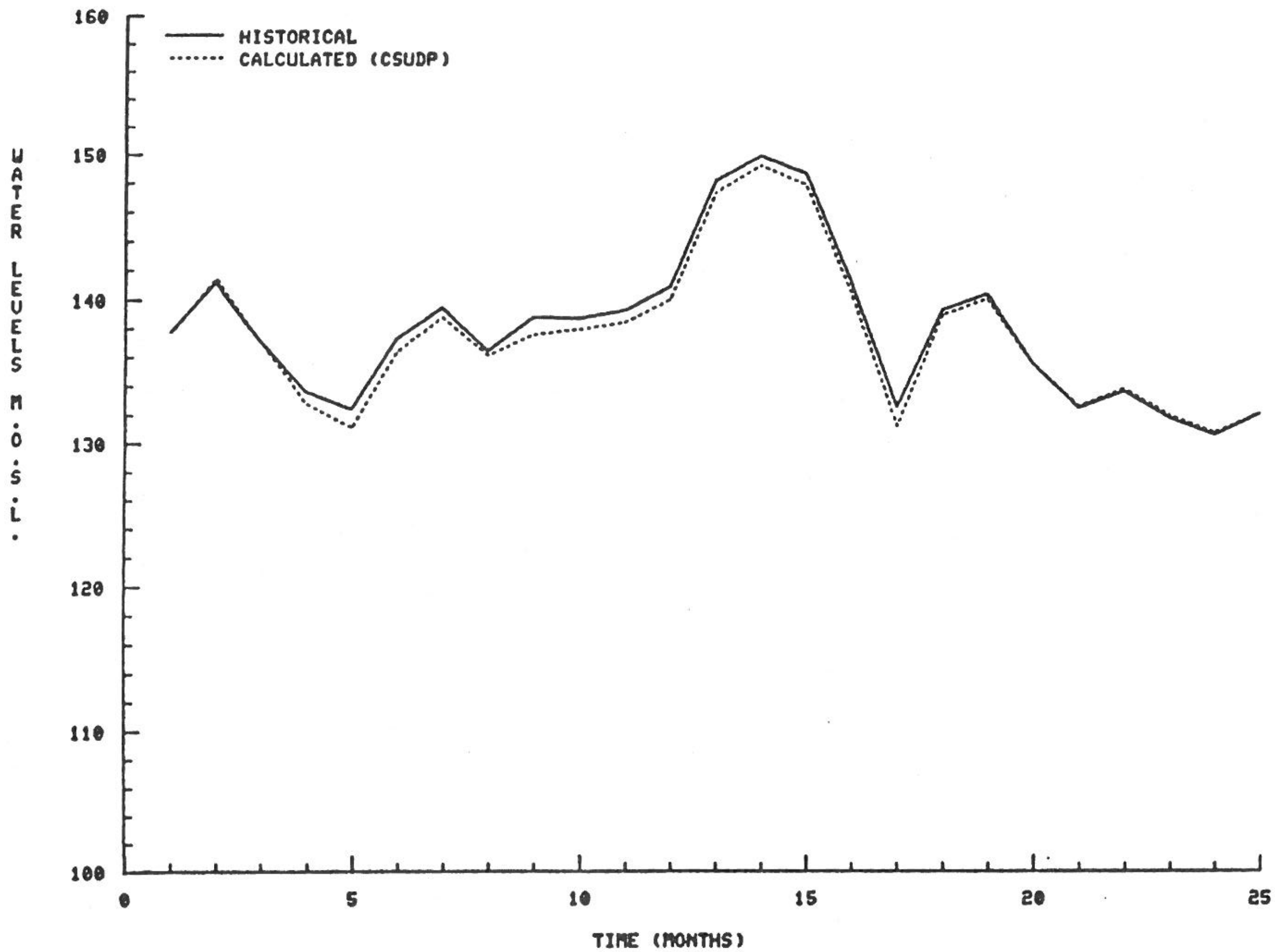


FIG. 2.4.8 MONTHLY RESERVOIR LEVELS FOR VALDESIA (1982-83). RUN 2

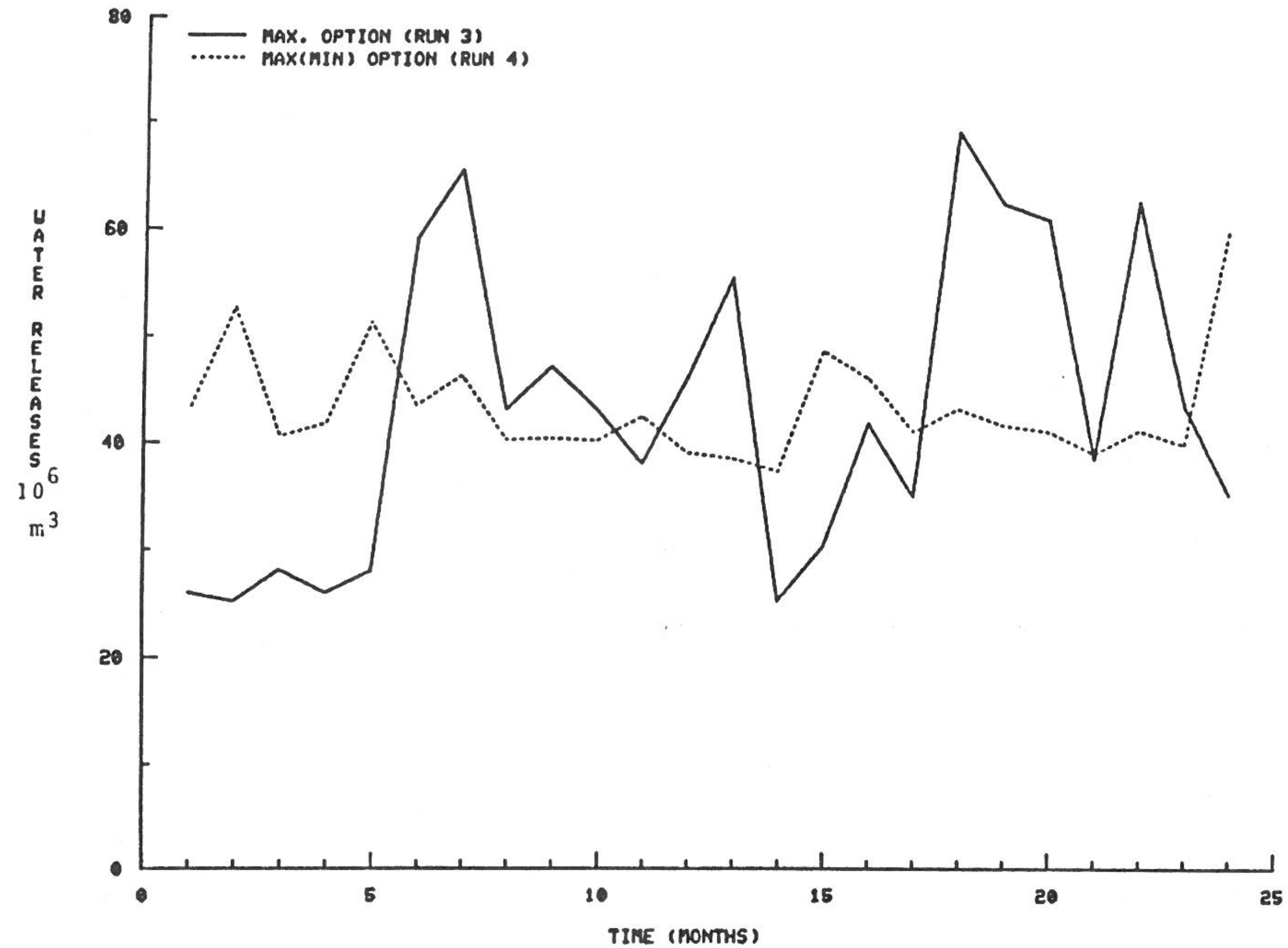


FIG. 2.4.9 WATER POWER RELEASES MAXIMIZATION - VALDESIA RES. (1982-83)

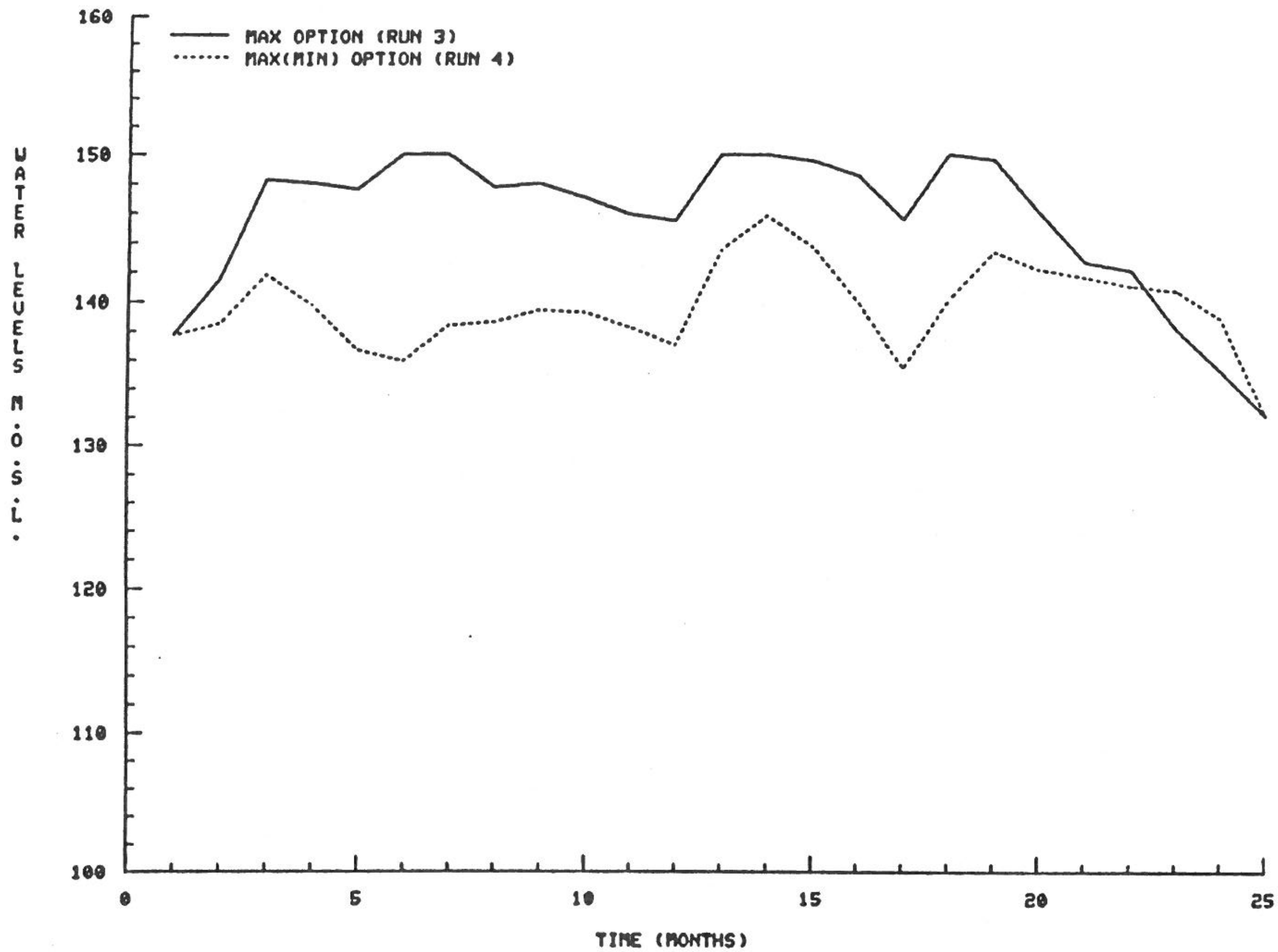


FIG. 2.4.10 WATER LEVELS MAXIMIZATION - VALDESIA RES. (1982-83)

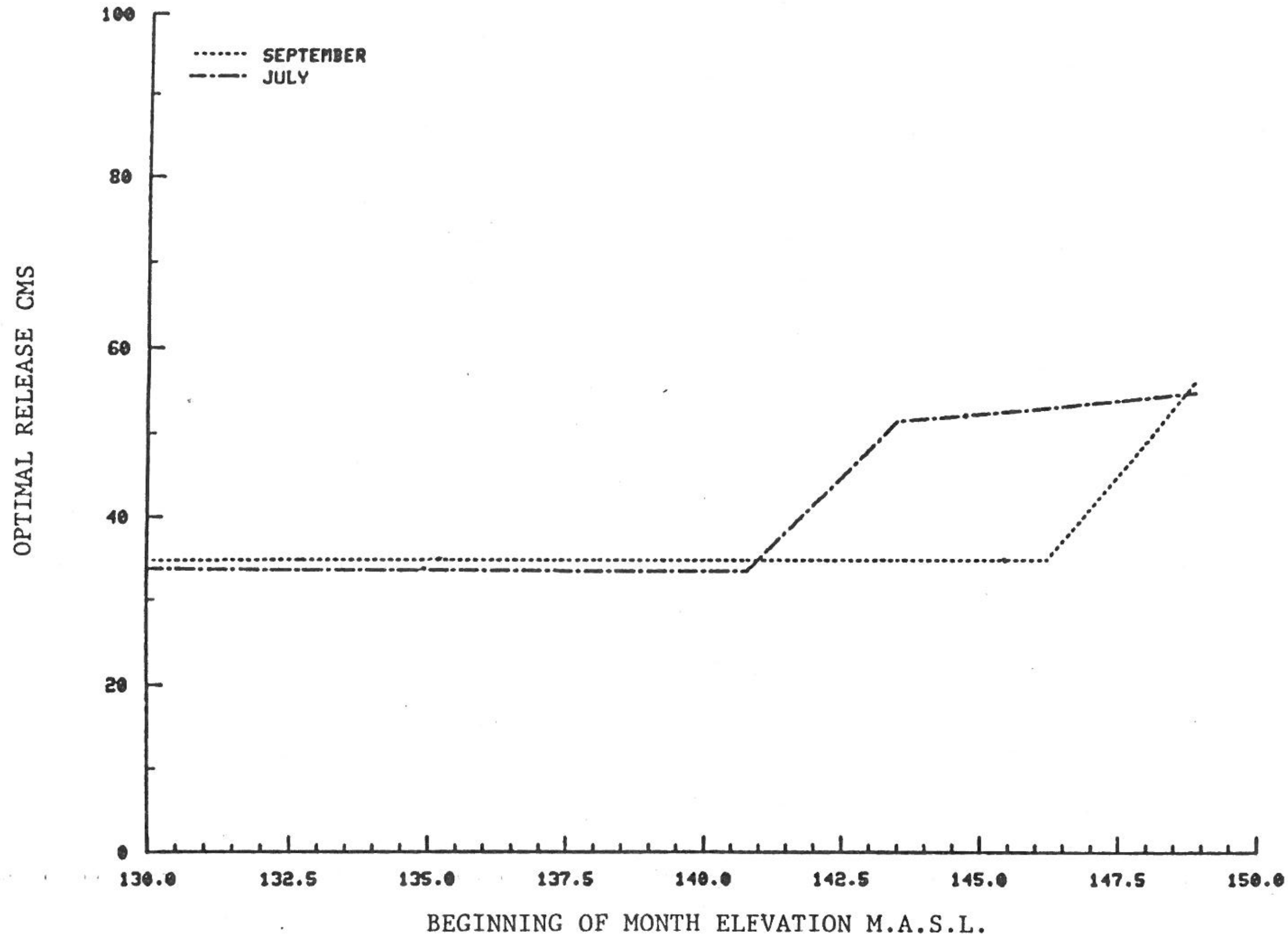


FIG. 2.4.11 CSUDP POLICIES FOR RELEASES (MAX(MIN) OPTION)-VALDESIA R. 1983

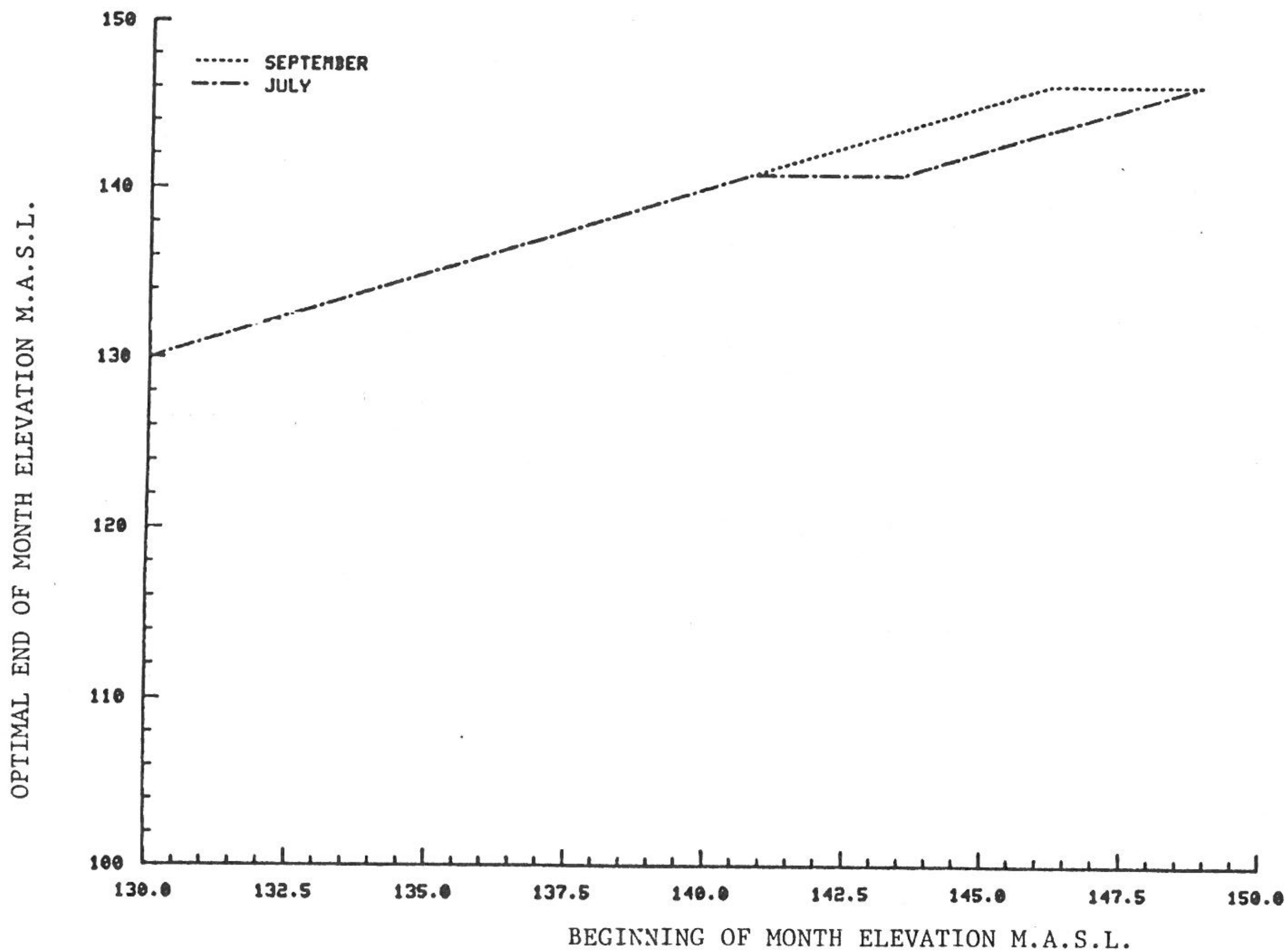


FIG. 2.4.12 CSUDP POLICIES FOR STORAGE (MAX(MIN) OPTION)-VALDESIA R. 1983

The historical total energy over the two year period was 145.11 GWh. Run #3 produced a total of 159.11 GWh, or approximately a 10% increase. Notice that in these runs we always started and ended with the historical reservoir storage. For run #4, total energy is less, but minimum energy in any month was increased from 1.97 GWh to 5.86 GWh, which represents almost a 200% increase in monthly firm or reliable energy. Though the total amount of water released over the two year period is almost the same for all these runs, the monthly distribution of releases differs. Further work in incorporating the irrigation demand model is needed to determine compatibility with the irrigation schedule.

c. <u>Analysis of calibration units</u>

Observing the results of runs 1 and 2, we can conclude that the calibration using either the power releases or the energy generated gives an excellent fit. Runs 3 and 4 show two different ways for future operation of the reservoir. One has the maximization objective function and the other the max-min or firm energy case. The second one releases water in a "smoother" manner than the first one (Figure 2.4.9), but maintains a lower level in the reservoir (Figure 2.4.10).

To show the capability of CSUDP in providing complete feedback operating policy information, a complete stage by stage of all optimal policies is given in Figure 2.4.13 for years 1982 and 1983. This printout is available at the user's option. Notice that these policies give optimal releases U* and end-of-month optimal target storages X1* for all possible discrete levels of initial storage X. These results are displayed graphically in Figures 2.4.11 and 2.4.12 only for two selected months. We can observe the different ways of operation for different months of the year: July (wet period), September (mid-season). This shows the value of

Figure 2.4.13

```
TITLE     CSUDP CALIBRATION FOR VALDESIA RESERVOIR. RUN #4
-----
****************************************
*                                      *
*        1 DIMENSIONAL PROBLEM         *
*                                      *
*         MAXIMIZATION PROBLEM         *
*                                      *
*      OBJECTIVE IS MAX(MIN) TYPE      *
*                                      *
*      DETERMINISTIC OPTIMIZATION      *
*                                      *
*      PROBLEM ASSUMED INVERTIBLE      *
*                                      *
*         LAST TIE VALUE TAKEN         *
*                                      *
*       SPLICING WILL OCCUR ON X       *
*         SPLICE =  3.000              *
*         XMULT =   3.000              *
*                                      *
*        NUMBER OF STAGES = 24         *
*                                      *
*                                      *
****************************************

0         INTERVAL FOR X =  2.700
          INTERVAL FOR U =  .1000
          TOLERANCE =  .0000
```

- UPPER AND LOWER BOUNDS ON X(I+1) AND U(I)

I	XMIN(I)	XMAX(I)	UMIN(I)	UMAX(I)
1	137.7	137.7	26.00	100.0
2	130.0	150.0	25.00	100.0
3	130.0	150.0	28.00	100.0
4	130.0	150.0	25.00	100.0
5	130.0	150.0	28.00	100.0
6	130.0	150.0	17.00	100.0
7	130.0	150.0	25.00	100.0
8	130.0	150.0	29.00	100.0
9	130.0	150.0	26.00	100.0
10	130.0	150.0	26.00	100.0
11	130.0	150.0	25.00	100.0
12	130.0	150.0	29.00	100.0
13	130.0	150.0	28.00	100.0
14	130.0	150.0	25.00	100.0
15	130.0	150.0	28.00	100.0
16	130.0	150.0	28.00	100.0
17	130.0	150.0	28.00	100.0
18	130.0	150.0	27.00	100.0

19	130.0	150.0	29.00	100.0
20	130.0	150.0	30.00	100.0
21	130.0	150.0	27.00	100.0
22	130.0	150.0	24.00	100.0
23	130.0	150.0	25.00	100.0
24	130.0	150.0	16.00	100.0
25	132.1	132.1		

```
1    OPTIMAL POLICIES
     ----------------


     ************
     *          *
     * STAGE 24 *
     *          *
     ************

0           X(24)   130.0       132.7       135.4       138.1       140.8       143.5
146.2     148.9
          U(X(24)   16.00       23.80       35.80       50.10       65.40       83.40
16.00     16.00
           X*(25)   132.1       132.1       132.1       132.1       132.1       132.1
132.1     132.1
          F(X(24)   -.1000E+32 2.891     3.945     5.083     6.368     7.984     -
.1000E+32-.1000E+32



    OPTIMAL POLICIES
    ----------------


     ************
     *          *
     * STAGE 23 *
     *          *
     ************

0           X(23)   130.0       132.7       135.4       138.1       140.8       143.5
146.2     148.9
          U(X(23)   28.00       27.90       27.80       42.00       43.10       45.70
47.10     68.50
           X*(24)   130.0       132.7       135.4       135.4       138.1       140.8
143.5     143.5
          F(X(23)   -.1000E+32  2.891       3.640       3.945       5.083       6.368
7.263     7.984



    OPTIMAL POLICIES
    ----------------
```

```
************
*          *
* STAGE 22 *
*          *
************
```

0

X(22)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(22)	27.40	26.90	39.00	39.00	38.90	38.90	58.40	60.30
X*(23)	132.7	135.4	135.4	138.1	140.8	143.5	143.5	146.2
F(X(22)	2.891	2.982	3.640	3.945	5.083	5.711	6.368	7.263

OPTIMAL POLICIES

```
************
*          *
* STAGE 21 *
*          *
************
```

0

X(21)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(21)	34.70	34.80	34.80	34.80	34.80	34.80	34.80	56.20
X*(22)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	146.2
F(X(21)	2.891	2.982	3.640	3.945	5.083	5.523	5.720	6.368

OPTIMAL POLICIES

```
************
*          *
* STAGE 20 *
*          *
************
```

0

X(20)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9

U(X(20)	36.90	36.90	37.00	37.10	37.10	37.20	56.70	37.30
X*(21)	130.0	132.7	135.4	138.1	140.8	143.5	143.5	148.9
F(X(20)	2.891	2.982	3.640	3.945	5.032	5.228	5.523	5.749

OPTIMAL POLICIES

```
************
*          *
* STAGE 19 *
*          *
************
```

0 X(19)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(19)	33.70	33.60	33.60	33.50	33.50	51.50	53.00	54.80
X*(20)	130.0	132.7	135.4	138.1	140.8	140.8	143.5	146.2
F(X(19)	2.891	2.982	3.640	3.945	4.198	5.032	5.228	5.523

OPTIMAL POLICIES

```
************
*          *
* STAGE 18 *
*          *
************
```

0 X(18)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(18)	42.20	39.70	36.40	50.70	48.10	46.70	44.80	66.20
X*(19)	135.4	138.1	140.8	140.8	143.5	146.2	148.9	148.9
F(X(18)	3.640	3.945	4.198	4.198	5.032	5.228	5.523	5.523

OPTIMAL POLICIES

```
************
*          *
* STAGE 17 *
*          *
************
```

0

X(17)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(17)	45.80	43.40	40.20	36.60	52.00	50.60	48.80	70.30
X*(18)	135.4	138.1	140.8	143.5	143.5	146.2	148.9	148.9
F(X(17)	4.198	4.198	5.032	5.228	5.228	5.523	5.523	5.523

OPTIMAL POLICIES

```
************
*          *
* STAGE 16 *
*          *
************
```

0

X(16)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(16)	28.00	29.60	41.60	44.20	47.60	51.30	55.50	58.90
X*(17)	130.0	130.0	130.0	132.7	135.4	138.1	140.8	143.5
F(X(16)	-.1000E+32	2.861	4.198	4.198	5.032	5.228	5.228	5.523

OPTIMAL POLICIES

```
************
*          *
* STAGE 15 *
*          *
************
```

```
0          X(15)   130.0       132.7       135.4       138.1       140.8       143.5
146.2      148.9
     U(X(15)   28.00       34.10       34.50       36.70       52.00       40.40
59.90      43.80
      X*(16)   130.0       130.0       132.7       135.4       135.4       140.8
140.8      146.2
     F(X(15)   -.1000E+32-.1000E+32  2.861       3.626       4.198       4.260
5.032      5.228
```

OPTIMAL POLICIES

```
************
*          *
* STAGE 14 *
*          *
************
```

```
0          X(14)   130.0       132.7       135.4       138.1       140.8       143.5
146.2      148.9
     U(X(14)   25.00       33.60       34.00       36.20       37.20       39.80
41.30      43.20
      X*(15)   130.0       130.0       132.7       135.4       138.1       140.8
143.5      146.2
     F(X(14)   -.1000E+32-.1000E+32-.1000E+32  2.861       3.626       4.198
4.260      5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE 13 *
*          *
************
```

```
0          X(13)   130.0       132.7       135.4       138.1       140.8       143.5
146.2      148.9
     U(X(13)   32.20       29.50       41.50       40.30       37.70       36.10
34.10      55.50
      X*(14)   135.4       138.1       138.1       140.8       143.5       146.2
148.9      148.9
     F(X(13)   -.1000E+32  2.861       2.861       3.626       4.198       4.260
5.032      5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE 12 *
*          *
************
```

0

X(12)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(12)	44.00	40.30	34.20	48.50	44.30	40.80	60.30	81.60
X*(13)	138.1	140.8	143.5	143.5	146.2	148.9	148.9	148.9
F(X(12)	3.626	4.198	4.260	4.260	5.032	5.032	5.032	5.032

OPTIMAL POLICIES

```
************
*          *
* STAGE 11 *
*          *
************
```

0

X(11)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
U(X(11)	35.00	35.00	35.00	35.00	35.00	34.90	34.90	34.90
X*(12)	130.0	132.7	135.4	138.1	140.8	143.5	146.2	148.9
F(X(11)	3.626	4.198	4.260	4.260	5.032	5.032	5.032	5.032

OPTIMAL POLICIES

```
************
*          *
* STAGE 10 *
*          *
************
```

```
0            X(10)   130.0        132.7       135.4       138.1       140.8       143.5
146.2     148.9
      U(X(10)   34.10        34.10       34.10       34.00       34.00       34.00
34.00     34.00
       X*(11)   130.0        132.7       135.4       138.1       140.8       143.5
146.2     148.9
      F(X(10)   3.626        4.198       4.260       4.260       5.032       5.032
5.032     5.032
```

```
    OPTIMAL POLICIES
     ----------------


     ************
     *          *
     * STAGE  9 *
     *          *
     ************

0            X(  9)   130.0       132.7       135.4       138.1       140.8       143.5
146.2     148.9
      U(X(  9)   39.40        39.40       39.50       39.50       39.50       39.50
39.50     39.60
       X*(10)   130.0        132.7       135.4       138.1       140.8       143.5
146.2     148.9
      F(X(  9)   3.626        4.198       4.260       4.260       5.032       5.032
5.032     5.032
```

```
    OPTIMAL POLICIES
     ----------------


     ************
     *          *
     * STAGE  8 *
     *          *
     ************

0            X(  8)   130.0       132.7       135.4       138.1       140.8       143.5
146.2     148.9
      U(X(  8)   33.70        33.30       45.30       45.20       45.20       45.10
45.10     45.00
       X*(  9)   132.7        135.4       135.4       138.1       140.8       143.5
146.2     148.9
      F(X(  8)   4.110        4.243       4.260       4.260       5.032       5.032
5.032     5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE  7 *
*          *
************
```

```
0            X(  7)   130.0      132.7      135.4      138.1      140.8      143.5
146.2      148.9
        U(X(  7)   47.90      47.80      47.80      47.70      47.70      47.60
47.60      47.50
         X*(  8)   130.0      132.7      135.4      138.1      140.8      143.5
146.2      148.9
        F(X(  7)   4.110      4.243      4.260      4.260      5.032      5.032
5.032      5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE  6 *
*          *
************
```

```
0            X(  6)   130.0      132.7      135.4      138.1      140.8      143.5
146.2      148.9
        U(X(  6)   46.60      46.40      44.30      43.30      40.80      39.40
37.60      59.10
         X*(  7)   132.7      135.4      138.1      140.8      143.5      146.2
148.9      148.9
        F(X(  6)   4.243      4.260      4.260      5.032      5.032      5.032
5.032      5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE  5 *
*          *
************
```

```
0          X(  5)   130.0      132.7      135.4      138.1      140.8      143.5
146.2     148.9
      U(X(  5)   46.40        34.50      32.40      46.70      46.80      46.90
47.00     47.10
       X*(  6)   130.0        135.4      138.1      138.1      140.8      143.5
146.2     148.9
      F(X(  5)   4.243        4.260      4.451      5.032      5.032      5.032
5.032     5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE  4 *
*          *
************
```

```
0          X(  4)   130.0      132.7      135.4      138.1      140.8      143.5
146.2     148.9
      U(X(  4)   25.00        34.60      35.00      37.20      38.30      40.90
42.40     44.20
       X*(  5)   130.0        130.0      132.7      135.4      138.1      140.8
143.5     146.2
      F(X(  4)   -.1000E+32  4.243       4.260      4.451      5.032      5.032
5.032     5.032
```

OPTIMAL POLICIES

```
************
*          *
* STAGE  3 *
*          *
************
```

```
0          X(  3)   130.0      132.7      135.4      138.1      140.8      143.5
146.2     148.9
      U(X(  3)   28.00        38.30      38.60      40.70      41.70      44.30
45.70     47.50
       X*(  4)   130.0        130.0      132.7      135.4      138.1      140.8
143.5     146.2
      F(X(  3)   -.1000E+32-.1000E+32  4.243      4.260      4.451      5.032
5.032     5.032
```

```
    OPTIMAL POLICIES
     ----------------


     ************
     *          *
     * STAGE  2 *
     *          *
     ************

0            X(  2)   130.0      132.7      135.4      138.1      140.8      143.5
146.2      148.9
         U(X(  2)   51.10          48.50      45.10      59.30      56.70      55.10
53.20      74.60
          X*(  3)   135.4          138.1      140.8      140.8      143.5      146.2
148.9      148.9
         F(X(  2)   4.243          4.260      4.451      4.451      5.032      5.032
5.032      5.032



    OPTIMAL POLICIES
     ----------------


     ************
     *          *
     * STAGE  1 *
     *          *
     ************

0          X( 1)  137.7
         U(X( 1)  45.70
          X*( 2)  138.1
         F(X( 1)  4.451
1
    OPTIMAL SOLUTION FOR X(1) = 137.700

    I       X*              U*

    1   137.7000        45.70000
    2   138.1000        59.30000
    3   140.8000        41.70000
    4   138.1000        37.20000
    5   135.4000        32.40000
    6   138.1000        43.30000
    7   140.8000        47.70000
    8   140.8000        45.20000
    9   140.8000        39.50000
   10   140.8000        34.00000
   11   140.8000        35.00000
   12   140.8000        44.30000
   13   146.2000        34.10000
```

14	148.9000	43.20000
15	146.2000	59.90000
16	140.8000	47.60000
17	135.4000	40.20000
18	140.8000	48.10000
19	143.5000	51.50000
20	140.8000	37.10000
21	140.8000	34.80000
22	140.8000	38.90000
23	140.8000	43.10000
24	138.1000	50.10000
25	132.1000	

MAXIMUM OBJECTIVE VALUE = 4.450777

CSUDP in producing general operating rules; either optimal releases as a function of initial storage, or optimal end-of-period target storage levels as a function of initial storage.

In Chapter 2.6 these results have been expanded to the full period of record and then a stochastic approach is introduced to develop the optimal operating rules.

2.4.2. Calibration of the MODSIM model

The MODSIMEP model is a MODSIM model especially developed for the Valdesia Reservoir system in the Dominican Republic. Several modifications were made in the MODSIM simulation model in order to adapt it to the data available and conditions existing in the Valdesia Reservoir system. In particular, the model previously allowed only average turbine efficiencies to be entered. Now, turbine efficiencies can vary with head and discharge, which is much more realistic for the Valdesia system. Another improvement is that now we can consider the number of hours that the turbines are working per period (i.e., week or month) instead of assuming constant work for the whole period of time.

a. Program setup and data input

As shown in Figure 2.1.1, the Valdesia Reservoir system has two reservoirs: the bigger one is the Valdesia Reservoir and the smaller is Las Barias Reservoir which regulates the water power releases. It has two irrigation zones; one is irrigated by the Marcos A. Cabral canal and the other by the Nizao-Najayo canal. The water that is spilled in Las Barias Reservoir goes to Nizao river. In Figure 2.4.14 the same system is shown, but in a network configuration to be used as input in the MODSIM runs. In Table 2.4.5 the nodes and links are shown with their priority cost and minimum and upper capacity bounds.

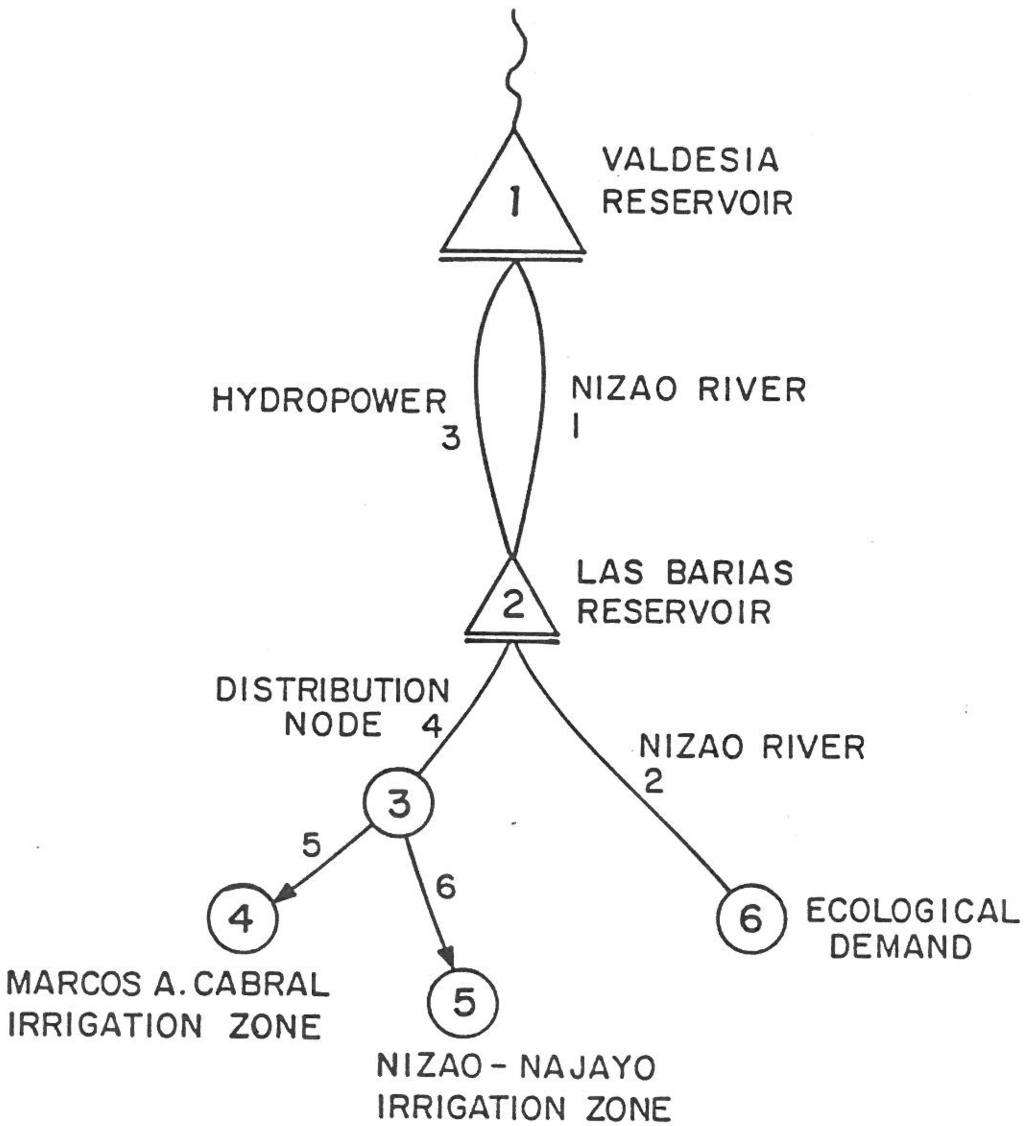


FIG. 2.4.14 MODSIM Network Configuration for the Valdesia Reservoir System

Data processing had two purposes during the calibration of MODSIMEP: as an input for the model, and as a reference for comparing historical and calculated storage levels, releases, and power. The input consisted of net evaporation (evaporation-precipitation), inflows, turbine operation time, reservoir releases, and water levels at Valdesia and Las Barias Reservoirs. Water surface areas and reservoir storages used in the model come from the elevation area-capacity curves provided by CDE. Also available were efficiency tables for the turbines at Valdesia Reservoir. Daily data were analyzed and completed before being summed into weekly values for use in the model. These weekly data were then divided into three groups: 180 weeks before Hurricane David in 1979, and two 132 week sets afterward. Simultaneously, records of the historical energy produced by the turbines, the actual releases of water from Valdesia and Las Barias Reservoirs, and the measured surface levels were organized for comparison to the calculations made by MODSIMEP.

The first step in the process was to order the data according to application, 1) the balance of resources, and 2) the production of power. Since direct measurement of incoming water is not available and very important to the model calibration, daily historical records of reservoir storage, releases, precipitation, and evaporation were balanced to estimate accurate values for inflows. Average net evaporation per month from Valdesia Reservoir was determined as follows:

Net Evap. = 0.8 (Pan Evap.) - (Precipitation) [m.] (2.4.1)

where precipitation and pan evaporation were measured at station Valdesia. Net evaporation was then multiplied by the reservoir surface area to get the net volume. Both reservoir surface area and storage capacity depend on water surface elevation; elevation vs. area capacity curves were provided by

CDE that correspond to data before and/or after Hurricane David. Records of reservoir releases are measurements of the discharge for successive hourly intervals over 24 hours periods. The first measurement of a period corresponds to the time when the storage level of the reservoir was measured; 18:00 hours each day. These hourly discharges were summed to obtain the volume of release per day. Using the following mass balance equation, inflows to Valdesia Reservoir were obtained:

$$I = V_{t+1} - V_t + R + E_{net} \tag{2.4.2}$$

where

I = inflow per day, m^3

V = volume of storage on day, t

R = reservoir releases per day

E_{net} = net evaporation per day (an average value for entire month)

The input file for the model then contained the net evaporation, the inflows and outflow demands. Finally, the operation times for the power turbines as recorded were input to render the intital data base.

Since much data was incorrect or simply missing, synthetic data had to be generated before summing it into weekly totals. All incomplete data were filled on a daily basis either by using an average value taken from bordering values, or by matching hydrologic conditions of another year and using the data for the needed period of that year. Upon statisfying all files with daily values, the data in each seven day interval were summed to obtain a weekly data base. The data were input to MODSIMEP in three separate groups along with the limits of reservoir storage capacity, of discharges through the turbines, and of flow through the canals; and the efficiency tables of the turbines.

b. Results

Serving as a comparison to the output of MODSIMEP, the reference data contained the historical power produced per week, the water surface levels of Valdesia and Las Barias Reservoirs, and the water releases to the Marcos A. Cabral and Nizao-Najayo canals.

For having complete reliability in the outputs of the MODSIM model we calibrated it comparing the historical with the calculated power supply and satisfying completely all the historical irrigation demands and reservoir levels.

Historical power values were plotted against the corresponding results of MODSIMEP so that problems could be identified and corrected to obtain the most realistic results possible. (See Figures 2.4.15, 2.4.16 and 2.4.17)

c. Analysis of calibration units

As is shown in the figures mentioned above, model MODSIM reproduced with minimum error the historical values. To improve results we decided to make a slight modification of the turbines efficiency (multiply all values by 0.96) given us. With these new values, more precise results were obtained.

We need to note that historical data was not available for water delivered through the Nizao-Najayo canal after August 1979 because the gage station was destroyed by hurricane David. The values for historical data shown on Figure 2.4.17 after August 1979 are actually the predicted values from MODSIM.

2.4.3 Development of monthly transition probabilities.

Due to the existence of serial correlation among inflows, the probability distribution of inflow in a given month always depends on what

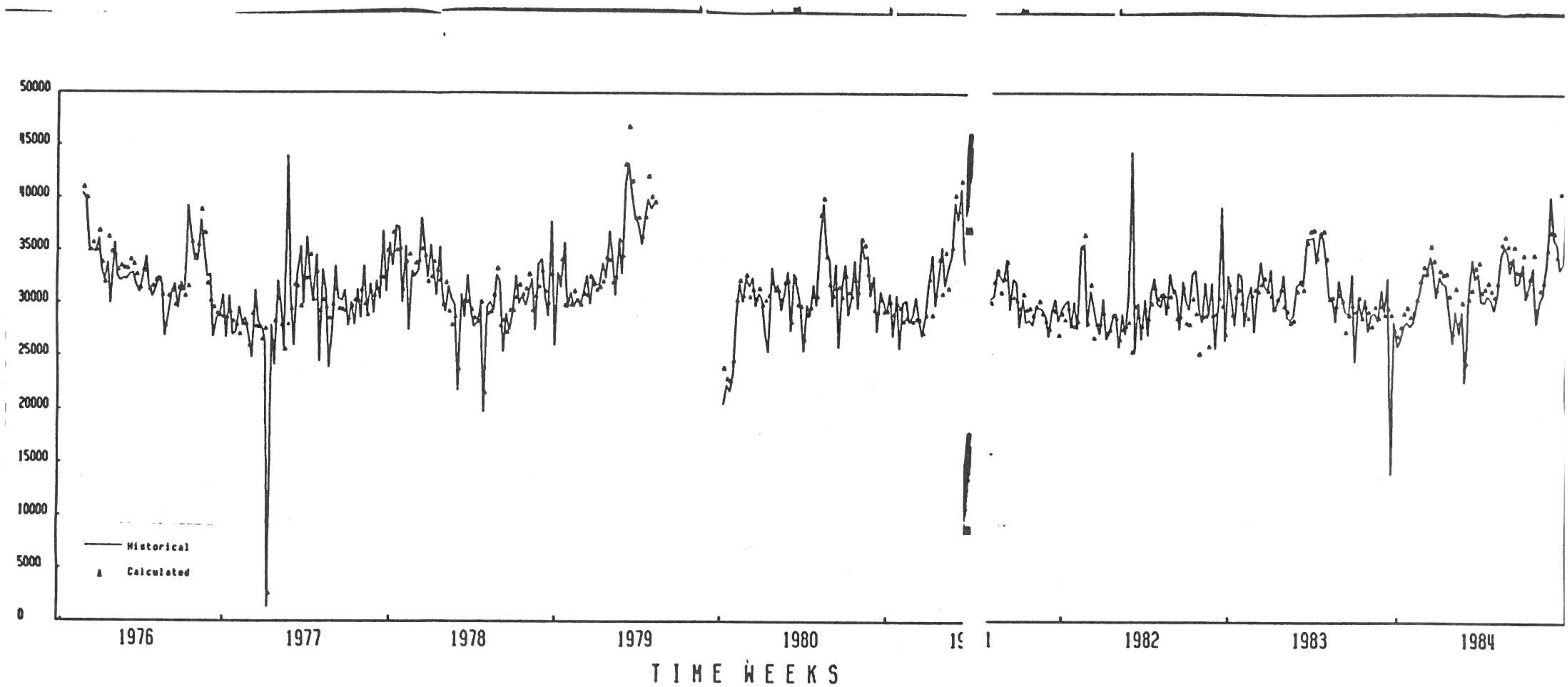


FIGURE 2.4.15 MODSIM POWER CALIBRATION FOR THE VALDESIA RESE /OIR SYSTEM

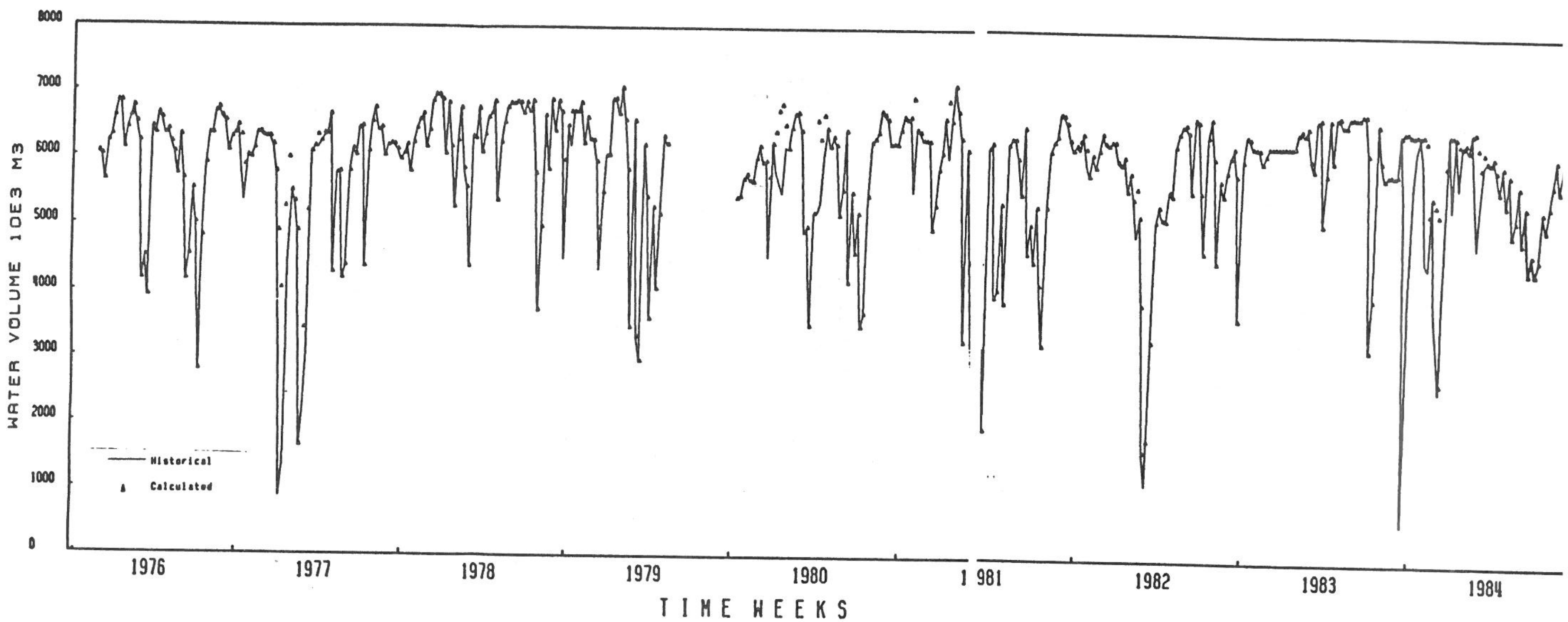


FIGURE 2.4.16 MODSIM CALIBRATION OF IRRIGATION FLOWS FOR THE MARCOS A. CABRAL CANAL

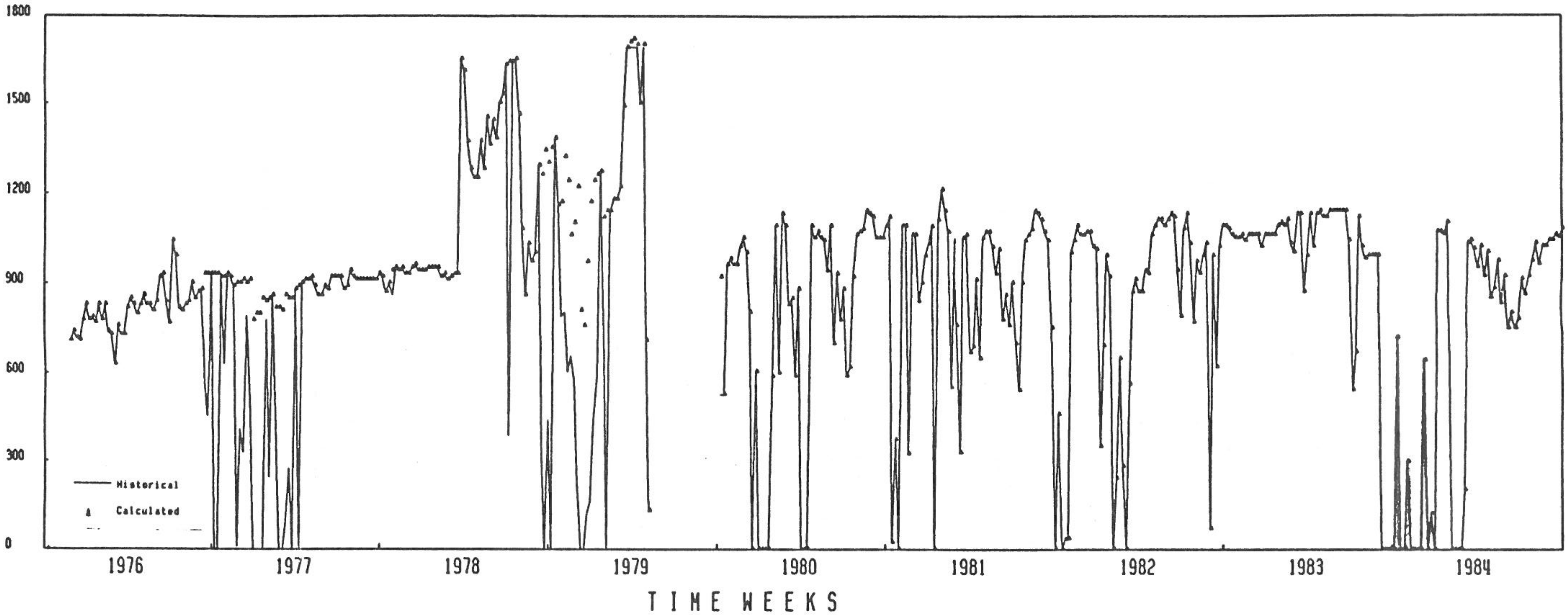


FIGURE 2.4.17 MODSIM CALIBRATION OF IRRIGATION FLOWS FOR THE NIZAO-NAJAYO CANAL

inflow actually occurred in the previous month. A set of discrete conditional probability distributions are developed for each month in the form of a transitional probability matrix to preserve these characteristics. Several transition matrices of different order have been calculated. They are 3x3, 3x9, 6x6 and 12x12. After analyzing the corresponding stationary operation policy, the 12x12 transition matrix was chosen for normal operation.

Data used for this analysis are based on 50 sets of 22-year of synthetically generated flows upstream of Valdesia reservoir and developed by the Emergency Operations Group. There are total of 1100 data sets (flows of current and previous month) for each month from February to December and 1050 data sets for January. For the 12x12 transition matrix, both inflows of the current and previous month are classified into twelve classes. There are eleven limits for these twelve classes and these limits are chosen as 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 95 percentile of the empirical accumulated probability distribution (refer to Fig. 2.6.3) of generated inflow of each month. The class mark of each class is taken as the mean value of all flow events in the class.

The transition probability matrix and corresponding class marks and limits of each month are shown on Table 2.4.6 and 2.4.7.

Table 2.4.6. 12x12 Transitional Probability Matrix of Generated Monthly Inflow, Data in (Probability)/(Frequency), Mark in CMS

(a) From December to January, 1050 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	5.5102	7.6897	9.4707	11.486	13.111	14.608	16.288	18.488	20.666	24.367	29.279	37.493
01	5.2181	0.5882	0.2157	0.1961	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		30	11	10	0	0	0	0	0	0	0	0	0
02	7.5660	0.1667	0.3148	0.2778	0.1481	0.0741	0.0185	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		9	17	15	8	4	1	0	0	0	0	0	0
03	9.7260	0.0833	0.1481	0.3426	0.2130	0.1204	0.0741	0.0093	0.0093	0.0000	0.0000	0.0000	0.0000
		9	16	37	23	13	8	1	1	0	0	0	0
04	12.574	0.0392	0.0294	0.1667	0.2059	0.2059	0.1176	0.0882	0.0882	0.0392	0.0196	0.0000	0.0000
		4	3	17	21	21	12	9	9	4	2	0	0
05	14.887	0.0000	0.0097	0.1262	0.2621	0.1553	0.1650	0.1262	0.1068	0.0388	0.0097	0.0000	0.0000
		0	1	13	27	16	17	13	11	4	1	0	0
06	17.367	0.0000	0.0377	0.0755	0.0849	0.1698	0.2264	0.1792	0.1226	0.0377	0.0472	0.0189	0.0000
		0	4	8	9	18	24	19	13	4	5	2	0
07	20.308	0.0000	0.0000	0.0288	0.0962	0.1442	0.1346	0.2404	0.1923	0.1154	0.0481	0.0000	0.0000
		0	0	3	10	15	14	25	20	12	5	0	0
08	24.184	0.0000	0.0094	0.0000	0.0283	0.1415	0.1792	0.1321	0.1226	0.2358	0.1415	0.0094	0.0000
		0	1	0	3	15	19	14	13	25	15	1	0
09	29.177	0.0000	0.0000	0.0095	0.0381	0.0190	0.0571	0.1333	0.2000	0.2857	0.1524	0.1048	0.0000
		0	0	1	4	2	6	14	21	30	16	11	0
10	36.336	0.0000	0.0000	0.0000	0.0094	0.0000	0.0377	0.0849	0.1038	0.1792	0.3396	0.1604	0.0849
		0	0	0	1	0	4	9	11	19	36	17	9
11	46.261	0.0000	0.0000	0.0000	0.0185	0.0185	0.0000	0.0185	0.0926	0.0741	0.3704	0.2037	0.2037
		0	0	0	1	1	0	1	5	4	20	11	11
12	69.050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0196	0.0196	0.1176	0.1961	0.6471
		0	0	0	0	0	0	0	1	1	6	10	33

Table 2.4.6.(Cont.)

(b) From January To February , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	4.0087	6.1114	7.8893	9.8973	11.740	13.528	15.542	17.757	20.398	24.194	29.196	38.625
01	5.4373	0.6182	0.2182	0.1091	0.0182	0.0182	0.0000	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000
		34	12	6	1	1	0	1	0	0	0	0	0
02	7.6887	0.1636	0.2545	0.2909	0.2000	0.0545	0.0182	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000
		9	14	16	11	3	1	1	0	0	0	0	0
03	9.4965	0.0917	0.1284	0.2936	0.1927	0.1560	0.0734	0.0459	0.0183	0.0000	0.0000	0.0000	0.0000
		10	14	32	21	17	8	5	2	0	0	0	0
04	11.477	0.0180	0.0541	0.2703	0.2613	0.1441	0.1261	0.0631	0.0360	0.0180	0.0090	0.0000	0.0000
		2	6	30	29	16	14	7	4	2	1	0	0
05	13.117	0.0000	0.0273	0.1091	0.2000	0.2455	0.1455	0.1364	0.0909	0.0273	0.0182	0.0000	0.0000
		0	3	12	22	27	16	15	10	3	2	0	0
06	14.603	0.0000	0.0273	0.1000	0.1000	0.1636	0.1364	0.1909	0.1545	0.0909	0.0273	0.0091	0.0000
		0	3	11	11	18	15	21	17	10	3	1	0
07	16.293	0.0000	0.0091	0.0273	0.1000	0.1364	0.1727	0.1636	0.1727	0.1091	0.0818	0.0273	0.0000
		0	1	3	11	15	19	18	19	12	9	3	0
08	18.472	0.0000	0.0000	0.0091	0.0182	0.0273	0.2000	0.1727	0.1909	0.1909	0.1727	0.0182	0.0000
		0	0	1	2	3	22	19	21	21	19	2	0
09	20.683	0.0000	0.0091	0.0000	0.0182	0.0727	0.0818	0.1636	0.1636	0.2364	0.1455	0.0909	0.0182
		0	1	0	2	8	9	18	18	26	16	10	2
10	24.433	0.0000	0.0000	0.0000	0.0000	0.0182	0.0455	0.0455	0.1364	0.2182	0.3545	0.1455	0.0364
		0	0	0	0	2	5	5	15	24	39	16	4
11	29.233	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0000	0.0364	0.1455	0.2727	0.2727	0.2545
		0	0	0	0	0	1	0	2	8	15	15	14
12	37.399	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0364	0.0727	0.1091	0.1455	0.6364
		0	0	0	0	0	0	0	2	4	6	8	35

Table 2.4.6. (Cont.)

(c) From February to March , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	3.9725	5.7109	7.1656	8.8120	10.275	12.016	13.763	15.501	17.678	21.527	26.341	34.457
01	4.0087	0.4364 24	0.2000 11	0.2545 14	0.0182 1	0.0182 1	0.0545 3	0.0000 0	0.0182 1	0.0000 0	0.0000 0	0.0000 0	0.0000 0
02	6.1114	0.2037 11	0.2037 11	0.2037 11	0.1667 9	0.1111 6	0.0556 3	0.0370 2	0.0000 0	0.0000 0	0.0185 1	0.0000 0	0.0000 0
03	7.8893	0.1171 13	0.1261 14	0.2252 25	0.1892 21	0.0991 11	0.0811 9	0.0541 6	0.0901 10	0.0180 2	0.0000 0	0.0000 0	0.0000 0
04	9.8973	0.0273 3	0.0455 5	0.1636 18	0.1909 21	0.2364 26	0.1545 17	0.0545 6	0.0909 10	0.0182 2	0.0182 2	0.0000 0	0.0000 0
05	11.740	0.0182 2	0.0727 8	0.1455 16	0.1182 13	0.2091 23	0.1091 12	0.1364 15	0.0909 10	0.0545 6	0.0455 5	0.0000 0	0.0000 0
06	13.528	0.0091 1	0.0545 6	0.1000 11	0.1455 16	0.1273 14	0.1455 16	0.1273 14	0.1364 15	0.0727 8	0.0636 7	0.0182 2	0.0000 0
07	15.542	0.0091 1	0.0000 0	0.0818 9	0.1182 13	0.1091 12	0.1545 17	0.1818 20	0.1182 13	0.1364 15	0.0909 10	0.0000 0	0.0000 0
08	17.757	0.0000 0	0.0000 0	0.0273 3	0.0818 9	0.1091 12	0.1273 14	0.1545 17	0.1545 17	0.1545 17	0.1364 15	0.0545 6	0.0000 0
09	20.398	0.0000 0	0.0000 0	0.0273 3	0.0455 5	0.0455 5	0.1091 12	0.1091 12	0.1545 17	0.2273 25	0.2091 23	0.0727 8	0.0000 0
10	24.194	0.0000 0	0.0000 0	0.0000 0	0.0182 2	0.0000 0	0.0545 6	0.1000 11	0.1273 14	0.1818 20	0.2273 25	0.1636 18	0.1273 14
11	29.196	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0182 1	0.0909 5	0.0545 3	0.1636 9	0.2364 13	0.1636 9	0.2727 15
12	38.625	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0364 2	0.0000 0	0.1091 6	0.1636 9	0.2182 12	0.4727 26

Table 2.4.6. (Cont.)

(d) From March to April , 1100 data

Level	Mark	01	02	03	04	05	06	07	08	09	10	11	12
	Mark	4.3508	5.9561	7.4184	8.9743	10.322	11.737	13.075	14.619	16.921	20.014	23.931	30.353
01	3.9725	0.4545 25	0.1273 7	0.1818 10	0.1091 6	0.0545 3	0.0364 2	0.0182 1	0.0000 0	0.0000 0	0.0182 1	0.0000 0	0.0000 0
02	5.7109	0.1455 8	0.2000 11	0.2727 15	0.1091 6	0.1455 8	0.0909 5	0.0182 1	0.0000 0	0.0182 1	0.0000 0	0.0000 0	0.0000 0
03	7.1656	0.1000 11	0.1182 13	0.2273 25	0.1545 17	0.1091 12	0.1273 14	0.0364 4	0.0455 5	0.0455 5	0.0273 3	0.0091 1	0.0000 0
04	8.8120	0.0182 2	0.0727 8	0.1818 20	0.2000 22	0.1364 15	0.0909 10	0.0909 10	0.1182 13	0.0727 8	0.0182 2	0.0000 0	0.0000 0
05	10.275	0.0455 5	0.0727 8	0.1000 11	0.1818 20	0.1636 18	0.1636 18	0.0818 9	0.1273 14	0.0455 5	0.0182 2	0.0000 0	0.0000 0
06	12.016	0.0273 3	0.0364 4	0.1364 15	0.0636 7	0.1545 17	0.1455 16	0.1636 18	0.0727 8	0.0909 10	0.0727 8	0.0273 3	0.0091 1
07	13.763	0.0000 0	0.0273 3	0.0545 6	0.1182 13	0.1000 11	0.1273 14	0.1273 14	0.1545 17	0.1182 13	0.1273 14	0.0364 4	0.0091 1
08	15.501	0.0000 0	0.0091 1	0.0364 4	0.0364 4	0.1364 15	0.1000 11	0.1818 20	0.1455 16	0.1636 18	0.1455 16	0.0182 2	0.0273 3
09	17.678	0.0000 0	0.0000 0	0.0182 2	0.1000 11	0.0727 8	0.0818 9	0.1364 15	0.1455 16	0.1364 15	0.1818 20	0.0909 10	0.0364 4
10	21.527	0.0091 1	0.0000 0	0.0182 2	0.0364 4	0.0273 3	0.1000 11	0.1091 12	0.1364 15	0.1545 17	0.1818 20	0.1182 13	0.1091 12
11	26.341	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.1091 6	0.0727 4	0.2000 11	0.3091 17	0.1818 10	0.1273 7
12	34.457	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0364 2	0.1273 7	0.1273 7	0.2182 12	0.4909 27

Table 2.4.6. (Cont.)

(e) From April to May , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	4.0241	6.1822	8.4843	11.781	15.218	18.337	22.153	27.156	33.337	43.358	55.936	83.589
01	4.3508	0.4000	0.2000	0.2364	0.0545	0.0182	0.0000	0.0364	0.0364	0.0182	0.0000	0.0000	0.0000
		22	11	13	3	1	0	2	2	1	0	0	0
02	5.9561	0.1818	0.1455	0.2727	0.1636	0.0727	0.0909	0.0182	0.0364	0.0182	0.0000	0.0000	0.0000
		10	8	15	9	4	5	1	2	1	0	0	0
03	7.4184	0.0909	0.1636	0.1727	0.1727	0.1091	0.1636	0.0727	0.0182	0.0273	0.0091	0.0000	0.0000
		10	18	19	19	12	18	8	2	3	1	0	0
04	8.9743	0.0545	0.0727	0.1727	0.1636	0.1636	0.1727	0.1182	0.0727	0.0091	0.0000	0.0000	0.0000
		6	8	19	18	18	19	13	8	1	0	0	0
05	10.322	0.0364	0.0273	0.1364	0.1455	0.1545	0.1364	0.0727	0.1091	0.1091	0.0545	0.0182	0.0000
		4	3	15	16	17	15	8	12	12	6	2	0
06	11.737	0.0182	0.0273	0.1091	0.1364	0.1636	0.0545	0.1182	0.1273	0.1364	0.1091	0.0000	0.0000
		2	3	12	15	18	6	13	14	15	12	0	0
07	13.075	0.0000	0.0182	0.1091	0.1273	0.0727	0.1182	0.1182	0.1727	0.1091	0.0818	0.0545	0.0182
		0	2	12	14	8	13	13	19	12	9	6	2
08	14.619	0.0000	0.0091	0.0364	0.0636	0.1818	0.1364	0.1455	0.1182	0.1182	0.1000	0.0545	0.0364
		0	1	4	7	20	15	16	13	13	11	6	4
09	16.921	0.0091	0.0091	0.0091	0.0273	0.0636	0.0727	0.1909	0.1364	0.2091	0.1091	0.1091	0.0545
		1	1	1	3	7	8	21	15	23	12	12	6
10	20.014	0.0000	0.0000	0.0000	0.0364	0.0364	0.0818	0.0909	0.1636	0.1636	0.2727	0.0727	0.0818
		0	0	0	4	4	9	10	18	18	30	8	9
11	23.931	0.0000	0.0000	0.0000	0.0364	0.0182	0.0364	0.0545	0.0545	0.0909	0.3273	0.1818	0.2000
		0	0	0	2	1	2	3	3	5	18	10	11
12	30.353	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0364	0.0364	0.1091	0.2000	0.2000	0.4182
		0	0	0	0	0	0	2	2	6	11	11	23

Table 2.4.6. (Cont.)

(f) From May to June , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	4.0005	6.3710	8.8024	11.431	14.444	17.989	22.483	28.019	34.578	45.814	59.784	97.299
01	4.0241	0.3636	0.3091	0.2000	0.0727	0.0545	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		20	17	11	4	3	0	0	0	0	0	0	0
02	6.1822	0.2364	0.0909	0.2364	0.2364	0.0727	0.1091	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000
		13	5	13	13	4	6	1	0	0	0	0	0
03	8.4843	0.1273	0.1091	0.2273	0.1545	0.1455	0.1000	0.0636	0.0545	0.0091	0.0091	0.0000	0.0000
		14	12	25	17	16	11	7	6	1	1	0	0
04	11.781	0.0364	0.1000	0.1818	0.1636	0.2182	0.1091	0.0455	0.0909	0.0455	0.0000	0.0000	0.0091
		4	11	20	18	24	12	5	10	5	0	0	1
05	15.218	0.0273	0.0273	0.1818	0.1364	0.1182	0.1273	0.1636	0.1000	0.0636	0.0455	0.0091	0.0000
		3	3	20	15	13	14	18	11	7	5	1	0
06	18.337	0.0091	0.0273	0.0545	0.1636	0.1636	0.1818	0.1455	0.0818	0.1182	0.0455	0.0091	0.0000
		1	3	6	18	18	20	16	9	13	5	1	0
07	22.153	0.0000	0.0182	0.0545	0.1091	0.1182	0.1182	0.1545	0.2000	0.0727	0.1182	0.0364	0.0000
		0	2	6	12	13	13	17	22	8	13	4	0
08	27.156	0.0000	0.0091	0.0636	0.0364	0.0727	0.1636	0.2091	0.1091	0.1818	0.1091	0.0364	0.0091
		0	1	7	4	8	18	23	12	20	12	4	1
09	33.337	0.0000	0.0091	0.0182	0.0455	0.0909	0.0727	0.1182	0.1273	0.1909	0.2273	0.0545	0.0455
		0	1	2	5	10	8	13	14	21	25	6	5
10	43.358	0.0000	0.0000	0.0000	0.0364	0.0091	0.0636	0.0636	0.1636	0.1818	0.2636	0.1455	0.0727
		0	0	0	4	1	7	7	18	20	29	16	8
11	55.936	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0909	0.1091	0.2727	0.2182	0.2909
		0	0	0	0	0	0	1	5	6	15	12	16
12	83.589	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0364	0.0545	0.1636	0.0909	0.2000	0.4364
		0	0	0	0	0	1	2	3	9	5	11	24

Table 2.4.6. (Cont.)

(g) From June to July , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	5.7850	7.9154	9.6742	11.845	14.233	16.714	19.446	22.400	26.659	32.556	39.482	55.894
01	4.0005	0.5273	0.2182	0.1455	0.0727	0.0364	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		29	12	8	4	2	0	0	0	0	0	0	0
02	6.3710	0.2000	0.2364	0.3636	0.1273	0.0727	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		11	13	20	7	4	0	0	0	0	0	0	0
03	8.8024	0.1000	0.1091	0.2818	0.2455	0.1636	0.0636	0.0182	0.0000	0.0182	0.0000	0.0000	0.0000
		11	12	31	27	18	7	2	0	2	0	0	0
04	11.431	0.0182	0.0909	0.2455	0.2000	0.1909	0.1455	0.0727	0.0182	0.0182	0.0000	0.0000	0.0000
		2	10	27	22	21	16	8	2	2	0	0	0
05	14.444	0.0091	0.0455	0.1273	0.2000	0.1545	0.1364	0.1818	0.0818	0.0545	0.0091	0.0000	0.0000
		1	5	14	22	17	15	20	9	6	1	0	0
06	17.989	0.0091	0.0091	0.0636	0.1545	0.1364	0.2273	0.1818	0.1091	0.0727	0.0273	0.0091	0.0000
		1	1	7	17	15	25	20	12	8	3	1	0
07	22.483	0.0000	0.0091	0.0182	0.0545	0.1636	0.1273	0.2182	0.1909	0.0909	0.1273	0.0000	0.0000
		0	1	2	6	18	14	24	21	10	14	0	0
08	28.019	0.0000	0.0000	0.0091	0.0364	0.1000	0.1727	0.1364	0.2000	0.1727	0.1182	0.0455	0.0091
		0	0	1	4	11	19	15	22	19	13	5	1
09	34.578	0.0000	0.0000	0.0000	0.0091	0.0273	0.1000	0.0909	0.2000	0.2364	0.2091	0.0909	0.0364
		0	0	0	1	3	11	10	22	26	23	10	4
10	45.814	0.0000	0.0000	0.0091	0.0000	0.0091	0.0091	0.0818	0.1182	0.2182	0.3273	0.1182	0.1091
		0	0	1	0	1	1	9	13	24	36	13	12
11	59.784	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0364	0.1091	0.1818	0.2545	0.1818	0.2182
		0	0	0	0	0	1	2	6	10	14	10	12
12	97.299	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0000	0.0545	0.0545	0.1091	0.2909	0.4727
		0	0	0	0	0	1	0	3	3	6	16	26

Table 2.4.6. (Cont.)

(h) From July to August , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	7.7630	10.646	13.213	16.576	19.307	22.898	26.456	30.446	36.775	46.200	60.206	111.41
01	5.7850	0.4364	0.2545	0.1818	0.0727	0.0364	0.0182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		24	14	10	4	2	1	0	0	0	0	0	0
02	7.9154	0.1667	0.2222	0.2963	0.1481	0.1111	0.0185	0.0370	0.0000	0.0000	0.0000	0.0000	0.0000
		9	12	16	8	6	1	2	0	0	0	0	0
03	9.6742	0.0901	0.1802	0.2072	0.2342	0.1712	0.0721	0.0450	0.0000	0.0000	0.0000	0.0000	0.0000
		10	20	23	26	19	8	5	0	0	0	0	0
04	11.845	0.0636	0.0455	0.2636	0.1455	0.1273	0.1455	0.0909	0.0455	0.0545	0.0182	0.0000	0.0000
		7	5	29	16	14	16	10	5	6	2	0	0
05	14.233	0.0364	0.0091	0.1909	0.2091	0.1636	0.1273	0.1091	0.0909	0.0364	0.0273	0.0000	0.0000
		4	1	21	23	18	14	12	10	4	3	0	0
06	16.714	0.0091	0.0182	0.0364	0.1364	0.2091	0.1818	0.1091	0.1727	0.0727	0.0545	0.0000	0.0000
		1	2	4	15	23	20	12	19	8	6	0	0
07	19.446	0.0000	0.0000	0.0182	0.0727	0.1182	0.1000	0.1636	0.2273	0.1545	0.1182	0.0273	0.0000
		0	0	2	8	13	11	18	25	17	13	3	0
08	22.400	0.0000	0.0091	0.0455	0.0455	0.0545	0.1545	0.1818	0.0909	0.1818	0.1909	0.0364	0.0091
		0	1	5	5	6	17	20	10	20	21	4	1
09	26.659	0.0000	0.0000	0.0000	0.0273	0.0636	0.1091	0.1636	0.1545	0.2091	0.2091	0.0364	0.0273
		0	0	0	3	7	12	18	17	23	23	4	3
10	32.556	0.0000	0.0000	0.0000	0.0182	0.0182	0.0909	0.1000	0.1455	0.1818	0.1818	0.1727	0.0909
		0	0	0	2	2	10	11	16	20	20	19	10
11	39.482	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.1091	0.1455	0.3091	0.2182	0.2000
		0	0	0	0	0	0	1	6	8	17	12	11
12	55.894	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0182	0.0364	0.0727	0.0909	0.2364	0.5455
		0	0	0	0	0	0	1	2	4	5	13	30

Table 2.4.6. (Cont.)

(i) From August to September , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	7.4465	9.3810	11.259	13.565	15.606	18.174	21.029	24.876	29.388	37.564	50.860	86.017
01	7.7630	0.3455	0.3091	0.1818	0.0909	0.0364	0.0364	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		19	17	10	5	2	2	0	0	0	0	0	0
02	10.646	0.1091	0.1636	0.3636	0.1455	0.0727	0.0364	0.0364	0.0727	0.0000	0.0000	0.0000	0.0000
		6	9	20	8	4	2	2	4	0	0	0	0
03	13.213	0.1091	0.1182	0.1818	0.2636	0.1182	0.0818	0.0636	0.0364	0.0273	0.0000	0.0000	0.0000
		12	13	20	29	13	9	7	4	3	0	0	0
04	16.576	0.1000	0.0909	0.1455	0.1455	0.1455	0.1182	0.1182	0.0545	0.0545	0.0273	0.0000	0.0000
		11	10	16	16	16	13	13	6	6	3	0	0
05	19.307	0.0364	0.0364	0.1909	0.0909	0.1182	0.1818	0.1273	0.0727	0.0818	0.0364	0.0273	0.0000
		4	4	21	10	13	20	14	8	9	4	3	0
06	22.898	0.0091	0.0273	0.0727	0.1273	0.1636	0.1364	0.1091	0.1182	0.1455	0.0818	0.0091	0.0000
		1	3	8	14	18	15	12	13	16	9	1	0
07	26.456	0.0000	0.0000	0.0455	0.0818	0.1727	0.1091	0.1909	0.1727	0.1182	0.0818	0.0182	0.0091
		0	0	5	9	19	12	21	19	13	9	2	1
08	30.446	0.0091	0.0000	0.0545	0.0909	0.0818	0.1455	0.1182	0.1455	0.1000	0.1909	0.0364	0.0273
		1	0	6	10	9	16	13	16	11	21	4	3
09	36.775	0.0000	0.0000	0.0273	0.0545	0.0727	0.0727	0.1091	0.1727	0.1636	0.1636	0.1091	0.0545
		0	0	3	6	8	8	12	19	18	18	12	6
10	46.200	0.0000	0.0000	0.0091	0.0273	0.0636	0.1182	0.1091	0.1364	0.1636	0.1727	0.1273	0.0727
		0	0	1	3	7	13	12	15	18	19	14	8
11	60.206	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0545	0.0909	0.2000	0.3091	0.1818	0.1636
		0	0	0	0	0	0	3	5	11	17	10	9
12	111.41	0.0000	0.0000	0.0000	0.0000	0.0182	0.0000	0.0182	0.0182	0.0909	0.1818	0.1636	0.5091
		0	0	0	0	1	0	1	1	5	10	9	28

Table 2.4.6. (Cont.)

(j) From September to October , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	8.4400	10.010	11.616	13.156	14.574	16.091	17.709	19.979	22.997	27.103	33.291	47.626
01	7.4465	0.3519 19	0.1111 6	0.2963 16	0.0741 4	0.0185 1	0.0741 4	0.0370 2	0.0000 0	0.0370 2	0.0000 0	0.0000 0	0.0000 0
02	9.3810	0.1964 11	0.1429 8	0.1250 7	0.2321 13	0.0714 4	0.0893 5	0.0536 3	0.0357 2	0.0536 3	0.0000 0	0.0000 0	0.0000 0
03	11.259	0.0818 9	0.1636 18	0.2000 22	0.1909 21	0.0818 9	0.1000 11	0.1091 12	0.0545 6	0.0091 1	0.0000 0	0.0091 1	0.0000 0
04	13.565	0.0545 6	0.1091 12	0.1364 15	0.1636 18	0.1455 16	0.1000 11	0.1000 11	0.0727 8	0.0636 7	0.0455 5	0.0091 1	0.0000 0
05	15.606	0.0727 8	0.0364 4	0.1818 20	0.1000 11	0.1909 21	0.1182 13	0.0909 10	0.0545 6	0.0545 6	0.0727 8	0.0182 2	0.0091 1
06	18.174	0.0091 1	0.0273 3	0.0727 8	0.1455 16	0.1091 12	0.1545 17	0.1727 19	0.1000 11	0.0818 9	0.1000 11	0.0273 3	0.0000 0
07	21.029	0.0000 0	0.0273 3	0.0818 9	0.1000 11	0.1455 16	0.1455 16	0.1182 13	0.1909 21	0.1455 16	0.0273 3	0.0000 0	0.0182 2
08	24.876	0.0000 0	0.0000 0	0.0545 6	0.0636 7	0.1364 15	0.1273 14	0.1182 13	0.0909 10	0.1545 17	0.1545 17	0.0909 10	0.0091 1
09	29.388	0.0091 1	0.0091 1	0.0545 6	0.0545 6	0.0636 7	0.0455 5	0.1273 14	0.1727 19	0.1455 16	0.1636 18	0.0818 9	0.0727 8
10	37.564	0.0000 0	0.0000 0	0.0000 0	0.0273 3	0.0636 7	0.1000 11	0.0909 10	0.1636 18	0.1636 18	0.2182 24	0.0818 9	0.0909 10
11	50.860	0.0000 0	0.0000 0	0.0000 0	0.0182 1	0.0364 2	0.0364 2	0.0364 2	0.0909 5	0.2000 11	0.1818 10	0.2545 14	0.1455 8
12	86.017	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0182 1	0.0182 1	0.0727 4	0.0727 4	0.2545 14	0.1091 6	0.4545 25

Table 2.4.6. (Cont.)

(k) From October to November , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	9.4234	11.310	12.869	14.762	16.259	17.935	19.885	21.879	24.449	29.050	34.409	46.006
01	8.4400	0.4909	0.2364	0.1455	0.0364	0.0545	0.0364	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		27	13	8	2	3	2	0	0	0	0	0	0
02	10.010	0.1273	0.1455	0.2909	0.1455	0.0909	0.1091	0.0182	0.0182	0.0364	0.0000	0.0000	0.0182
		7	8	16	8	5	6	1	1	2	0	0	1
03	11.616	0.0459	0.0826	0.2018	0.1927	0.2018	0.1009	0.0642	0.0642	0.0183	0.0275	0.0000	0.0000
		5	9	22	21	22	11	7	7	2	3	0	0
04	13.156	0.0450	0.0991	0.1712	0.1441	0.1532	0.1261	0.0901	0.0631	0.0360	0.0450	0.0270	0.0000
		5	11	19	16	17	14	10	7	4	5	3	0
05	14.574	0.0636	0.0455	0.1000	0.1091	0.1727	0.1182	0.0909	0.1273	0.1182	0.0364	0.0182	0.0000
		7	5	11	12	19	13	10	14	13	4	2	0
06	16.091	0.0273	0.0000	0.1273	0.1545	0.1273	0.1636	0.1818	0.0909	0.0818	0.0455	0.0000	0.0000
		3	0	14	17	14	18	20	10	9	5	0	0
07	17.709	0.0000	0.0545	0.0818	0.1182	0.1273	0.0818	0.1545	0.0818	0.1636	0.0909	0.0091	0.0364
		0	6	9	13	14	9	17	9	18	10	1	4
08	19.979	0.0000	0.0182	0.0545	0.1000	0.0545	0.1091	0.1364	0.1455	0.1455	0.1455	0.0364	0.0545
		0	2	6	11	6	12	15	16	16	16	4	6
09	22.997	0.0000	0.0091	0.0364	0.0364	0.0545	0.0545	0.0818	0.1636	0.1545	0.2182	0.1091	0.0818
		0	1	4	4	6	6	9	18	17	24	12	9
10	27.103	0.0000	0.0091	0.0091	0.0273	0.0182	0.1364	0.1455	0.1455	0.1545	0.1455	0.1364	0.0727
		0	1	1	3	2	15	16	16	17	16	15	8
11	33.291	0.0000	0.0000	0.0000	0.0364	0.0182	0.0545	0.0545	0.1091	0.1091	0.2909	0.1636	0.1636
		0	0	0	2	1	3	3	6	6	16	9	9
12	47.626	0.0000	0.0000	0.0000	0.0182	0.0182	0.0182	0.0364	0.1091	0.1091	0.2000	0.1636	0.3273
		0	0	0	1	1	1	2	6	6	11	9	18

Table 2.4.6. (Cont.)

(1) From November to December , 1100 data

Level		01	02	03	04	05	06	07	08	09	10	11	12
	Mark	5.1575	7.5630	9.7400	12.589	14.874	17.343	20.320	24.207	29.173	36.263	46.281	68.123
01	9.4234	0.4444 24	0.1667 9	0.1852 10	0.1111 6	0.0185 1	0.0556 3	0.0000 0	0.0000 0	0.0185 1	0.0000 0	0.0000 0	0.0000 0
02	11.310	0.2321 13	0.2321 13	0.2500 14	0.1429 8	0.0357 2	0.0179 1	0.0536 3	0.0357 2	0.0000 0	0.0000 0	0.0000 0	0.0000 0
03	12.869	0.1364 15	0.1273 14	0.2091 23	0.1818 20	0.1545 17	0.1182 13	0.0455 5	0.0091 1	0.0182 2	0.0000 0	0.0000 0	0.0000 0
04	14.762	0.0091 1	0.1000 11	0.1909 21	0.2000 22	0.1364 15	0.1364 15	0.0909 10	0.1000 11	0.0273 3	0.0091 1	0.0000 0	0.0000 0
05	16.259	0.0091 1	0.0455 5	0.1727 19	0.1273 14	0.1909 21	0.1636 18	0.0818 9	0.1364 15	0.0545 6	0.0091 1	0.0091 1	0.0000 0
06	17.935	0.0000 0	0.0182 2	0.1182 13	0.1000 11	0.1636 18	0.1545 17	0.1455 16	0.0727 8	0.1091 12	0.0909 10	0.0273 3	0.0000 0
07	19.885	0.0000 0	0.0091 1	0.0455 5	0.1000 11	0.1364 15	0.1273 14	0.2000 22	0.1182 13	0.1455 16	0.0909 10	0.0273 3	0.0000 0
08	21.879	0.0000 0	0.0000 0	0.0273 3	0.0818 9	0.1000 11	0.1091 12	0.1636 18	0.1545 17	0.1273 14	0.1364 15	0.0909 10	0.0091 1
09	24.449	0.0000 0	0.0000 0	0.0182 2	0.0636 7	0.0455 5	0.0818 9	0.1545 17	0.2000 22	0.1636 18	0.1636 18	0.0364 4	0.0727 8
10	29.050	0.0091 1	0.0000 0	0.0000 0	0.0182 2	0.0273 3	0.0636 7	0.0818 9	0.1182 13	0.2182 24	0.2364 26	0.1455 16	0.0818 9
11	34.409	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0364 2	0.0182 1	0.0182 1	0.1091 6	0.2000 11	0.2727 15	0.1636 9	0.1818 10
12	46.006	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0000 0	0.0364 2	0.0545 3	0.2545 14	0.1636 9	0.4909 27

Table. 2.4.7 Class limits in transition matrix of each month and its corresponding percentile in probability distribution

Percentile	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Minimum	2.656	1.547	1.821	2.058	1.000	1.491	2.651	4.471	5.867	6.256	6.224	3.304
5	6.935	5.293	5.149	5.347	5.366	5.567	7.188	9.330	8.695	9.316	10.583	6.598
10	8.420	6.793	6.174	6.504	6.895	7.174	8.527	11.663	10.170	10.584	11.960	8.308
20	10.654	8.860	8.005	8.251	9.966	10.138	10.839	14.840	12.308	12.476	13.877	11.245
30	12.370	10.771	9.512	9.686	13.533	12.898	13.034	18.018	14.603	13.880	15.537	13.809
40	13.890	12.600	11.034	11.035	16.773	16.113	15.505	20.707	16.851	15.333	17.015	16.002
50	15.300	14.516	12.925	12.284	20.087	19.859	18.246	24.803	19.401	16.743	18.908	18.742
60	17.510	16.617	14.606	13.846	24.552	24.962	20.569	28.122	22.768	18.661	20.906	22.079
70	19.441	19.089	16.387	15.650	29.811	31.513	24.613	33.263	27.162	21.423	23.011	26.356
80	22.240	21.967	19.218	18.196	38.052	39.128	29.083	40.871	32.440	24.700	26.161	32.026
90	27.220	27.168	24.387	22.292	50.282	53.552	36.335	52.939	44.292	30.468	32.444	42.556
95	31.829	31.841	28.491	26.061	63.229	67.877	43.221	70.433	58.197	36.716	36.521	50.928
Next to Max	52.530	52.551	48.354	41.821	136.869	210.144	108.817	273.411	153.707	69.865	67.980	136.722
Maximum	59.104	53.239	51.971	50.333	197.840	225.957	109.485	430.546	163.226	77.526	69.895	142.059

Unit: CMS

2.5 Calculation of irrigation demands and turbine operating hours.

2.5.1 Irrigation demands.

As mentioned before in Section 2.2, monthly irrigation demands have been calculated based on a Modified Penman model. Also the effect of the effective precipitation was calculated by a method developed by J. Restrepo and H. S. Morel-Seytoux. Table 2.5.1 shows the results for year 1983 and 1984. The total irrigation area has been divided in 8 sectors from 30 old zones. In Table 2.5.2, the distribution of the old zones is shown and in Table 2.5.3, the new sectors. Figure 2.5.1 is also included which shows the new distribution of the sectors. This information was taken from the report "Organizacion de operacion y mantenimiento Informe preliminar de diagnostico," by Fredericksen, Kamine and Assist. and EDASA, February, 1985.

Using the same methodology, weekly irrigation demands have been estimated for years 1983 and 1984 for each of th eight sectors. In table 2.5.4 the mean consumptive use is shown for sector and week. We considered a total efficiency of 35%.

2.5.2 Generation of turbine operating hours.

The turbine operating hours monthly time series as a required input of the MODSIM program have been generated using stochastic procedures. For details refer to Section 1.9, stochastic generation of turbine operating hours, in Volume 1.

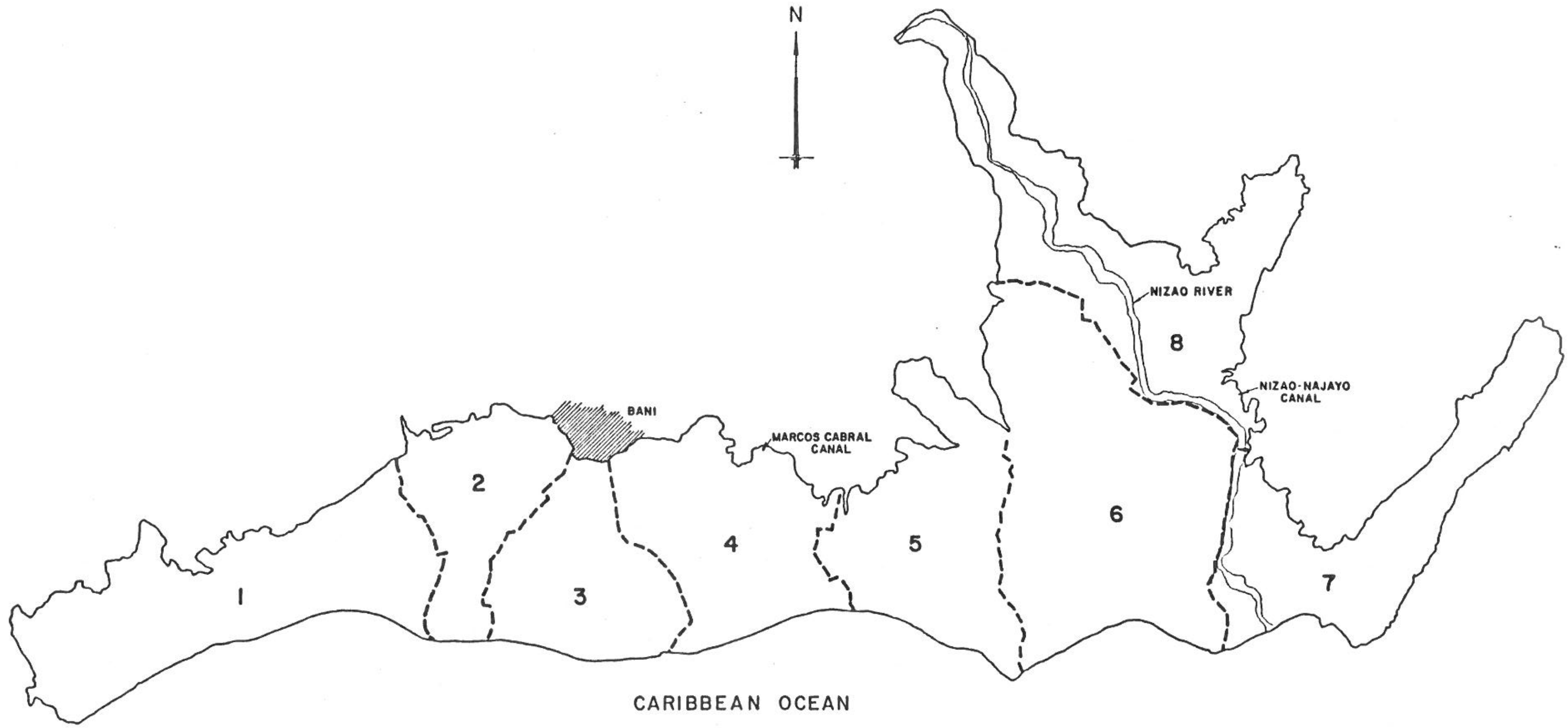


FIG. 2.5.1 Distribution of the New Sectors for the Valdesia Irrigation Zone

Table 2.5.1 Monthly calculated irrigation demands for year 1983 and 1984 for the Valdesia irrigation zone.

	1984						1983						Total Average m^3/s (1983-84)
	ETP(mm)	Efect Precip (mm)	Consumptive Use Total (mm)	Consumptive Use Cabral (m^3/s)	Consumptive Use Nizao (m^3/s)	Consumptive Use Total (m^3/s)	ETP(mm)	Efect Precip (mm)	Consumptive Use Total (mm)	Consumptive Use Cabral (m^3/s)	Consumptive Use Nizao (m^3/s)	Consumptive Use Total (m^3/s)	(m^3/s)*
Jan	130.79	38.61	263.37	6.86	.80	7.66	113.09	12.72	286.77	7.68	.87	8.55	8.11
Feb	123.72	41.09	236.09	6.35	.72	7.07	129.91	0.00	371.17	10.05	1.14	11.19	9.13
Mar	169.39	20.00	426.83	11.33	1.29	12.62	145.68	25.07	344.60	9.27	1.10	10.38	11.50
Apr	168.23	41.18	363.00	9.75	1.09	10.84	153.31	32.93	343.94	9.91	1.14	10.05	10.44
May	178.22	49.40	368.06	9.99	1.12	11.11	141.84	88.69	151.86	3.81	.49	4.30	7.71
Jun	138.91	33.38	301.51	8.14	.94	9.08	144.14	62.92	232.06	5.89	.76	6.65	7.87
Jul	170.11	85.05	243.03	6.49	.82	7.31	174.62	24.12	430.00	11.06	1.38	12.44	9.88
Aug	181.28	60.33	345.57	8.74	1.15	9.89	157.41	95.61	176.57	4.50	.57	5.07	7.48
Sep	164.36	78.81	244.43	6.01	.80	6.81	168.69	40.26	366.94	9.33	1.19	10.52	8.67
Oct	160.45	75.61	242.40	5.81	.79	6.60	151.56	39.80	319.31	8.13	1.02	9.15	7.88
Nov	158.71	20.00	396.31	10.21	1.26	11.47	156.23	28.89	363.83	9.41	1.10	10.51	10.99
Dec	149.12	32.99	331.80	8.31	1.04	9.35	141.61	30.26	318.14	7.92	.99	8.91	9.13

*Was considered a total efficiency of 35%.

Table 2.5.2 Old sectors in the Valdesia irrigation sub-system.

Marcos A. Cabral Canal

Number	Name	Number	Name
1	Maximo Gomez	13	Sector Escondido
2	Matanzas	14	Paya Sar
3	Los Jobos	15	Paya Norte
4	Canafistol	16	Salto de Agua
5	Sombrero Norte	17	Carreton
6	Sombrero Sor	18	Catalina
7	El Llano Norte	19	Nizao 1
8	El Llano	20	Nizao 2
9	Boca Canasta Norte	21	Santana
10	Boca Canasta Sor	22	Pizarrete
11	Corbanal	23	Robledal
12	Mata Gorda	24	Las Barias

Nizao-Najayo Canal

Number	Name	Number	Name
1	Semana Santa	4	Sabana Palenque
2	La Cabria	5	Sabana Grande de Palenque
3	Juan Baron	6	La Reforma

Table 2.5.3 New sectors in the Valdesia irrigation sub-system.

Number	Numbers of Old Sectors
1	1,2,3
2	4,5,6,7
3	8,9,10
4	11,12,13,14,15
5	16,17
6	18,19,20,21,22,23,24
7	1,2(*)
8	3,4,5,6(*)

(*) Sectors of the Nizao-Najayo Canal. The rest are from the Marcos A. Cabral Canal.

Table 2.5.4 Calculated mean weekly consumptive use for the Valdesia irrigation subsystem (m^3/s).

WEEK	S. 1	S. 2	S. 3	S. 4	S. 5	S. 6	S. 7
1	1.41429	0.94286	1.50000	0.94286	3.01429	1.01429	0.92857
2	0.95714	0.64286	1.04286	0.62857	2.18571	0.65714	0.67143
3	0.95714	0.67143	1.08571	0.64286	2.25714	0.68571	0.70000
4	1.10000	0.74286	1.20000	0.72857	2.48571	0.75714	0.75714
5	1.34286	0.85714	1.28571	1.04286	3.10000	1.17143	0.94286
6	0.88571	0.58571	0.85714	0.64286	2.32857	0.84286	0.71429
7	1.02857	0.67143	0.98571	0.74286	2.58571	0.94286	0.78571
8	1.51429	0.97143	1.47143	1.17143	3.48571	1.32857	1.05714
9	1.62857	1.02857	1.60000	1.20000	3.18571	1.35714	0.95714
10	1.47143	0.92857	1.45714	1.11429	2.94286	1.24286	0.88571
11	1.45714	0.92857	1.44286	1.10000	2.94286	1.24286	0.88571
12	1.61429	1.01429	1.58571	1.18571	3.20000	1.35714	0.95714
13	1.97143	1.25714	1.98571	1.42857	4.05714	1.70000	1.21429
14	1.31429	0.85714	1.37143	1.00000	2.98571	1.30000	0.91429
15	1.58571	1.00000	1.62857	1.24286	3.45714	1.54286	1.05714
16	1.47143	0.92857	1.50000	1.14286	3.24286	1.44286	0.98571
17	1.01429	0.67143	1.05714	0.80000	2.42857	1.05714	0.74286
18	1.97143	1.22857	1.98571	1.52857	4.01429	1.85714	1.24286
19	1.47143	0.90000	1.48571	1.21429	3.05714	1.45714	0.95714
20	1.07143	0.65714	1.08571	0.94286	2.32857	1.12857	0.72857
21	0.30000	0.20000	0.31429	0.27143	0.81429	0.38571	0.25714
22	0.55714	0.35714	0.58571	0.38571	1.07143	0.45714	0.34286
23	1.28571	0.80000	1.31429	0.94286	2.48571	1.11429	0.77143
24	0.67143	0.40000	0.68571	0.54286	1.30000	0.62857	0.40000
25	1.48571	0.90000	1.50000	1.11429	2.84286	1.30000	0.88571
26	2.10000	1.21429	2.05714	1.45714	3.80000	1.72857	1.17143
27	1.07143	0.61429	1.07143	0.70000	1.91429	0.88571	0.60000
28	2.05714	1.20000	2.02857	1.37143	3.64286	1.67143	1.14286
29	1.90000	1.10000	1.87143	1.24286	3.35714	1.52857	1.04286
30	0.80000	0.47143	0.80000	0.48571	1.41429	0.61429	0.44286
31	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
32	1.57143	0.91429	1.61429	0.90000	2.71429	1.22857	0.84286
33	2.11429	1.22857	2.15714	1.21429	3.68571	1.64286	1.15714
34	1.60000	0.92857	1.65714	0.91429	2.75714	1.24286	0.87143
35	1.07143	0.67143	1.21429	0.52857	2.15714	0.80000	0.70000
36	1.84286	1.11429	1.95714	0.97143	3.52857	1.38571	1.11429
37	1.81429	1.08571	1.92857	0.95714	3.47143	1.35714	1.10000
38	0.48571	0.28571	0.51429	0.24286	0.94286	0.37143	0.30000
39	1.02857	0.61429	1.21429	0.54286	2.15714	0.80000	0.67143
40	1.42857	0.84286	1.60000	0.87143	2.70000	1.00000	0.85714
41	1.38571	0.81429	1.54286	0.82857	2.58571	0.95714	0.82857
42	0.85714	0.52857	0.94286	0.52857	1.55714	0.58571	0.48571
43	1.18571	0.72857	1.31429	0.71429	2.20000	0.81429	0.70000
44	1.45714	0.91429	1.87143	0.97143	2.78571	0.95714	0.85714
45	1.58571	0.98571	1.85714	1.02857	2.90000	0.98571	0.90000
46	1.90000	1.18571	2.30000	1.28571	3.55714	1.22857	1.10000
47	1.54286	0.94286	1.75714	1.00000	2.78571	0.97143	0.87143
48	1.38571	1.05714	2.01429	1.05714	3.10000	1.07143	0.98571
49	0.77143	0.64286	1.28571	0.58571	1.91429	0.57143	0.58571

50	1.57143	1.12857	2.12857	1.14286	3.31429	1.15714	1.05714
51	1.18571	0.82857	1.54286	0.81429	2.40000	0.82857	0.75714
52	1.25714	0.95714	1.80000	0.95714	2.80000	0.94286	0.87143

WEEK	S. 8	TOTAL
1	0.171429	9.890
2	0.100000	6.880
3	0.114286	7.090
4	0.114286	7.895
5	0.185714	9.930
6	0.114286	6.965
7	0.142857	7.885
8	0.214286	11.225
9	0.257143	11.210
10	0.228571	10.270
11	0.228571	10.205
12	0.257143	11.190
13	0.328571	13.940
14	0.257143	9.995
15	0.271429	11.785
16	0.257143	10.995
17	0.185714	7.945
18	0.328571	14.145
19	0.228571	10.820
20	0.171429	8.125
21	0.057143	2.610
22	0.100000	3.850
23	0.214286	8.925
24	0.100000	4.715
25	0.242857	10.265
26	0.314286	13.865
27	0.171429	7.020
28	0.342857	13.465
29	0.314286	12.375
30	0.114286	5.160
31	0.000000	0.000
32	0.285714	10.065
33	0.371429	13.575
34	0.285714	10.225
35	0.142857	7.280
36	0.271429	12.190
37	0.271429	12.000
38	0.057143	3.195
39	0.171429	7.215
40	0.214286	9.515
41	0.214286	9.140
42	0.128571	5.595
43	0.171429	7.815
44	0.228571	10.045
45	0.214286	10.465
46	0.285714	12.845
47	0.214286	10.085
48	0.214286	10.890
49	0.114286	6.480

50	0.228571	11.725
51	0.171429	8.530
52	0.200000	9.795

2.6 Stochastic dynamic programming

2.6.1 Use of dynamic programming with Transition probabilities.

As described in Section 2.4, the CSUDP dynamic programming model can be used in a deterministic sense to analyze the optimal reservoir operation for any given period of input data. The results of the analysis are based upon that specific period of input data and generalized operational policies can be obtained only by analyzing many such periods of data. Unfortunately this can be both time consuming and computationally extensive.

Since inflows to a reservoir are stochastic processes, operational policies that consider this stochasticity directly can be obtained by using a stochastic model. Stochastic dynamic programming, which was selected for this analysis, can find policies that optimize the expected value of the operational objective over a long operation period. The transition probability matrix describes the discrete conditional probability between two consecutive monthly reservoir random inflows. Optimal policies are determined in stochastic dynamic programming by searching over all possible inflows of a current month conditioned on a specific inflow of the previous month. For random inflow I in month i, the general form of the recursion equation used in stochastic dynamic programming can be written as:

$$F_i(S_i, I_{i-1}) = \underset{S_{i+1} \text{ (or } R_i)}{\text{MAX}} \sum_{k=1}^{K} p(I_{ik}/I_{i-1}) \cdot [\, f_i(S_i, R_i, S_{i+1}, I_{ik}) + F_{i+1}(S_{i+1}, I_{ik}) \,] \qquad (2.6.1)$$

where, $i = 1, \ldots, N$ is index of months

$k = 1, \ldots, K$ is index of discrete values of random inflow

S_i = Reservoir initial storage of month i

R_i = Reservoir release during month i

I_{i-1} = value of a specific random inflow at month i-1

I_{ik} = value of random inflow at month i, discrete level k

$p(I_{ik}/I_{i-1})$ = probability of occurence of I_{ik} conditioned on the previous I_{i-1}.

$$\sum_{k=1}^{K} p(I_{ik}/I_{i-1}) = 1 \qquad (2.6.2)$$

Since the probability distributions of the random inflows are periodic year after year, the optimal policies will repeat themselves every 12 months. Thus, a so called stationary operation policy is obtained. This policy can be applied each year over the entire operation horizon with any sequence of inflows. To find a stationary policy, all other variables used in the reservoir analysis, such as typical irrigation demand, net evaporation, average hours for power generation etc. in each month, must be provided as average representative values. These values are shown in Table 2.6.1.

Subroutines STATE, OBJECT, READIN and the input data file were developed for CSUDP. They are shown on Figure 2.6.1 and 2.6.2. A stationary policy was reached after calculation for 48 months with CSUDP.

To get optimal policies, the CSUDP model is run using both the invertible and non-invertible form of the system state equation in Subroutine STATE. Using the invertible form analysis, the optimal policy of end-of-month target storage as a function of initial storage is determined. From the non-invertible form analysis, an optimal policy of required optimal release for any particular level of initial storage is obtained.

Only the results from the invertible form of the state equation, that is target end-of-month storage as a function of initial storage are presented in this report.

Table 2.6.1. Averaged Represented Values used for Analyzing Optimal (Statioanary) Policy in CSUDP

Variables	Irrigation Demand (CMS)	Net Evaporation (mm)	Maximum Storage (MCM)	Time for Power Generation (fraction)	Number of Days	Convert 1 CMS to MCM
January	8.11	89.44	153	.230968	31	.373357
February	9.13	88.20	153	.313894	28.25	.409702
March	11.50	103.13	153	.250793	31	.373357
April	10.44	57.89	153	.243139	30	.385802
May	7.71	-269.78	153	.283427	31	.373357
June	7.87	-170.89	153	.461958	30	.385802
July	9.88	26.13	153	.403858	31	.373357
August	7.48	-32.88	133	.384355	31	.373357
September	8.67	-0.57	113	.278681	30	.385802
October	7.88	-47.13	137	.303253	31	.373357
November	10.99	22.88	153	.378194	30	.385802
December	9.13	79.75	153	.219758	31	.373357

Reservoir Geometric Data

Elevation (M , o.s.l.)	105.	110.	115.	120.	125.	130.	135.	140.	145.	150.	155.	160.
Area (1000 M*M)	324.	871.	1572.	2310.	3406.	4537.	5664.	6677.	7492.	8357.	9000.	9776.
Volume (MCM)	0.	.600	1.173	6.182	16.21	32.16	53.74	80.14	113.5	153.1	196.5	243.4

Power Table (MW) for one Turbine

Head (M) / Discharge (CMS)	130.75	134.0	137.0	141.0	144.0	147.0	150.0
20.5	8.0	8.3	8.7	9.0	9.3	9.9	10.5
25.0	10.7	11.2	11.8	12.5	13.0	13.6	14.4
30.0	13.2	14.1	14.9	16.0	16.8	17.4	18.2
32.5	14.5	15.6	16.4	17.7	18.5	19.2	20.0
35.0	15.6	16.8	17.8	19.2	20.2	20.9	21.8
37.5	16.6	17.9	19.1	20.4	21.6	22.4	23.5
40.0	17.5	18.9	20.3	21.7	22.9	23.8	24.9
42.5	17.7	19.8	21.3	22.7	24.0	25.1	26.0
45.0	19.0	20.5	22.0	23.5	24.9	26.1	27.0

Figure 2.6.1. Subroutines used in the CSUDP runs.

```
C ######################################################################
C
C       STATIONARY OPERATION POLICY ANALYSIS: STOCHASTIC DP,  RUN#02
C
C       VALDESIA RESERVOIR:  MAX ENERGY  ST  MEET IRRIGATION DEMAND
C                            RANDOM INFLOW (CONDITIONAL PROBABILITY)
C
C ######################################################################
C
C
C **********************************************************************
C
      SUBROUTINE STATE
C
C     ******************************************************************
C
C        THIS SUBROUTINE CALCULATES THE MONTHLY WATER POWER RELEASES
C        INVERTIBLE FORM
C        A SMALL PENALTY IS ADDED TO THE CASE THAT
C        RESERVOIR RELEASE IS GREATER THAN TURBINE DISCHARGE CAPACITY
C
C        X    : STORAGE VOLUME AT THE INITIAL OF THE MONTH IN  MCM
C        X1   : STORAGE VOLUME AT THE END     OF THE MONTH IN  MCM
C        U    : RESERVOIR RELEASE, AVAILABLE FOR POWER  IN CMS
C        R    : RANDOM INFLOW IN  CMS
C        QIRR : TYPICAL MONTHLY IRRIGATION DEMAND OF ZONE A1 (CMS)
C        EMP  : AVERAGED NET EVAPORATION (EVAPOR-PRECIP) IN  MM
C        TCF  : MONTHLY CONVERSION FACTOR,  1 MCM = TCF CMS
C        WS   : ENERGY PENALTY WEIGHTING FACTOR, FOR
C               NOT MEETING THE IRRIGATION DEMAND, IN GWH
C        WU   : NEGATIVE RELEASE PENALTY WEIGHTING FACTOR
C        SPILL: EXCESS WATER AFTER MEETING IRRIGATION DEMAND
C
C     ******************************************************************
C
C
      COMMON /ONEDM/ X, X1, U, F, I, J, K, L, R, PNALTY
C
      DIMENSION  QIRR(12), EMP(12), TCF(12)
C
      DATA  QIRR/  8.11,  9.13, 11.50, 10.44,  7.71,  7.87,
     2             9.88,  7.48,  8.67,  7.88, 10.99,  9.13/
      DATA  EMP/  89.44,  88.20, 103.13,  57.89, -269.78, -170.89,
     2            26.13, -32.88,  -0.57, -47.13,   22.88,   79.75/
      DATA  TCF/ .373357, .409702, .373357, .385802, .373357, .385802,
     2          .373357, .373357, .385802, .373357, .385802, .373357/
      DATA  WS/ 100./,  WUX/ 1./,  WUN/ 100000./
C
      CALL  VTABL ( X , EL, A , 2)
      CALL  VTABL ( X1, EL, A1, 2)
C
```

```
      IM = MOD(I,12)
      IF (IM.EQ.0)  IM = 12
      U = (X - X1 - EMP(IM)*(A+A1)*.5E-6) * TCF(IM) + R
C
C **  PENALTY WILL BE COUNTED IN GWH
C
      F = 0.
C
C **  IF  U > 300 ,  LET  U = 300  TO AVOID A LARGE PENALTY
C
      IF (U.GT.300.)  THEN
          F = F - WUX * ( U - 300. )
          U = 300.
      ENDIF
C
C **  IF  U < 0 ,  LET  U = 0  TO AVOID DOUBLE PENALTY ON NEGATIVE RELEASE
C
      IF (U.LT.0.)  THEN
          F = F + WUN * U
          U = 0.
      ENDIF
C
C **  FOR U THAT LIES BETWEEN 0 AND QIRR(IM) WILL BE PENALIZED HERE ...
C **  IF SPILL < 0 MEANS INSUFFICIENT WATER SUPPLY FOR IRRIGATION
C **  USE A LARGE PENALTY WEIGHTING FACTOR WS TO PENALIZE IT
C
      SPILL = U - QIRR(IM)
      IF (SPILL.LT.0.)  F = F + WS * SPILL
C
      RETURN
      END


C ********************************************************************
C
      SUBROUTINE VTABL ( VO, EL, AR, IC)
C
C     ****************************************************************
C
C        VOLUME-HEAD-AREA TABLE OF VALDESIA
C        FOR INTERPOLATION OF HEAD OR AREA FROM KNOWN VOLUME
C
C        V  :  VOLUME.  MCM
C        E  :  ELEVATION.  M  (A.S.L.)
C        A  :  SURFACE AREA.  1000*M*M
C        IC :  CHOICE OF INTERPOLATION.  1 FOR HEAD,  2 FOR AREA
C
C         INPUT:  VO, IC
C        OUTPUT:  EL  OR  AR
C
C     ****************************************************************
C
C
```

```
      DIMENSION  V(12), E(12), A(12)
C
      DATA  V/   0.    ,    .600,   1.173,   6.182,  16.214,  32.163,
     2          53.736,  80.145, 113.465, 153.088, 196.481, 243.421/
      DATA  E/   105.,    110.,    115.,    120.,    125.,    130.,
     2           135.,    140.,    145.,    150.,    155.,    160./
      DATA  A/   324.,    871.,   1572.,   2310.,   3406.,   4537.,
     2          5664.,   6677.,   7492.,   8357.,   9000.,   9776./
C
      DO 20 I = 2,12
      IF (VO.LT.V(I))  GOTO 30
   20 CONTINUE
   30 NV = I
      IF (IC.EQ.1) CALL TWOPLN (VO, V(NV), V(NV-1), E(NV), E(NV-1), EL)
      IF (IC.EQ.2) CALL TWOPLN (VO, V(NV), V(NV-1), A(NV), A(NV-1), AR)
C
      RETURN
      END


C ***********************************************************************
C
      SUBROUTINE TWOPLN (X, X1, X2, Y1, Y2, Y)
C
C     *******************************************************************
C
C        LINEAR INTERPOLATION BETWEEN 2 POINTS
C
C        FOR VALUE X BETWEEN (X1,X2), LINEARLY INTERPOLATE THE
C        CORRESPONDING VALUE Y OF (X,Y) BETWEEN (X1,Y1) AND (X2,Y2)
C
C          - ---------*---------------*---------------*-------- +
C                (X2,Y2)           (X,Y)            (X1,Y1)
C
C         INPUT:  X, X1, X2, Y1, Y2
C        OUTPUT:  Y
C
C     *******************************************************************
C
C
      IF (X1.EQ.X2) THEN
         IF (Y1.NE.Y2) STOP 'CAN''T INTERPOLATE LINE Y=C FOR 2 X''S !'
         Y = Y1
         RETURN
      END IF
C
      Y = Y2+(Y2-Y1)*(X-X2)/(X2-X1)
C
      RETURN
      END
```

```
C *******************************************************************
C
      SUBROUTINE SRFLN2 (PW, HDI, QPI)                              041786
C
C     **************************************************************
C
C       LINEAR INTERPOLATION OF TABLE DATA
C
C       POWR, NH, NQ
C       THE POWER DATA SET OF RESERVOIR, POWR (NH*NQ MATRIX),
C       WITH H-AXIS ARRAY H  AND  Q-AXIS ARRAY Q
C       BOTH H AND Q ARRAY SHOULD BE IN ASSCENDING ORDER.           041786
C
C       PW, HD, QP
C       FIND THE INTERPOLATED VALUE "PW" FOR A SPECIFIC
C       COORDINATE (HD,QP) ON THE TABLE (MATRIX)
C       POWR : POWER, IN MW
C         HT : ELEVATION, IN M (A.S.L.)
C         QT : POWER RELEASE, IN CMS
C
C       TAKE AVERAGE POWER COEFFICIENT OF 2 CORRESPONDING POINTS
C       FIRST, THE VALUE IS INTERPOLATED OVER H AXIS FIRST.
C       THEN INTERPOLATE THE FINAL POWER COEFFICIENT FROM THESE
C       2 NEW POINTS (E1 & E2) OVER Q AXIS.
C
C       FOR POINTS OUTSIDE THE TABLE IS ASSIGNED VALUED WITH
C       ALL DATA WITH EITHER HEAD OR DISCHARGE SMALLER THAN THE     041786
C       MINIMUM H OR Q VALUE IS RETURNED WITH ZERO COEFFICIENT.     041786
C       IF BOTH HEAD AND DISCHARGE OF THE POINT ARE GREATER THAN    041786
C       THE MAXIMUM H AND Q VALUE, THEN POWR(NH,NQ) IS RETURNED.    041786
C       IN CASE QP IS LARGER THAN THE MAXIMUM QT(NQ), THEN QP IS    041786
C       TRUNCATED TO QT(NQ), OR QP=QT(NQ).                          041786
C       FOR HD IS LARGER THAN THE MAXIMUM HT(NH), THEN IH=NH IS     041786
C       RETURNED.
C
C         KNOWN :  POWR(NH,NQ), HT(NH), QT(NQ)
C         INPUT :  HDI=HD,  QPI=QP
C        OUTPUT :  PW
C
C     **************************************************************
C
C
      DIMENSION  POWR(7,9), HT(7), QT(9)
C
C     TOTAL  63 (NH*NQ)  DATA POINTS ON THE TABLE
C
      DATA  NH, NQ/ 7, 9/
      DATA  QT/  20.0, 25.0, 30.0, 32.5, 35.0, 37.5, 40.0, 42.5, 45.0/
      DATA  HT/  130.75, 134.0, 137.0, 141.0, 144.0, 147.0, 150.0/
      DATA  POWR/  8.0,    8.3,    8.7,    9.0,    9.3,    9.9,   10.5,
     2            10.7,   11.2,   11.8,   12.5,   13.0,   13.6,   14.4,
     3            13.2,   14.1,   14.9,   16.0,   16.8,   17.4,   18.2,
     4            14.5,   15.6,   16.4,   17.7,   18.5,   19.2,   20.0,
     5            15.6,   16.8,   17.8,   19.2,   20.2,   20.9,   21.8,
```

```
     6              16.6,   17.9,   19.1,   20.4,   21.6,   22.4,   23.5,
     7              17.5,   18.9,   20.3,   21.7,   22.9,   23.8,   24.9,
     8              17.7,   19.8,   21.3,   22.7,   24.0,   25.1,   26.0,
     9              19.0,   20.5,   22.0,   23.5,   24.9,   26.1,   27.0/
C
      HD = HDI
      QP = QPI
C
      IF (HD.LT.HT(1) .OR. QP.LT.QT(1))  THEN                           041786
                                         PW = 0.                        041786
                                         RETURN                         041786
                                         ENDIF                          041786
C
C
      IH=0
      IQ=0
      IF (HD.GE.HT(NH))  IH = NH                                        041786
      IF (QP.GE.QT(NQ))  IQ = NQ                                        041786
      IF (QP.GT.QT(NQ))  QP = QT(NQ)                                    041786
C
      DO 200 I=1,NH-1                                                   041786
      IF (HD.EQ.HT(I))  THEN
                        IH = I
                        GO TO 300
                        ENDIF
      IF (HD.GT.HT(I))  IH1 = I
  200 CONTINUE
      IH2=IH1+1
C
  300 DO 400 I=1,NQ-1                                                   041786
      IF (QP.EQ.QT(I))  THEN
                        IQ = I
                        GO TO 500
                        ENDIF
      IF (QP.GT.QT(I))  IQ1=I
  400 CONTINUE
      IQ2=IQ1+1
C
C **  FOR POINT CLASSIFIED TO CORNER OR GRID POINT, JUST RETURN THE VALUE
C
  500 IF (IH.NE.0 .AND. IQ.NE.0) THEN
                                 PW = POWR(IH,IQ)
                                 RETURN
                                 ENDIF
C
C **  PERFORM LINEAR INTERPOLATION ON A LINE
C **  FOR POINT SIT AT BOUNDARY OR GRID LINE
C
      IF (IH.NE.0)  THEN
         CALL TWOPLN
     1        (QP,QT(IQ1),QT(IQ2),POWR(IH,IQ1),POWR(IH,IQ2),PW)
         RETURN
         ENDIF
      IF (IQ.NE.0)  THEN
```

```
          CALL TWOPLN
     1         (HD,HT(IH1),HT(IH2),POWR(IH1,IQ),POWR(IH2,IQ),PW)
          RETURN
          ENDIF
C
C **  PERFORM LINEAR INTERPOLATION ON A THE TABLE
C
C **  FIRST, 2 LINEAR INTERPOLATIONS OVER H-AXIS FOR NEW PWI VALUE
C **   THEN, GET NEW VALUE OVER THE Q-AXIS DIRECTION
C
      CALL TWOPLN (HD,HT(IH1),HT(IH2),POWR(IH1,IQ1),POWR(IH2,IQ1),PW1)
      CALL TWOPLN (HD,HT(IH1),HT(IH2),POWR(IH1,IQ2),POWR(IH2,IQ2),PW2)
      CALL TWOPLN (QP,QT(IQ1),QT(IQ2),PW1,PW2,PW)
C
      RETURN
C
      END


C *********************************************************************
C
      SUBROUTINE OBJECT
C
C     *****************************************************************
C
C       THIS SUBROUTINE CALCULATES THE ENERGY GENERATED IN EACH MONTH
C
C       FPG  : AVERAGED TOTAL POWER GENERATION TIME IN EACH MONTH
C       TCF  : MONTHLY CONVERSION FACTOR,  1 MCM = TCF CMS
C              (FRACTION)
C       DAYM : TOTAL DAYS IN A MONTH
C       U    : CALCULATED WATER POWER RELEASE PER MONTH    (CMS)
C       QP   : ACTUAL FLOW RELEASE RATE THRU TURBINE        (CMS)
C       QTBX : MAXIMUM FLOW CAPACITY THRU A SINGLE TURBINE (CMS)
C       QTBN : MINIMUM FLOW CAPACITY THRU A SINGLE TURBINE (CMS)
C       XMAX : MAXIMUM ALLOWED STORAGE IN CURRENT MONTH IM (MCM)
C       POW  : AVERAGE POWER GENERATED BY INTERPOLATION      (MW)
C       ENG  : ACTUAL ENERGY PRODUCED                       (GWH)
C       F    : CCLCULATED ENERGY INCLUDING PENALTY          (GWH)
C       WP   : ENERGY PENALTY WEIGHTING FACTOR, FOR
C              WATER RELEASE EXCESS THE MAXIMUM TURBINE DISCHARGE
C
C     *****************************************************************
C
      COMMON /ONEDM/ X, X1, U, F, I, J, K, L, R, PNALTY
C
      DIMENSION  FPG(12),  DAYM(12),  XMAX(12),  TCF(12)
C
      DATA   FPG/ .230968, .313894, .250793, .243139, .283427, .461958,
     2            .403858, .384355, .278681, .303253, .378194, .219758/
      DATA   TCF/ .373357, .409702, .373357, .385802, .373357, .385802,
     2            .373357, .373357, .385802, .373357, .385802, .373357/
      DATA  DAYM/ 31.,28.25,31.,30.,31.,30.,31.,31.,30.,31.,30.,31./
```

```
      DATA  XMAX/  153., 153., 153., 153., 153., 153.,
     2             153., 133., 113., 137., 153., 153./
      DATA  WP/ 0.1/,  QTBX/ 45./,  QTBN/ 20./
C
      IM = MOD(I,12)
      IF (IM.EQ.0)  IM=12
C
      CALL  VTABL ( X , E , AR, 1)
      CALL  VTABL ( X1, E1, AR, 1)
      EM = (E+E1)/2.
C
C **  FROM POWER TABLE, THERE WILL GENERATE MUCH MORE POWER  ....
C **  LET ONE TURBINE WORK TILL ITS MAXIMUM CAPACITY, IF QP < 65 CMS
C **  LET TWO TURBINE WORK AT SAME TIME, IF QP >= 65 CMS
C
      QP = U / FPG(IM)

      IF (QP.LT.65.)  THEN
          QP1 = AMIN1 (QP,QTBX)
          IF (QP1.LT.QTBN)  THEN
              POW1 = 0.
              POW2 = 0.
          ELSE
              QP2 = QP - QP1
              CALL SRFLN2 (POW1, EM, QP1)
              IF (QP2.LT.QTBN)  POW2 = 0.
              IF (QP2.GE.QTBN)  CALL SRFLN2 (POW2, EM, QP2)
          ENDIF
      ELSE
          QP1 = QP * 0.5
          CALL SRFLN2 (POW1, EM, QP1)
          POW2 = POW1
      ENDIF
C
      ENG = (POW1+POW2) * .024 * DAYM(IM) * FPG(IM)
      F = F + ENG
C
C
C **  THE MAXIMUM EQUIVALENT AVERAGE RESERVOIR RELEASE FOR POWER GENERATION
C **  WILL BE UMAX=2*QTUB*FPG(IM) FOR TWO TURBINES.
C **  ONCE THERE IS (UNNECESSARY) EXCESS RELEASE AND X1 IS NOT FULL,
C **  A SMALL PENALTY WEIGHTING FACTOR WP IS APPLIED TO THE AVAILABLE STORAGE
C **  THUS, DRIVE THE STORAGE KEEP AS HIGH AS POSSIBLE !
C
      IF (X1.LT.XMAX(IM))  THEN
          UMAX = 2. * QTBX * FPG(IM)
          UEXCS = U - UMAX
          IF (UEXCS.GT.0.)  THEN
              XEXCS = ( XMAX(IM) - X1 ) * TCF(IM)
              IF (UEXCS.GT.XEXCS)  UEXCS = XEXCS
              F = F - WP * UEXCS
          ENDIF
      ENDIF
C
```

```
      RETURN
      END


C **********************************************************************
C
      SUBROUTINE READIN
C
C     ******************************************************************
C
      RETURN
      END
```

Figure 2.6.2. Input data file used in CSUDP runs (optimal operation rules)

```
STATIONARY OPERATION POLICY ANALYSIS OF VALDESIA RESERVOIR.
  -1     1    48     1     1     1
   1     1    48     0     0     2
       2.0        0.1        0.0        0.0        0.0
  17
   1        3.       153.
   8        3.       133.
   9        3.       113.
  10        3.       137.
  11        3.       153.
  20        3.       133.
  21        3.       113.
  22        3.       137.
  23        3.       153.
  32        3.       133.
  33        3.       113.
  34        3.       137.
  35        3.       153.
  44        3.       133.
  45        3.       113.
  46        3.       137.
  47        3.       153.
   1
   1        0.       300.
        12
   5.5102    7.6897    9.4707    11.486    13.111    14.608    16.288    18.488
   20.666    24.367    29.279    37.493                                  01  01
        12
   4.0087    6.1114    7.8893    9.8973    11.740    13.528    15.542    17.757
   20.398    24.194    29.196    38.625                                  02
        12
   3.9725    5.7109    7.1656    8.8120    10.275    12.016    13.763    15.501
   17.678    21.527    26.341    34.457                                  03
        12
   4.3508    5.9561    7.4184    8.9743    10.322    11.737    13.075    14.619
   16.921    20.014    23.931    30.353                                  04
        12
   4.0241    6.1822    8.4843    11.781    15.218    18.337    22.153    27.156
   33.337    43.358    55.936    83.589                                  05
        12
   4.0005    6.3710    8.8024    11.431    14.444    17.989    22.483    28.019
   34.578    45.814    59.784    97.299                                  06
        12
   5.7850    7.9154    9.6742    11.845    14.233    16.714    19.446    22.400
   26.659    32.556    39.482    55.894                                  07
        12
   7.7630    10.646    13.213    16.576    19.307    22.898    26.456    30.446
   36.775    46.200    60.206    111.41                                  08
        12
   7.4465    9.3810    11.259    13.565    15.606    18.174    21.029    24.876
   29.388    37.564    50.860    86.017                                  09
```

12							
8.4400	10.010	11.616	13.156	14.574	16.091	17.709	19.979
22.997	27.103	33.291	47.626				10
12							
9.4234	11.310	12.869	14.762	16.259	17.935	19.885	21.879
24.449	29.050	34.409	46.006				11
12							
5.1575	7.5630	9.7400	12.589	14.874	17.343	20.320	24.207
29.173	36.263	46.281	68.123				12
12							
5.5102	7.6897	9.4707	11.486	13.111	14.608	16.288	18.488
20.666	24.367	29.279	37.493				01 02
12							
4.0087	6.1114	7.8893	9.8973	11.740	13.528	15.542	17.757
20.398	24.194	29.196	38.625				02
12							
3.9725	5.7109	7.1656	8.8120	10.275	12.016	13.763	15.501
17.678	21.527	26.341	34.457				03
12							
4.3508	5.9561	7.4184	8.9743	10.322	11.737	13.075	14.619
16.921	20.014	23.931	30.353				04
12							
4.0241	6.1822	8.4843	11.781	15.218	18.337	22.153	27.156
33.337	43.358	55.936	83.589				05
12							
4.0005	6.3710	8.8024	11.431	14.444	17.989	22.483	28.019
34.578	45.814	59.784	97.299				06
12							
5.7850	7.9154	9.6742	11.845	14.233	16.714	19.446	22.400
26.659	32.556	39.482	55.894				07
12							
7.7630	10.646	13.213	16.576	19.307	22.898	26.456	30.446
36.775	46.200	60.206	111.41				08
12							
7.4465	9.3810	11.259	13.565	15.606	18.174	21.029	24.876
29.388	37.564	50.860	86.017				09
12							
8.4400	10.010	11.616	13.156	14.574	16.091	17.709	19.979
22.997	27.103	33.291	47.626				10
12							
9.4234	11.310	12.869	14.762	16.259	17.935	19.885	21.879
24.449	29.050	34.409	46.006				11
12							
5.1575	7.5630	9.7400	12.589	14.874	17.343	20.320	24.207
29.173	36.263	46.281	68.123				12
12							
5.5102	7.6897	9.4707	11.486	13.111	14.608	16.288	18.488
20.666	24.367	29.279	37.493				01 03
12							
4.0087	6.1114	7.8893	9.8973	11.740	13.528	15.542	17.757
20.398	24.194	29.196	38.625				02
12							
3.9725	5.7109	7.1656	8.8120	10.275	12.016	13.763	15.501
17.678	21.527	26.341	34.457				03

12							
4.3508	5.9561	7.4184	8.9743	10.322	11.737	13.075	14.619
16.921	20.014	23.931	30.353				04
12							
4.0241	6.1822	8.4843	11.781	15.218	18.337	22.153	27.156
33.337	43.358	55.936	83.589				05
12							
4.0005	6.3710	8.8024	11.431	14.444	17.989	22.483	28.019
34.578	45.814	59.784	97.299				06
12							
5.7850	7.9154	9.6742	11.845	14.233	16.714	19.446	22.400
26.659	32.556	39.482	55.894				07
12							
7.7630	10.646	13.213	16.576	19.307	22.898	26.456	30.446
36.775	46.200	60.206	111.41				08
12							
7.4465	9.3810	11.259	13.565	15.606	18.174	21.029	24.876
29.388	37.564	50.860	86.017				09
12							
8.4400	10.010	11.616	13.156	14.574	16.091	17.709	19.979
22.997	27.103	33.291	47.626				10
12							
9.4234	11.310	12.869	14.762	16.259	17.935	19.885	21.879
24.449	29.050	34.409	46.006				11
12							
5.1575	7.5630	9.7400	12.589	14.874	17.343	20.320	24.207
29.173	36.263	46.281	68.123				12
12							
5.5102	7.6897	9.4707	11.486	13.111	14.608	16.288	18.488
20.666	24.367	29.279	37.493				01 04
12							
4.0087	6.1114	7.8893	9.8973	11.740	13.528	15.542	17.757
20.398	24.194	29.196	38.625				02
12							
3.9725	5.7109	7.1656	8.8120	10.275	12.016	13.763	15.501
17.678	21.527	26.341	34.457				03
12							
4.3508	5.9561	7.4184	8.9743	10.322	11.737	13.075	14.619
16.921	20.014	23.931	30.353				04
12							
4.0241	6.1822	8.4843	11.781	15.218	18.337	22.153	27.156
33.337	43.358	55.936	83.589				05
12							
4.0005	6.3710	8.8024	11.431	14.444	17.989	22.483	28.019
34.578	45.814	59.784	97.299				06
12							
5.7850	7.9154	9.6742	11.845	14.233	16.714	19.446	22.400
26.659	32.556	39.482	55.894				07
12							
7.7630	10.646	13.213	16.576	19.307	22.898	26.456	30.446
36.775	46.200	60.206	111.41				08
12							
7.4465	9.3810	11.259	13.565	15.606	18.174	21.029	24.876
29.388	37.564	50.860	86.017				09

```
      12
    8.4400    10.010    11.616    13.156    14.574    16.091    17.709    19.979
    22.997    27.103    33.291    47.626                                  10
      12
    9.4234    11.310    12.869    14.762    16.259    17.935    19.885    21.879
    24.449    29.050    34.409    46.006                                  11
      12
    5.1575    7.5630    9.7400    12.589    14.874    17.343    20.320    24.207
    29.173    36.263    46.281    68.123                                  12
.5882.2157.1961.0000.0000.0000.0000.0000.0000.0000.0000.0000      01   01
.1667.3148.2778.1481.0741.0185.0000.0000.0000.0000.0000.0000
.0833.1481.3426.2130.1204.0741.0093.0093.0000.0000.0000.0000
.0392.0294.1667.2059.2059.1176.0882.0882.0392.0196.0000.0000
.0000.0097.1262.2621.1553.1650.1262.1068.0388.0097.0000.0000
.0000.0377.0755.0849.1698.2264.1792.1226.0377.0472.0189.0000
.0000.0000.0288.0962.1442.1346.2404.1923.1154.0481.0000.0000
.0000.0094.0000.0283.1415.1792.1321.1226.2358.1415.0094.0000
.0000.0000.0095.0381.0190.0571.1333.2000.2857.1524.1048.0000
.0000.0000.0000.0094.0000.0377.0849.1038.1792.3396.1604.0849
.0000.0000.0000.0185.0185.0000.0185.0926.0741.3704.2037.2037
.0000.0000.0000.0000.0000.0000.0000.0196.0196.1176.1961.6471
.6182.2182.1091.0182.0182.0000.0182.0000.0000.0000.0000.0000      02
.1636.2545.2909.2000.0545.0182.0182.0000.0000.0000.0000.0000
.0917.1284.2936.1927.1560.0734.0459.0183.0000.0000.0000.0000
.0180.0541.2703.2613.1441.1261.0631.0360.0180.0090.0000.0000
.0000.0273.1091.2000.2455.1455.1364.0909.0273.0182.0000.0000
.0000.0273.1000.1000.1636.1364.1909.1545.0909.0273.0091.0000
.0000.0091.0273.1000.1364.1727.1636.1727.1091.0818.0273.0000
.0000.0000.0091.0182.0273.2000.1727.1909.1909.1727.0182.0000
.0000.0091.0000.0182.0727.0818.1636.1636.2364.1455.0909.0182
.0000.0000.0000.0000.0182.0455.0455.1364.2182.3545.1455.0364
.0000.0000.0000.0000.0000.0182.0000.0364.1455.2727.2727.2545
.0000.0000.0000.0000.0000.0000.0000.0364.0727.1091.1455.6364
.4364.2000.2545.0182.0182.0545.0000.0182.0000.0000.0000.0000      03
.2037.2037.2037.1667.1111.0556.0370.0000.0000.0185.0000.0000
.1171.1261.2252.1892.0991.0811.0541.0901.0180.0000.0000.0000
.0273.0455.1636.1909.2364.1545.0545.0909.0182.0182.0000.0000
.0182.0727.1455.1182.2091.1091.1364.0909.0545.0455.0000.0000
.0091.0545.1000.1455.1273.1455.1273.1364.0727.0636.0182.0000
.0091.0000.0818.1182.1091.1545.1818.1182.1364.0909.0000.0000
.0000.0000.0273.0818.1091.1273.1545.1545.1545.1364.0545.0000
.0000.0000.0273.0455.0455.1091.1091.1545.2273.2091.0727.0000
.0000.0000.0000.0182.0000.0545.1000.1273.1818.2273.1636.1273
.0000.0000.0000.0000.0000.0182.0909.0545.1636.2364.1636.2727
.0000.0000.0000.0000.0000.0000.0364.0000.1091.1636.2182.4727
.4545.1273.1818.1091.0545.0364.0182.0000.0000.0182.0000.0000      04
.1455.2000.2727.1091.1455.0909.0182.0000.0182.0000.0000.0000
.1000.1182.2273.1545.1091.1273.0364.0455.0455.0273.0091.0000
.0182.0727.1818.2000.1364.0909.0909.1182.0727.0182.0000.0000
.0455.0727.1000.1818.1636.1636.0818.1273.0455.0182.0000.0000
.0273.0364.1364.0636.1545.1455.1636.0727.0909.0727.0273.0091
.0000.0273.0545.1182.1000.1273.1273.1545.1182.1273.0364.0091
.0000.0091.0364.0364.1364.1000.1818.1455.1636.1455.0182.0273
.0000.0000.0182.1000.0727.0818.1364.1455.1364.1818.0909.0364
```

.0091.0000.0182.0364.0273.1000.1091.1364.1545.1818.1182.1091
.0000.0000.0000.0000.0000.0000.1091.0727.2000.3091.1818.1273
.0000.0000.0000.0000.0000.0000.0000.0364.1273.1273.2182.4909
.4000.2000.2364.0545.0182.0000.0364.0364.0182.0000.0000.0000 05
.1818.1455.2727.1636.0727.0909.0182.0364.0182.0000.0000.0000
.0909.1636.1727.1727.1091.1636.0727.0182.0273.0091.0000.0000
.0545.0727.1727.1636.1636.1727.1182.0727.0091.0000.0000.0000
.0364.0273.1364.1455.1545.1364.0727.1091.1091.0545.0182.0000
.0182.0273.1091.1364.1636.0545.1182.1273.1364.1091.0000.0000
.0000.0182.1091.1273.0727.1182.1182.1727.1091.0818.0545.0182
.0000.0091.0364.0636.1818.1364.1455.1182.1182.1000.0545.0364
.0091.0091.0091.0273.0636.0727.1909.1364.2091.1091.1091.0545
.0000.0000.0000.0364.0364.0818.0909.1636.1636.2727.0727.0818
.0000.0000.0000.0364.0182.0364.0545.0545.0909.3273.1818.2000
.0000.0000.0000.0000.0000.0000.0364.0364.1091.2000.2000.4182
.3636.3091.2000.0727.0545.0000.0000.0000.0000.0000.0000.0000 06
.2364.0909.2364.2364.0727.1091.0182.0000.0000.0000.0000.0000
.1273.1091.2273.1545.1455.1000.0636.0545.0091.0091.0000.0000
.0364.1000.1818.1636.2182.1091.0455.0909.0455.0000.0000.0091
.0273.0273.1818.1364.1182.1273.1636.1000.0636.0455.0091.0000
.0091.0273.0545.1636.1636.1818.1455.0818.1182.0455.0091.0000
.0000.0182.0545.1091.1182.1182.1545.2000.0727.1182.0364.0000
.0000.0091.0636.0364.0727.1636.2091.1091.1818.1091.0364.0091
.0000.0091.0182.0455.0909.0727.1182.1273.1909.2273.0545.0455
.0000.0000.0000.0364.0091.0636.0636.1636.1818.2636.1455.0727
.0000.0000.0000.0000.0000.0000.0182.0909.1091.2727.2182.2909
.0000.0000.0000.0000.0000.0182.0364.0545.1636.0909.2000.4364
.5273.2182.1455.0727.0364.0000.0000.0000.0000.0000.0000.0000 07
.2000.2364.3636.1273.0727.0000.0000.0000.0000.0000.0000.0000
.1000.1091.2818.2455.1636.0636.0182.0000.0182.0000.0000.0000
.0182.0909.2455.2000.1909.1455.0727.0182.0182.0000.0000.0000
.0091.0455.1273.2000.1545.1364.1818.0818.0545.0091.0000.0000
.0091.0091.0636.1545.1364.2273.1818.1091.0727.0273.0091.0000
.0000.0091.0182.0545.1636.1273.2182.1909.0909.1273.0000.0000
.0000.0000.0091.0364.1000.1727.1364.2000.1727.1182.0455.0091
.0000.0000.0000.0091.0273.1000.0909.2000.2364.2091.0909.0364
.0000.0000.0091.0000.0091.0091.0818.1182.2182.3273.1182.1091
.0000.0000.0000.0000.0000.0182.0364.1091.1818.2545.1818.2182
.0000.0000.0000.0000.0000.0182.0000.0545.0545.1091.2909.4727
.4364.2545.1818.0727.0364.0182.0000.0000.0000.0000.0000.0000 08
.1667.2222.2963.1481.1111.0185.0370.0000.0000.0000.0000.0000
.0901.1802.2072.2342.1712.0721.0450.0000.0000.0000.0000.0000
.0636.0455.2636.1455.1273.1455.0909.0455.0545.0182.0000.0000
.0364.0091.1909.2091.1636.1273.1091.0909.0364.0273.0000.0000
.0091.0182.0364.1364.2091.1818.1091.1727.0727.0545.0000.0000
.0000.0000.0182.0727.1182.1000.1636.2273.1545.1182.0273.0000
.0000.0091.0455.0455.0545.1545.1818.0909.1818.1909.0364.0091
.0000.0000.0000.0273.0636.1091.1636.1545.2091.2091.0364.0273
.0000.0000.0000.0182.0182.0909.1000.1455.1818.1818.1727.0909
.0000.0000.0000.0000.0000.0000.0182.1091.1455.3091.2182.2000
.0000.0000.0000.0000.0000.0000.0182.0364.0727.0909.2364.5455
.3455.3091.1818.0909.0364.0364.0000.0000.0000.0000.0000.0000 09
.1091.1636.3636.1455.0727.0364.0364.0727.0000.0000.0000.0000
.1091.1182.1818.2636.1182.0818.0636.0364.0273.0000.0000.0000

.1000.0909.1455.1455.1455.1182.1182.0545.0545.0273.0000.0000
.0364.0364.1909.0909.1182.1818.1273.0727.0818.0364.0273.0000
.0091.0273.0727.1273.1636.1364.1091.1182.1455.0818.0091.0000
.0000.0000.0455.0818.1727.1091.1909.1727.1182.0818.0182.0091
.0091.0000.0545.0909.0818.1455.1182.1455.1000.1909.0364.0273
.0000.0000.0273.0545.0727.0727.1091.1727.1636.1636.1091.0545
.0000.0000.0091.0273.0636.1182.1091.1364.1636.1727.1273.0727
.0000.0000.0000.0000.0000.0000.0545.0909.2000.3091.1818.1636
.0000.0000.0000.0000.0182.0000.0182.0182.0909.1818.1636.5091
.3519.1111.2963.0741.0185.0741.0370.0000.0370.0000.0000.0000 10
.1964.1429.1250.2321.0714.0893.0536.0357.0536.0000.0000.0000
.0818.1636.2000.1909.0818.1000.1091.0545.0091.0000.0091.0000
.0545.1091.1364.1636.1455.1000.1000.0727.0636.0455.0091.0000
.0727.0364.1818.1000.1909.1182.0909.0545.0545.0727.0182.0091
.0091.0273.0727.1455.1091.1545.1727.1000.0818.1000.0273.0000
.0000.0273.0818.1000.1455.1455.1182.1909.1455.0273.0000.0182
.0000.0000.0545.0636.1364.1273.1182.0909.1545.1545.0909.0091
.0091.0091.0545.0545.0636.0455.1273.1727.1455.1636.0818.0727
.0000.0000.0000.0273.0636.1000.0909.1636.1636.2182.0818.0909
.0000.0000.0000.0182.0364.0364.0364.0909.2000.1818.2545.1455
.0000.0000.0000.0000.0000.0182.0182.0727.0727.2545.1091.4545
.4909.2364.1455.0364.0545.0364.0000.0000.0000.0000.0000.0000 11
.1273.1455.2909.1455.0909.1091.0182.0182.0364.0000.0000.0182
.0459.0826.2018.1927.2018.1009.0642.0642.0183.0275.0000.0000
.0450.0991.1712.1441.1532.1261.0901.0631.0360.0450.0270.0000
.0636.0455.1000.1091.1727.1182.0909.1273.1182.0364.0182.0000
.0273.0000.1273.1545.1273.1636.1818.0909.0818.0455.0000.0000
.0000.0545.0818.1182.1273.0818.1545.0818.1636.0909.0091.0364
.0000.0182.0545.1000.0545.1091.1364.1455.1455.1455.0364.0545
.0000.0091.0364.0364.0545.0545.0818.1636.1545.2182.1091.0818
.0000.0091.0091.0273.0182.1364.1455.1455.1545.1455.1364.0727
.0000.0000.0000.0364.0182.0545.0545.1091.1091.2909.1636.1636
.0000.0000.0000.0182.0182.0182.0364.1091.1091.2000.1636.3273
.4444.1667.1852.1111.0185.0556.0000.0000.0185.0000.0000.0000 12
.2321.2321.2500.1429.0357.0179.0536.0357.0000.0000.0000.0000
.1364.1273.2091.1818.1545.1182.0455.0091.0182.0000.0000.0000
.0091.1000.1909.2000.1364.1364.0909.1000.0273.0091.0000.0000
.0091.0455.1727.1273.1909.1636.0818.1364.0545.0091.0091.0000
.0000.0182.1182.1000.1636.1545.1455.0727.1091.0909.0273.0000
.0000.0091.0455.1000.1364.1273.2000.1182.1455.0909.0273.0000
.0000.0000.0273.0818.1000.1091.1636.1545.1273.1364.0909.0091
.0000.0000.0182.0636.0455.0818.1545.2000.1636.1636.0364.0727
.0091.0000.0000.0182.0273.0636.0818.1182.2182.2364.1455.0818
.0000.0000.0000.0000.0364.0182.0182.1091.2000.2727.1636.1818
.0000.0000.0000.0000.0000.0000.0000.0364.0545.2545.1636.4909
.5882.2157.1961.0000.0000.0000.0000.0000.0000.0000.0000.0000 01 02
.1667.3148.2778.1481.0741.0185.0000.0000.0000.0000.0000.0000
.0833.1481.3426.2130.1204.0741.0093.0093.0000.0000.0000.0000
.0392.0294.1667.2059.2059.1176.0882.0882.0392.0196.0000.0000
.0000.0097.1262.2621.1553.1650.1262.1068.0388.0097.0000.0000
.0000.0377.0755.0849.1698.2264.1792.1226.0377.0472.0189.0000
.0000.0000.0288.0962.1442.1346.2404.1923.1154.0481.0000.0000
.0000.0094.0000.0283.1415.1792.1321.1226.2358.1415.0094.0000
.0000.0000.0095.0381.0190.0571.1333.2000.2857.1524.1048.0000

.0000.0000.0000.0094.0000.0377.0849.1038.1792.3396.1604.0849
.0000.0000.0000.0185.0185.0000.0185.0926.0741.3704.2037.2037
.0000.0000.0000.0000.0000.0000.0000.0196.0196.1176.1961.6471
.6182.2182.1091.0182.0182.0000.0182.0000.0000.0000.0000.0000 02
.1636.2545.2909.2000.0545.0182.0182.0000.0000.0000.0000.0000
.0917.1284.2936.1927.1560.0734.0459.0183.0000.0000.0000.0000
.0180.0541.2703.2613.1441.1261.0631.0360.0180.0090.0000.0000
.0000.0273.1091.2000.2455.1455.1364.0909.0273.0182.0000.0000
.0000.0273.1000.1000.1636.1364.1909.1545.0909.0273.0091.0000
.0000.0091.0273.1000.1364.1727.1636.1727.1091.0818.0273.0000
.0000.0000.0091.0182.0273.2000.1727.1909.1909.1727.0182.0000
.0000.0091.0000.0182.0727.0818.1636.1636.2364.1455.0909.0182
.0000.0000.0000.0000.0182.0455.0455.1364.2182.3545.1455.0364
.0000.0000.0000.0000.0000.0182.0000.0364.1455.2727.2727.2545
.0000.0000.0000.0000.0000.0000.0000.0364.0727.1091.1455.6364
.4364.2000.2545.0182.0182.0545.0000.0182.0000.0000.0000.0000 03
.2037.2037.2037.1667.1111.0556.0370.0000.0000.0185.0000.0000
.1171.1261.2252.1892.0991.0811.0541.0901.0180.0000.0000.0000
.0273.0455.1636.1909.2364.1545.0545.0909.0182.0182.0000.0000
.0182.0727.1455.1182.2091.1091.1364.0909.0545.0455.0000.0000
.0091.0545.1000.1455.1273.1455.1273.1364.0727.0636.0182.0000
.0091.0000.0818.1182.1091.1545.1818.1182.1364.0909.0000.0000
.0000.0000.0273.0818.1091.1273.1545.1545.1545.1364.0545.0000
.0000.0000.0273.0455.0455.1091.1091.1545.2273.2091.0727.0000
.0000.0000.0000.0182.0000.0545.1000.1273.1818.2273.1636.1273
.0000.0000.0000.0000.0000.0182.0909.0545.1636.2364.1636.2727
.0000.0000.0000.0000.0000.0000.0364.0000.1091.1636.2182.4727
.4545.1273.1818.1091.0545.0364.0182.0000.0000.0182.0000.0000 04
.1455.2000.2727.1091.1455.0909.0182.0000.0182.0000.0000.0000
.1000.1182.2273.1545.1091.1273.0364.0455.0455.0273.0091.0000
.0182.0727.1818.2000.1364.0909.0909.1182.0727.0182.0000.0000
.0455.0727.1000.1818.1636.1636.0818.1273.0455.0182.0000.0000
.0273.0364.1364.0636.1545.1455.1636.0727.0909.0727.0273.0091
.0000.0273.0545.1182.1000.1273.1273.1545.1182.1273.0364.0091
.0000.0091.0364.0364.1364.1000.1818.1455.1636.1455.0182.0273
.0000.0000.0182.1000.0727.0818.1364.1455.1364.1818.0909.0364
.0091.0000.0182.0364.0273.1000.1091.1364.1545.1818.1182.1091
.0000.0000.0000.0000.0000.0000.1091.0727.2000.3091.1818.1273
.0000.0000.0000.0000.0000.0000.0000.0364.1273.1273.2182.4909
.4000.2000.2364.0545.0182.0000.0364.0364.0182.0000.0000.0000 05
.1818.1455.2727.1636.0727.0909.0182.0364.0182.0000.0000.0000
.0909.1636.1727.1727.1091.1636.0727.0182.0273.0091.0000.0000
.0545.0727.1727.1636.1636.1727.1182.0727.0091.0000.0000.0000
.0364.0273.1364.1455.1545.1364.0727.1091.1091.0545.0182.0000
.0182.0273.1091.1364.1636.0545.1182.1273.1364.1091.0000.0000
.0000.0182.1091.1273.0727.1182.1182.1727.1091.0818.0545.0182
.0000.0091.0364.0636.1818.1364.1455.1182.1182.1000.0545.0364
.0091.0091.0091.0273.0636.0727.1909.1364.2091.1091.1091.0545
.0000.0000.0000.0364.0364.0818.0909.1636.1636.2727.0727.0818
.0000.0000.0000.0364.0182.0364.0545.0545.0909.3273.1818.2000
.0000.0000.0000.0000.0000.0000.0364.0364.1091.2000.2000.4182
.3636.3091.2000.0727.0545.0000.0000.0000.0000.0000.0000.0000 06
.2364.0909.2364.2364.0727.1091.0182.0000.0000.0000.0000.0000
.1273.1091.2273.1545.1455.1000.0636.0545.0091.0091.0000.0000

```
.0364.1000.1818.1636.2182.1091.0455.0909.0455.0000.0000.0091
.0273.0273.1818.1364.1182.1273.1636.1000.0636.0455.0091.0000
.0091.0273.0545.1636.1636.1818.1455.0818.1182.0455.0091.0000
.0000.0182.0545.1091.1182.1182.1545.2000.0727.1182.0364.0000
.0000.0091.0636.0364.0727.1636.2091.1091.1818.1091.0364.0091
.0000.0091.0182.0455.0909.0727.1182.1273.1909.2273.0545.0455
.0000.0000.0000.0364.0091.0636.0636.1636.1818.2636.1455.0727
.0000.0000.0000.0000.0000.0000.0182.0909.1091.2727.2182.2909
.0000.0000.0000.0000.0000.0182.0364.0545.1636.0909.2000.4364
.5273.2182.1455.0727.0364.0000.0000.0000.0000.0000.0000.0000    07
.2000.2364.3636.1273.0727.0000.0000.0000.0000.0000.0000.0000
.1000.1091.2818.2455.1636.0636.0182.0000.0182.0000.0000.0000
.0182.0909.2455.2000.1909.1455.0727.0182.0182.0000.0000.0000
.0091.0455.1273.2000.1545.1364.1818.0818.0545.0091.0000.0000
.0091.0091.0636.1545.1364.2273.1818.1091.0727.0273.0091.0000
.0000.0091.0182.0545.1636.1273.2182.1909.0909.1273.0000.0000
.0000.0000.0091.0364.1000.1727.1364.2000.1727.1182.0455.0091
.0000.0000.0000.0091.0273.1000.0909.2000.2364.2091.0909.0364
.0000.0000.0091.0000.0091.0091.0818.1182.2182.3273.1182.1091
.0000.0000.0000.0000.0000.0182.0364.1091.1818.2545.1818.2182
.0000.0000.0000.0000.0000.0182.0000.0545.0545.1091.2909.4727
.4364.2545.1818.0727.0364.0182.0000.0000.0000.0000.0000.0000    08
.1667.2222.2963.1481.1111.0185.0370.0000.0000.0000.0000.0000
.0901.1802.2072.2342.1712.0721.0450.0000.0000.0000.0000.0000
.0636.0455.2636.1455.1273.1455.0909.0455.0545.0182.0000.0000
.0364.0091.1909.2091.1636.1273.1091.0909.0364.0273.0000.0000
.0091.0182.0364.1364.2091.1818.1091.1727.0727.0545.0000.0000
.0000.0000.0182.0727.1182.1000.1636.2273.1545.1182.0273.0000
.0000.0091.0455.0455.0545.1545.1818.0909.1818.1909.0364.0091
.0000.0000.0000.0273.0636.1091.1636.1545.2091.2091.0364.0273
.0000.0000.0000.0182.0182.0909.1000.1455.1818.1818.1727.0909
.0000.0000.0000.0000.0000.0000.0182.1091.1455.3091.2182.2000
.0000.0000.0000.0000.0000.0000.0182.0364.0727.0909.2364.5455
.3455.3091.1818.0909.0364.0364.0000.0000.0000.0000.0000.0000    09
.1091.1636.3636.1455.0727.0364.0364.0727.0000.0000.0000.0000
.1091.1182.1818.2636.1182.0818.0636.0364.0273.0000.0000.0000
.1000.0909.1455.1455.1455.1182.1182.0545.0545.0273.0000.0000
.0364.0364.1909.0909.1182.1818.1273.0727.0818.0364.0273.0000
.0091.0273.0727.1273.1636.1364.1091.1182.1455.0818.0091.0000
.0000.0000.0455.0818.1727.1091.1909.1727.1182.0818.0182.0091
.0091.0000.0545.0909.0818.1455.1182.1455.1000.1909.0364.0273
.0000.0000.0273.0545.0727.0727.1091.1727.1636.1636.1091.0545
.0000.0000.0091.0273.0636.1182.1091.1364.1636.1727.1273.0727
.0000.0000.0000.0000.0000.0000.0545.0909.2000.3091.1818.1636
.0000.0000.0000.0000.0182.0000.0182.0182.0909.1818.1636.5091
.3519.1111.2963.0741.0185.0741.0370.0000.0370.0000.0000.0000    10
.1964.1429.1250.2321.0714.0893.0536.0357.0536.0000.0000.0000
.0818.1636.2000.1909.0818.1000.1091.0545.0091.0000.0091.0000
.0545.1091.1364.1636.1455.1000.1000.0727.0636.0455.0091.0000
.0727.0364.1818.1000.1909.1182.0909.0545.0545.0727.0182.0091
.0091.0273.0727.1455.1091.1545.1727.1000.0818.1000.0273.0000
.0000.0273.0818.1000.1455.1455.1182.1909.1455.0273.0000.0182
.0000.0000.0545.0636.1364.1273.1182.0909.1545.1545.0909.0091
.0091.0091.0545.0545.0636.0455.1273.1727.1455.1636.0818.0727
```

```
.0000.0000.0000.0273.0636.1000.0909.1636.1636.2182.0818.0909
.0000.0000.0000.0182.0364.0364.0364.0909.2000.1818.2545.1455
.0000.0000.0000.0000.0000.0182.0182.0727.0727.2545.1091.4545
.4909.2364.1455.0364.0545.0364.0000.0000.0000.0000.0000.0000     11
.1273.1455.2909.1455.0909.1091.0182.0182.0364.0000.0000.0182
.0459.0826.2018.1927.2018.1009.0642.0642.0183.0275.0000.0000
.0450.0991.1712.1441.1532.1261.0901.0631.0360.0450.0270.0000
.0636.0455.1000.1091.1727.1182.0909.1273.1182.0364.0182.0000
.0273.0000.1273.1545.1273.1636.1818.0909.0818.0455.0000.0000
.0000.0545.0818.1182.1273.0818.1545.0818.1636.0909.0091.0364
.0000.0182.0545.1000.0545.1091.1364.1455.1455.1455.0364.0545
.0000.0091.0364.0364.0545.0545.0818.1636.1545.2182.1091.0818
.0000.0091.0091.0273.0182.1364.1455.1455.1545.1455.1364.0727
.0000.0000.0000.0364.0182.0545.0545.1091.1091.2909.1636.1636
.0000.0000.0000.0182.0182.0182.0364.1091.1091.2000.1636.3273
.4444.1667.1852.1111.0185.0556.0000.0000.0185.0000.0000.0000     12
.2321.2321.2500.1429.0357.0179.0536.0357.0000.0000.0000.0000
.1364.1273.2091.1818.1545.1182.0455.0091.0182.0000.0000.0000
.0091.1000.1909.2000.1364.1364.0909.1000.0273.0091.0000.0000
.0091.0455.1727.1273.1909.1636.0818.1364.0545.0091.0091.0000
.0000.0182.1182.1000.1636.1545.1455.0727.1091.0909.0273.0000
.0000.0091.0455.1000.1364.1273.2000.1182.1455.0909.0273.0000
.0000.0000.0273.0818.1000.1091.1636.1545.1273.1364.0909.0091
.0000.0000.0182.0636.0455.0818.1545.2000.1636.1636.0364.0727
.0091.0000.0000.0182.0273.0636.0818.1182.2182.2364.1455.0818
.0000.0000.0000.0000.0364.0182.0182.1091.2000.2727.1636.1818
.0000.0000.0000.0000.0000.0000.0000.0364.0545.2545.1636.4909
.5882.2157.1961.0000.0000.0000.0000.0000.0000.0000.0000.0000     01   03
.1667.3148.2778.1481.0741.0185.0000.0000.0000.0000.0000.0000
.0833.1481.3426.2130.1204.0741.0093.0093.0000.0000.0000.0000
.0392.0294.1667.2059.2059.1176.0882.0882.0392.0196.0000.0000
.0000.0097.1262.2621.1553.1650.1262.1068.0388.0097.0000.0000
.0000.0377.0755.0849.1698.2264.1792.1226.0377.0472.0189.0000
.0000.0000.0288.0962.1442.1346.2404.1923.1154.0481.0000.0000
.0000.0094.0000.0283.1415.1792.1321.1226.2358.1415.0094.0000
.0000.0000.0095.0381.0190.0571.1333.2000.2857.1524.1048.0000
.0000.0000.0000.0094.0000.0377.0849.1038.1792.3396.1604.0849
.0000.0000.0000.0185.0185.0000.0185.0926.0741.3704.2037.2037
.0000.0000.0000.0000.0000.0000.0000.0196.0196.1176.1961.6471
.6182.2182.1091.0182.0182.0000.0182.0000.0000.0000.0000.0000     02
.1636.2545.2909.2000.0545.0182.0182.0000.0000.0000.0000.0000
.0917.1284.2936.1927.1560.0734.0459.0183.0000.0000.0000.0000
.0180.0541.2703.2613.1441.1261.0631.0360.0180.0090.0000.0000
.0000.0273.1091.2000.2455.1455.1364.0909.0273.0182.0000.0000
.0000.0273.1000.1000.1636.1364.1909.1545.0909.0273.0091.0000
.0000.0091.0273.1000.1364.1727.1636.1727.1091.0818.0273.0000
.0000.0000.0091.0182.0273.2000.1727.1909.1909.1727.0182.0000
.0000.0091.0000.0182.0727.0818.1636.1636.2364.1455.0909.0182
.0000.0000.0000.0000.0182.0455.0455.1364.2182.3545.1455.0364
.0000.0000.0000.0000.0000.0182.0000.0364.1455.2727.2727.2545
.0000.0000.0000.0000.0000.0000.0000.0364.0727.1091.1455.6364
.4364.2000.2545.0182.0182.0545.0000.0182.0000.0000.0000.0000     03
.2037.2037.2037.1667.1111.0556.0370.0000.0000.0185.0000.0000
.1171.1261.2252.1892.0991.0811.0541.0901.0180.0000.0000.0000
```

```
.0273.0455.1636.1909.2364.1545.0545.0909.0182.0182.0000.0000
.0182.0727.1455.1182.2091.1091.1364.0909.0545.0455.0000.0000
.0091.0545.1000.1455.1273.1455.1273.1364.0727.0636.0182.0000
.0091.0000.0818.1182.1091.1545.1818.1182.1364.0909.0000.0000
.0000.0000.0273.0818.1091.1273.1545.1545.1545.1364.0545.0000
.0000.0000.0273.0455.0455.1091.1091.1545.2273.2091.0727.0000
.0000.0000.0000.0182.0000.0545.1000.1273.1818.2273.1636.1273
.0000.0000.0000.0000.0000.0182.0909.0545.1636.2364.1636.2727
.0000.0000.0000.0000.0000.0000.0364.0000.1091.1636.2182.4727
.4545.1273.1818.1091.0545.0364.0182.0000.0000.0182.0000.0000     04
.1455.2000.2727.1091.1455.0909.0182.0000.0182.0000.0000.0000
.1000.1182.2273.1545.1091.1273.0364.0455.0455.0273.0091.0000
.0182.0727.1818.2000.1364.0909.0909.1182.0727.0182.0000.0000
.0455.0727.1000.1818.1636.1636.0818.1273.0455.0182.0000.0000
.0273.0364.1364.0636.1545.1455.1636.0727.0909.0727.0273.0091
.0000.0273.0545.1182.1000.1273.1273.1545.1182.1273.0364.0091
.0000.0091.0364.0364.1364.1000.1818.1455.1636.1455.0182.0273
.0000.0000.0182.1000.0727.0818.1364.1455.1364.1818.0909.0364
.0091.0000.0182.0364.0273.1000.1091.1364.1545.1818.1182.1091
.0000.0000.0000.0000.0000.0000.1091.0727.2000.3091.1818.1273
.0000.0000.0000.0000.0000.0000.0000.0364.1273.1273.2182.4909
.4000.2000.2364.0545.0182.0000.0364.0364.0182.0000.0000.0000     05
.1818.1455.2727.1636.0727.0909.0182.0364.0182.0000.0000.0000
.0909.1636.1727.1727.1091.1636.0727.0182.0273.0091.0000.0000
.0545.0727.1727.1636.1636.1727.1182.0727.0091.0000.0000.0000
.0364.0273.1364.1455.1545.1364.0727.1091.1091.0545.0182.0000
.0182.0273.1091.1364.1636.0545.1182.1273.1364.1091.0000.0000
.0000.0182.1091.1273.0727.1182.1182.1727.1091.0818.0545.0182
.0000.0091.0364.0636.1818.1364.1455.1182.1182.1000.0545.0364
.0091.0091.0091.0273.0636.0727.1909.1364.2091.1091.1091.0545
.0000.0000.0000.0364.0364.0818.0909.1636.1636.2727.0727.0818
.0000.0000.0000.0364.0182.0364.0545.0545.0909.3273.1818.2000
.0000.0000.0000.0000.0000.0000.0364.0364.1091.2000.2000.4182
.3636.3091.2000.0727.0545.0000.0000.0000.0000.0000.0000.0000     06
.2364.0909.2364.2364.0727.1091.0182.0000.0000.0000.0000.0000
.1273.1091.2273.1545.1455.1000.0636.0545.0091.0091.0000.0000
.0364.1000.1818.1636.2182.1091.0455.0909.0455.0000.0000.0091
.0273.0273.1818.1364.1182.1273.1636.1000.0636.0455.0091.0000
.0091.0273.0545.1636.1636.1818.1455.0818.1182.0455.0091.0000
.0000.0182.0545.1091.1182.1182.1545.2000.0727.1182.0364.0000
.0000.0091.0636.0364.0727.1636.2091.1091.1818.1091.0364.0091
.0000.0091.0182.0455.0909.0727.1182.1273.1909.2273.0545.0455
.0000.0000.0000.0364.0091.0636.0636.1636.1818.2636.1455.0727
.0000.0000.0000.0000.0000.0000.0182.0909.1091.2727.2182.2909
.0000.0000.0000.0000.0000.0182.0364.0545.1636.0909.2000.4364
.5273.2182.1455.0727.0364.0000.0000.0000.0000.0000.0000.0000     07
.2000.2364.3636.1273.0727.0000.0000.0000.0000.0000.0000.0000
.1000.1091.2818.2455.1636.0636.0182.0000.0182.0000.0000.0000
.0182.0909.2455.2000.1909.1455.0727.0182.0182.0000.0000.0000
.0091.0455.1273.2000.1545.1364.1818.0818.0545.0091.0000.0000
.0091.0091.0636.1545.1364.2273.1818.1091.0727.0273.0091.0000
.0000.0091.0182.0545.1636.1273.2182.1909.0909.1273.0000.0000
.0000.0000.0091.0364.1000.1727.1364.2000.1727.1182.0455.0091
.0000.0000.0000.0091.0273.1000.0909.2000.2364.2091.0909.0364
```

.0000.0000.0091.0000.0091.0091.0818.1182.2182.3273.1182.1091
.0000.0000.0000.0000.0000.0182.0364.1091.1818.2545.1818.2182
.0000.0000.0000.0000.0000.0182.0000.0545.0545.1091.2909.4727
.4364.2545.1818.0727.0364.0182.0000.0000.0000.0000.0000.0000 08
.1667.2222.2963.1481.1111.0185.0370.0000.0000.0000.0000.0000
.0901.1802.2072.2342.1712.0721.0450.0000.0000.0000.0000.0000
.0636.0455.2636.1455.1273.1455.0909.0455.0545.0182.0000.0000
.0364.0091.1909.2091.1636.1273.1091.0909.0364.0273.0000.0000
.0091.0182.0364.1364.2091.1818.1091.1727.0727.0545.0000.0000
.0000.0000.0182.0727.1182.1000.1636.2273.1545.1182.0273.0000
.0000.0091.0455.0455.0545.1545.1818.0909.1818.1909.0364.0091
.0000.0000.0000.0273.0636.1091.1636.1545.2091.2091.0364.0273
.0000.0000.0000.0182.0182.0909.1000.1455.1818.1818.1727.0909
.0000.0000.0000.0000.0000.0000.0182.1091.1455.3091.2182.2000
.0000.0000.0000.0000.0000.0000.0182.0364.0727.0909.2364.5455
.3455.3091.1818.0909.0364.0364.0000.0000.0000.0000.0000.0000 09
.1091.1636.3636.1455.0727.0364.0364.0727.0000.0000.0000.0000
.1091.1182.1818.2636.1182.0818.0636.0364.0273.0000.0000.0000
.1000.0909.1455.1455.1455.1182.1182.0545.0545.0273.0000.0000
.0364.0364.1909.0909.1182.1818.1273.0727.0818.0364.0273.0000
.0091.0273.0727.1273.1636.1364.1091.1182.1455.0818.0091.0000
.0000.0000.0455.0818.1727.1091.1909.1727.1182.0818.0182.0091
.0091.0000.0545.0909.0818.1455.1182.1455.1000.1909.0364.0273
.0000.0000.0273.0545.0727.0727.1091.1727.1636.1636.1091.0545
.0000.0000.0091.0273.0636.1182.1091.1364.1636.1727.1273.0727
.0000.0000.0000.0000.0000.0000.0545.0909.2000.3091.1818.1636
.0000.0000.0000.0000.0182.0000.0182.0182.0909.1818.1636.5091
.3519.1111.2963.0741.0185.0741.0370.0000.0370.0000.0000.0000 10
.1964.1429.1250.2321.0714.0893.0536.0357.0536.0000.0000.0000
.0818.1636.2000.1909.0818.1000.1091.0545.0091.0000.0091.0000
.0545.1091.1364.1636.1455.1000.1000.0727.0636.0455.0091.0000
.0727.0364.1818.1000.1909.1182.0909.0545.0545.0727.0182.0091
.0091.0273.0727.1455.1091.1545.1727.1000.0818.1000.0273.0000
.0000.0273.0818.1000.1455.1455.1182.1909.1455.0273.0000.0182
.0000.0000.0545.0636.1364.1273.1182.0909.1545.1545.0909.0091
.0091.0091.0545.0545.0636.0455.1273.1727.1455.1636.0818.0727
.0000.0000.0000.0273.0636.1000.0909.1636.1636.2182.0818.0909
.0000.0000.0000.0182.0364.0364.0364.0909.2000.1818.2545.1455
.0000.0000.0000.0000.0000.0182.0182.0727.0727.2545.1091.4545
.4909.2364.1455.0364.0545.0364.0000.0000.0000.0000.0000.0000 11
.1273.1455.2909.1455.0909.1091.0182.0182.0364.0000.0000.0182
.0459.0826.2018.1927.2018.1009.0642.0642.0183.0275.0000.0000
.0450.0991.1712.1441.1532.1261.0901.0631.0360.0450.0270.0000
.0636.0455.1000.1091.1727.1182.0909.1273.1182.0364.0182.0000
.0273.0000.1273.1545.1273.1636.1818.0909.0818.0455.0000.0000
.0000.0545.0818.1182.1273.0818.1545.0818.1636.0909.0091.0364
.0000.0182.0545.1000.0545.1091.1364.1455.1455.1455.0364.0545
.0000.0091.0364.0364.0545.0545.0818.1636.1545.2182.1091.0818
.0000.0091.0091.0273.0182.1364.1455.1455.1545.1455.1364.0727
.0000.0000.0000.0364.0182.0545.0545.1091.1091.2909.1636.1636
.0000.0000.0000.0182.0182.0182.0364.1091.1091.2000.1636.3273
.4444.1667.1852.1111.0185.0556.0000.0000.0185.0000.0000.0000 12
.2321.2321.2500.1429.0357.0179.0536.0357.0000.0000.0000.0000
.1364.1273.2091.1818.1545.1182.0455.0091.0182.0000.0000.0000

```
.0091.1000.1909.2000.1364.1364.0909.1000.0273.0091.0000.0000
.0091.0455.1727.1273.1909.1636.0818.1364.0545.0091.0091.0000
.0000.0182.1182.1000.1636.1545.1455.0727.1091.0909.0273.0000
.0000.0091.0455.1000.1364.1273.2000.1182.1455.0909.0273.0000
.0000.0000.0273.0818.1000.1091.1636.1545.1273.1364.0909.0091
.0000.0000.0182.0636.0455.0818.1545.2000.1636.1636.0364.0727
.0091.0000.0000.0182.0273.0636.0818.1182.2182.2364.1455.0818
.0000.0000.0000.0000.0364.0182.0182.1091.2000.2727.1636.1818
.0000.0000.0000.0000.0000.0000.0000.0364.0545.2545.1636.4909
.5882.2157.1961.0000.0000.0000.0000.0000.0000.0000.0000.0000    01   04
.1667.3148.2778.1481.0741.0185.0000.0000.0000.0000.0000.0000
.0833.1481.3426.2130.1204.0741.0093.0093.0000.0000.0000.0000
.0392.0294.1667.2059.2059.1176.0882.0882.0392.0196.0000.0000
.0000.0097.1262.2621.1553.1650.1262.1068.0388.0097.0000.0000
.0000.0377.0755.0849.1698.2264.1792.1226.0377.0472.0189.0000
.0000.0000.0288.0962.1442.1346.2404.1923.1154.0481.0000.0000
.0000.0094.0000.0283.1415.1792.1321.1226.2358.1415.0094.0000
.0000.0000.0095.0381.0190.0571.1333.2000.2857.1524.1048.0000
.0000.0000.0000.0094.0000.0377.0849.1038.1792.3396.1604.0849
.0000.0000.0000.0185.0185.0000.0185.0926.0741.3704.2037.2037
.0000.0000.0000.0000.0000.0000.0000.0196.0196.1176.1961.6471
.6182.2182.1091.0182.0182.0000.0182.0000.0000.0000.0000.0000    02
.1636.2545.2909.2000.0545.0182.0182.0000.0000.0000.0000.0000
.0917.1284.2936.1927.1560.0734.0459.0183.0000.0000.0000.0000
.0180.0541.2703.2613.1441.1261.0631.0360.0180.0090.0000.0000
.0000.0273.1091.2000.2455.1455.1364.0909.0273.0182.0000.0000
.0000.0273.1000.1000.1636.1364.1909.1545.0909.0273.0091.0000
.0000.0091.0273.1000.1364.1727.1636.1727.1091.0818.0273.0000
.0000.0000.0091.0182.0273.2000.1727.1909.1909.1727.0182.0000
.0000.0091.0000.0182.0727.0818.1636.1636.2364.1455.0909.0182
.0000.0000.0000.0000.0182.0455.0455.1364.2182.3545.1455.0364
.0000.0000.0000.0000.0000.0182.0000.0364.1455.2727.2727.2545
.0000.0000.0000.0000.0000.0000.0000.0364.0727.1091.1455.6364
.4364.2000.2545.0182.0182.0545.0000.0182.0000.0000.0000.0000    03
.2037.2037.2037.1667.1111.0556.0370.0000.0000.0185.0000.0000
.1171.1261.2252.1892.0991.0811.0541.0901.0180.0000.0000.0000
.0273.0455.1636.1909.2364.1545.0545.0909.0182.0182.0000.0000
.0182.0727.1455.1182.2091.1091.1364.0909.0545.0455.0000.0000
.0091.0545.1000.1455.1273.1455.1273.1364.0727.0636.0182.0000
.0091.0000.0818.1182.1091.1545.1818.1182.1364.0909.0000.0000
.0000.0000.0273.0818.1091.1273.1545.1545.1545.1364.0545.0000
.0000.0000.0273.0455.0455.1091.1091.1545.2273.2091.0727.0000
.0000.0000.0000.0182.0000.0545.1000.1273.1818.2273.1636.1273
.0000.0000.0000.0000.0000.0182.0909.0545.1636.2364.1636.2727
.0000.0000.0000.0000.0000.0000.0364.0000.1091.1636.2182.4727
.4545.1273.1818.1091.0545.0364.0182.0000.0000.0182.0000.0000    04
.1455.2000.2727.1091.1455.0909.0182.0000.0182.0000.0000.0000
.1000.1182.2273.1545.1091.1273.0364.0455.0455.0273.0091.0000
.0182.0727.1818.2000.1364.0909.0909.1182.0727.0182.0000.0000
.0455.0727.1000.1818.1636.1636.0818.1273.0455.0182.0000.0000
.0273.0364.1364.0636.1545.1455.1636.0727.0909.0727.0273.0091
.0000.0273.0545.1182.1000.1273.1273.1545.1182.1273.0364.0091
.0000.0091.0364.0364.1364.1000.1818.1455.1636.1455.0182.0273
.0000.0000.0182.1000.0727.0818.1364.1455.1364.1818.0909.0364
```

```
.0091.0000.0182.0364.0273.1000.1091.1364.1545.1818.1182.1091
.0000.0000.0000.0000.0000.0000.1091.0727.2000.3091.1818.1273
.0000.0000.0000.0000.0000.0000.0000.0364.1273.1273.2182.4909
.4000.2000.2364.0545.0182.0000.0364.0364.0182.0000.0000.0000     05
.1818.1455.2727.1636.0727.0909.0182.0364.0182.0000.0000.0000
.0909.1636.1727.1727.1091.1636.0727.0182.0273.0091.0000.0000
.0545.0727.1727.1636.1636.1727.1182.0727.0091.0000.0000.0000
.0364.0273.1364.1455.1545.1364.0727.1091.1091.0545.0182.0000
.0182.0273.1091.1364.1636.0545.1182.1273.1364.1091.0000.0000
.0000.0182.1091.1273.0727.1182.1182.1727.1091.0818.0545.0182
.0000.0091.0364.0636.1818.1364.1455.1182.1182.1000.0545.0364
.0091.0091.0091.0273.0636.0727.1909.1364.2091.1091.1091.0545
.0000.0000.0000.0364.0364.0818.0909.1636.1636.2727.0727.0818
.0000.0000.0000.0364.0182.0364.0545.0545.0909.3273.1818.2000
.0000.0000.0000.0000.0000.0000.0364.0364.1091.2000.2000.4182
.3636.3091.2000.0727.0545.0000.0000.0000.0000.0000.0000.0000     06
.2364.0909.2364.2364.0727.1091.0182.0000.0000.0000.0000.0000
.1273.1091.2273.1545.1455.1000.0636.0545.0091.0091.0000.0000
.0364.1000.1818.1636.2182.1091.0455.0909.0455.0000.0000.0091
.0273.0273.1818.1364.1182.1273.1636.1000.0636.0455.0091.0000
.0091.0273.0545.1636.1636.1818.1455.0818.1182.0455.0091.0000
.0000.0182.0545.1091.1182.1182.1545.2000.0727.1182.0364.0000
.0000.0091.0636.0364.0727.1636.2091.1091.1818.1091.0364.0091
.0000.0091.0182.0455.0909.0727.1182.1273.1909.2273.0545.0455
.0000.0000.0000.0364.0091.0636.0636.1636.1818.2636.1455.0727
.0000.0000.0000.0000.0000.0000.0182.0909.1091.2727.2182.2909
.0000.0000.0000.0000.0000.0182.0364.0545.1636.0909.2000.4364
.5273.2182.1455.0727.0364.0000.0000.0000.0000.0000.0000.0000     07
.2000.2364.3636.1273.0727.0000.0000.0000.0000.0000.0000.0000
.1000.1091.2818.2455.1636.0636.0182.0000.0182.0000.0000.0000
.0182.0909.2455.2000.1909.1455.0727.0182.0182.0000.0000.0000
.0091.0455.1273.2000.1545.1364.1818.0818.0545.0091.0000.0000
.0091.0091.0636.1545.1364.2273.1818.1091.0727.0273.0091.0000
.0000.0091.0182.0545.1636.1273.2182.1909.0909.1273.0000.0000
.0000.0000.0091.0364.1000.1727.1364.2000.1727.1182.0455.0091
.0000.0000.0000.0091.0273.1000.0909.2000.2364.2091.0909.0364
.0000.0000.0091.0000.0091.0091.0818.1182.2182.3273.1182.1091
.0000.0000.0000.0000.0000.0182.0364.1091.1818.2545.1818.2182
.0000.0000.0000.0000.0000.0182.0000.0545.0545.1091.2909.4727
.4364.2545.1818.0727.0364.0182.0000.0000.0000.0000.0000.0000     08
.1667.2222.2963.1481.1111.0185.0370.0000.0000.0000.0000.0000
.0901.1802.2072.2342.1712.0721.0450.0000.0000.0000.0000.0000
.0636.0455.2636.1455.1273.1455.0909.0455.0545.0182.0000.0000
.0364.0091.1909.2091.1636.1273.1091.0909.0364.0273.0000.0000
.0091.0182.0364.1364.2091.1818.1091.1727.0727.0545.0000.0000
.0000.0000.0182.0727.1182.1000.1636.2273.1545.1182.0273.0000
.0000.0091.0455.0455.0545.1545.1818.0909.1818.1909.0364.0091
.0000.0000.0000.0273.0636.1091.1636.1545.2091.2091.0364.0273
.0000.0000.0000.0182.0182.0909.1000.1455.1818.1818.1727.0909
.0000.0000.0000.0000.0000.0000.0182.1091.1455.3091.2182.2000
.0000.0000.0000.0000.0000.0000.0182.0364.0727.0909.2364.5455
.3455.3091.1818.0909.0364.0364.0000.0000.0000.0000.0000.0000     09
.1091.1636.3636.1455.0727.0364.0364.0727.0000.0000.0000.0000
.1091.1182.1818.2636.1182.0818.0636.0364.0273.0000.0000.0000
```

```
.1000.0909.1455.1455.1455.1182.1182.0545.0545.0273.0000.0000
.0364.0364.1909.0909.1182.1818.1273.0727.0818.0364.0273.0000
.0091.0273.0727.1273.1636.1364.1091.1182.1455.0818.0091.0000
.0000.0000.0455.0818.1727.1091.1909.1727.1182.0818.0182.0091
.0091.0000.0545.0909.0818.1455.1182.1455.1000.1909.0364.0273
.0000.0000.0273.0545.0727.0727.1091.1727.1636.1636.1091.0545
.0000.0000.0091.0273.0636.1182.1091.1364.1636.1727.1273.0727
.0000.0000.0000.0000.0000.0000.0545.0909.2000.3091.1818.1636
.0000.0000.0000.0000.0182.0000.0182.0182.0909.1818.1636.5091
.3519.1111.2963.0741.0185.0741.0370.0000.0370.0000.0000.0000     10
.1964.1429.1250.2321.0714.0893.0536.0357.0536.0000.0000.0000
.0818.1636.2000.1909.0818.1000.1091.0545.0091.0000.0091.0000
.0545.1091.1364.1636.1455.1000.1000.0727.0636.0455.0091.0000
.0727.0364.1818.1000.1909.1182.0909.0545.0545.0727.0182.0091
.0091.0273.0727.1455.1091.1545.1727.1000.0818.1000.0273.0000
.0000.0273.0818.1000.1455.1455.1182.1909.1455.0273.0000.0182
.0000.0000.0545.0636.1364.1273.1182.0909.1545.1545.0909.0091
.0091.0091.0545.0545.0636.0455.1273.1727.1455.1636.0818.0727
.0000.0000.0000.0273.0636.1000.0909.1636.1636.2182.0818.0909
.0000.0000.0000.0182.0364.0364.0364.0909.2000.1818.2545.1455
.0000.0000.0000.0000.0000.0182.0182.0727.0727.2545.1091.4545
.4909.2364.1455.0364.0545.0364.0000.0000.0000.0000.0000.0000     11
.1273.1455.2909.1455.0909.1091.0182.0182.0364.0000.0000.0182
.0459.0826.2018.1927.2018.1009.0642.0642.0183.0275.0000.0000
.0450.0991.1712.1441.1532.1261.0901.0631.0360.0450.0270.0000
.0636.0455.1000.1091.1727.1182.0909.1273.1182.0364.0182.0000
.0273.0000.1273.1545.1273.1636.1818.0909.0818.0455.0000.0000
.0000.0545.0818.1182.1273.0818.1545.0818.1636.0909.0091.0364
.0000.0182.0545.1000.0545.1091.1364.1455.1455.1455.0364.0545
.0000.0091.0364.0364.0545.0545.0818.1636.1545.2182.1091.0818
.0000.0091.0091.0273.0182.1364.1455.1455.1545.1455.1364.0727
.0000.0000.0000.0364.0182.0545.0545.1091.1091.2909.1636.1636
.0000.0000.0000.0182.0182.0182.0364.1091.1091.2000.1636.3273
.4444.1667.1852.1111.0185.0556.0000.0000.0185.0000.0000.0000     12
.2321.2321.2500.1429.0357.0179.0536.0357.0000.0000.0000.0000
.1364.1273.2091.1818.1545.1182.0455.0091.0182.0000.0000.0000
.0091.1000.1909.2000.1364.1364.0909.1000.0273.0091.0000.0000
.0091.0455.1727.1273.1909.1636.0818.1364.0545.0091.0091.0000
.0000.0182.1182.1000.1636.1545.1455.0727.1091.0909.0273.0000
.0000.0091.0455.1000.1364.1273.2000.1182.1455.0909.0273.0000
.0000.0000.0273.0818.1000.1091.1636.1545.1273.1364.0909.0091
.0000.0000.0182.0636.0455.0818.1545.2000.1636.1636.0364.0727
.0091.0000.0000.0182.0273.0636.0818.1182.2182.2364.1455.0818
.0000.0000.0000.0000.0364.0182.0182.1091.2000.2727.1636.1818
.0000.0000.0000.0000.0000.0000.0000.0364.0545.2545.1636.4909
```

2.6.2 Tradeoffs between irrigation supply and energy production.

The objective of determining optimal monthly operating rules is to meet both the irrigation demand and a certain level of power requirement. Compared to inflow, see Table 2.6.5 and Fig. 2.6.3, the average irrigation demand is approximately equal to 15 percentile value of the monthly inflow probability distribution. In March, the driest month, irrigation demand can almost be satisfied when a single turbine generates power at its full capacity which is 45 cms. So, with suitable operation, a certain level of energy requirement and irrigation demand should be able to be achieved by carry over storage from year to year in Valdesia reservoir.

Thus, the approach adopted for analyzing the optimal operation rule is to maximize expected energy production subject to meeting irrigation demand as the highest priority. If release is greater than maximum turbine capacity, which is 90 cms for two turbines, the water is supposed to be stored in the reservoir until the reservoir is full.

2.6.3 Optimal monthly operation rules.

Normal operation rules are designed to guide the operation of a reservoir to meet its objectives. Without considering real-time feedback control, a set of rule curves is usually developed for operation over the project life of the reservoir. Instead of providing simple operation rule curves, this study makes a further step in considering much more detailed previous monthly inflow and different beginning storage of Valdesia reservoir into normal operation.

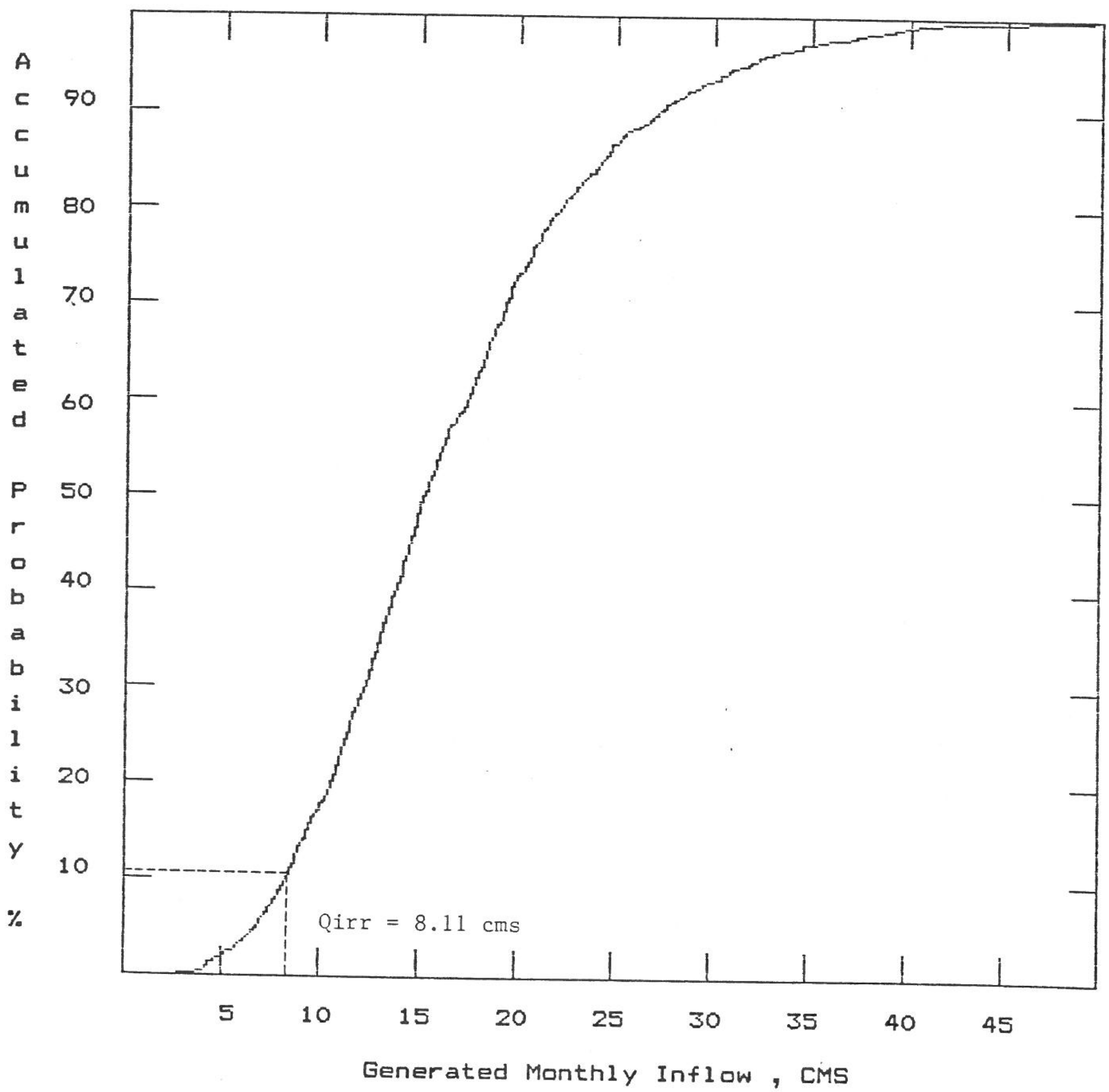
For the purpose of flexibility to operation, a family of target storage operation curves which correspond to each level of conditioned previous random inflows was developed from the results of the invertible form analysis. With such an operation rule, no forecasting of inflows are necessary, only the information about inflow in the previous month is used to determine the corresponding operating curve. The available forecasting of inflow, if there is one, can thus be used by the operator to decide the rate of reaching the known target storage after meeting the demand. In other words, the operator can adjust releases on a weekly (or daily) basis in response to observed or forecasted weekly (or daily) inflows, so as to achieve the target storage as closely as possible by the end of month.

For the approach described in Section 2.6.2, the corresponding optimal (stationary) operation rules are shown on Figures 2.6.4 to 2.6.15 and Table 2.6.3. All policies shown form approximately a linear type relationship between beginning and end-of-month storage.

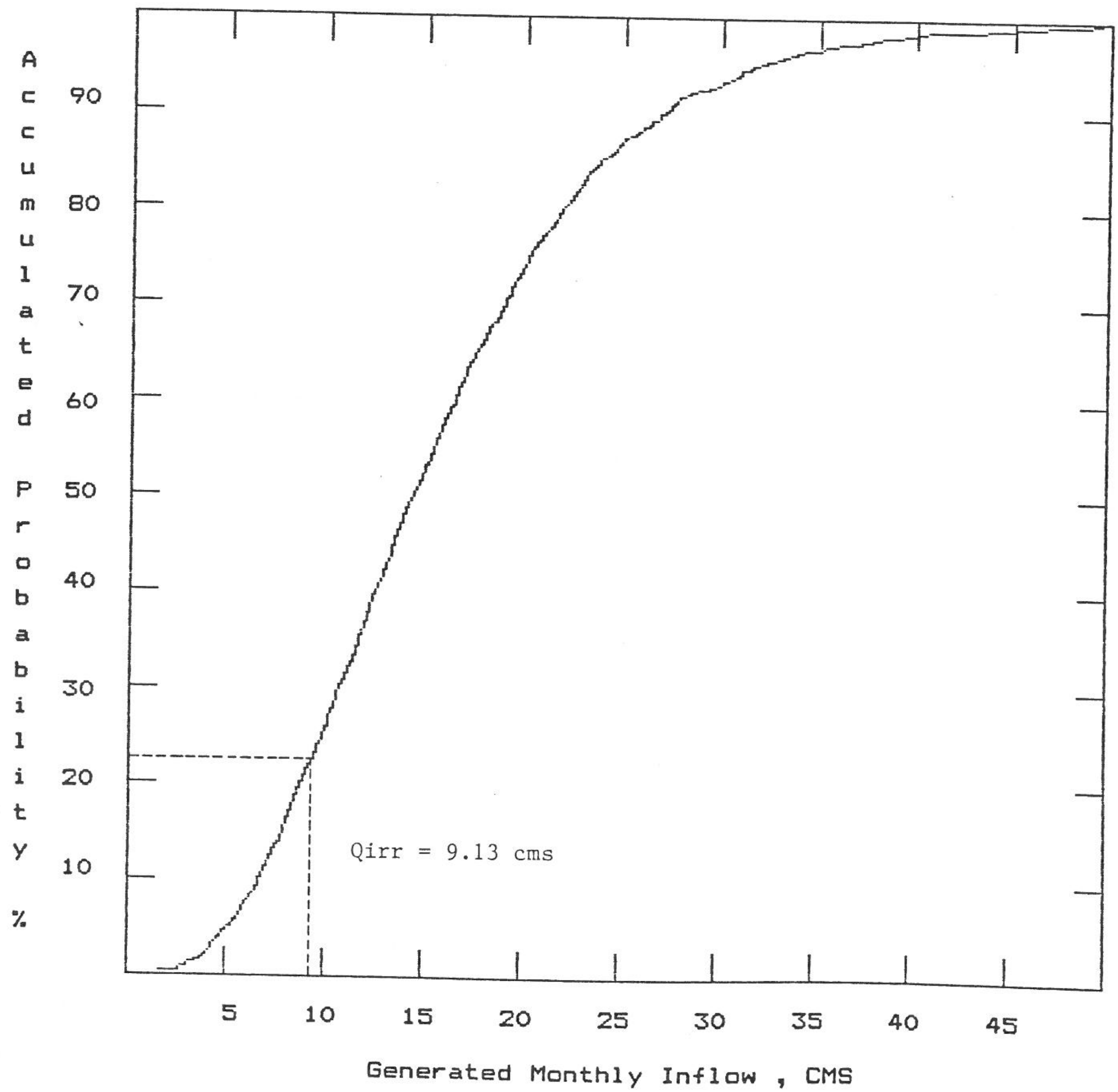
Table 2.6.2. Irrigation Demand and its corresponding Percentile in Inflow Probability Distribution

Month	Irrigation Demand (CMS)	Percentile	Equivalent Power Release
January	8.11	8.8	35.11
February	9.13	21.3	29.09
March	11.50	41.9	45.85
April	10.44	36.1	42.94
May	7.71	12.2	27.20
June	7.87	11.9	17.04
July	9.88	15.8	24.46
Aubust	7.48	1.8	19.46
September	8.67	4.9	31.11
October	7.88	1.1	25.98
November	10.99	6.3	29.06
December	9.13	12.6	41.55

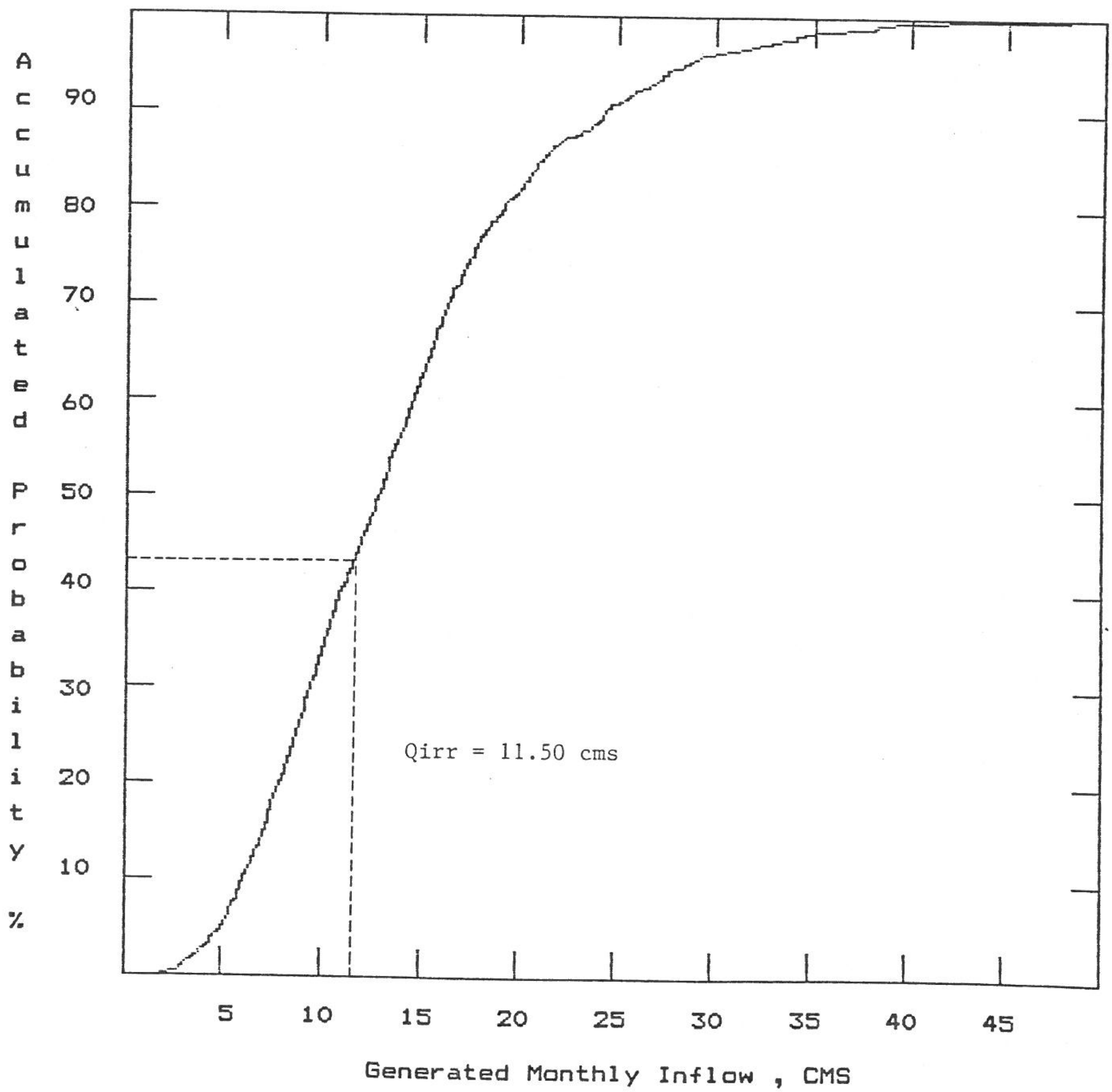
Fig 2.6.3 Probability Distribution of Generated Monthly Inflow



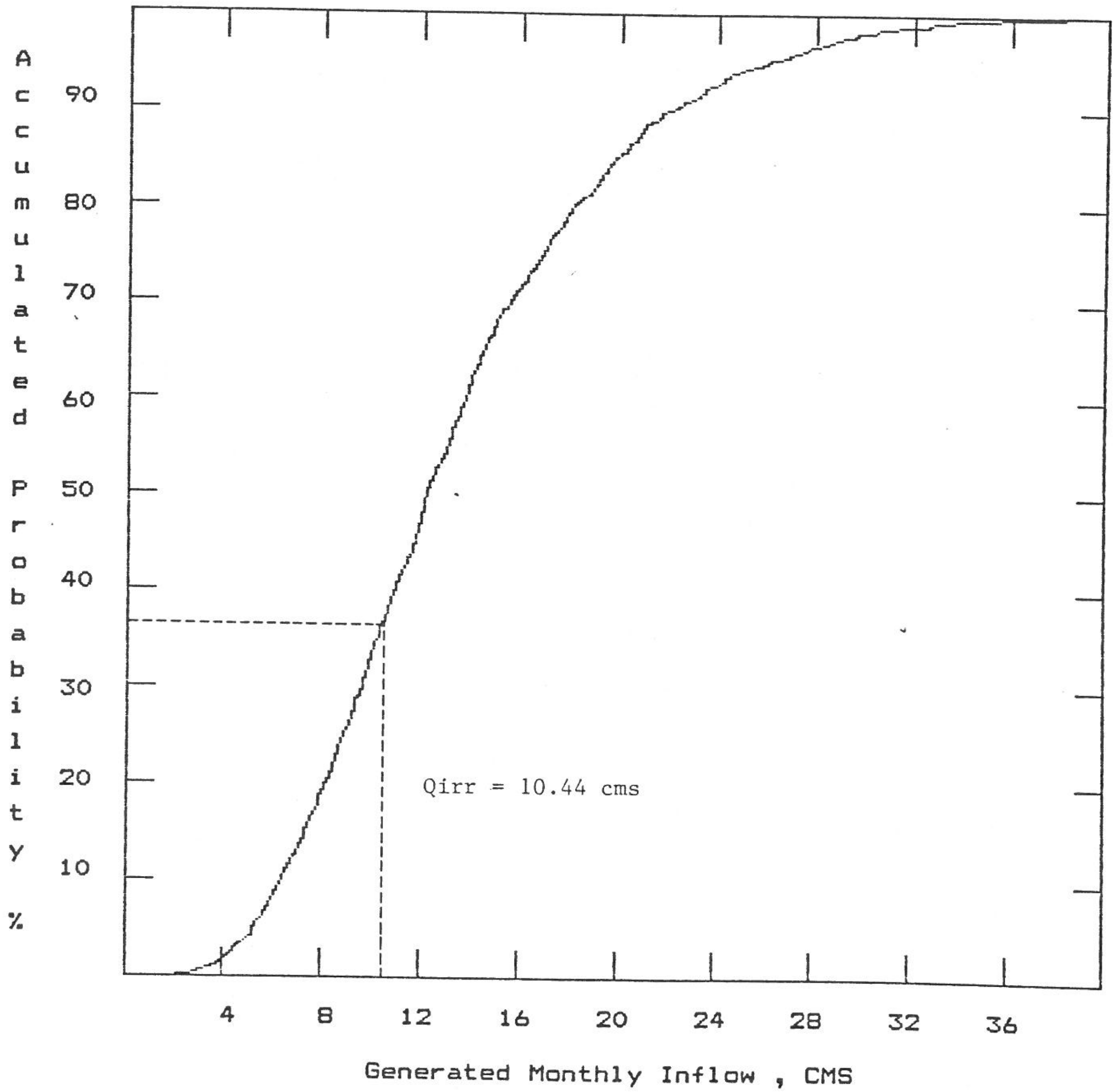
(a) January


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 9.13 cms
5
10
15
20
25
30
35
40
45
Generated Monthly Inflow , CMS

(b) February

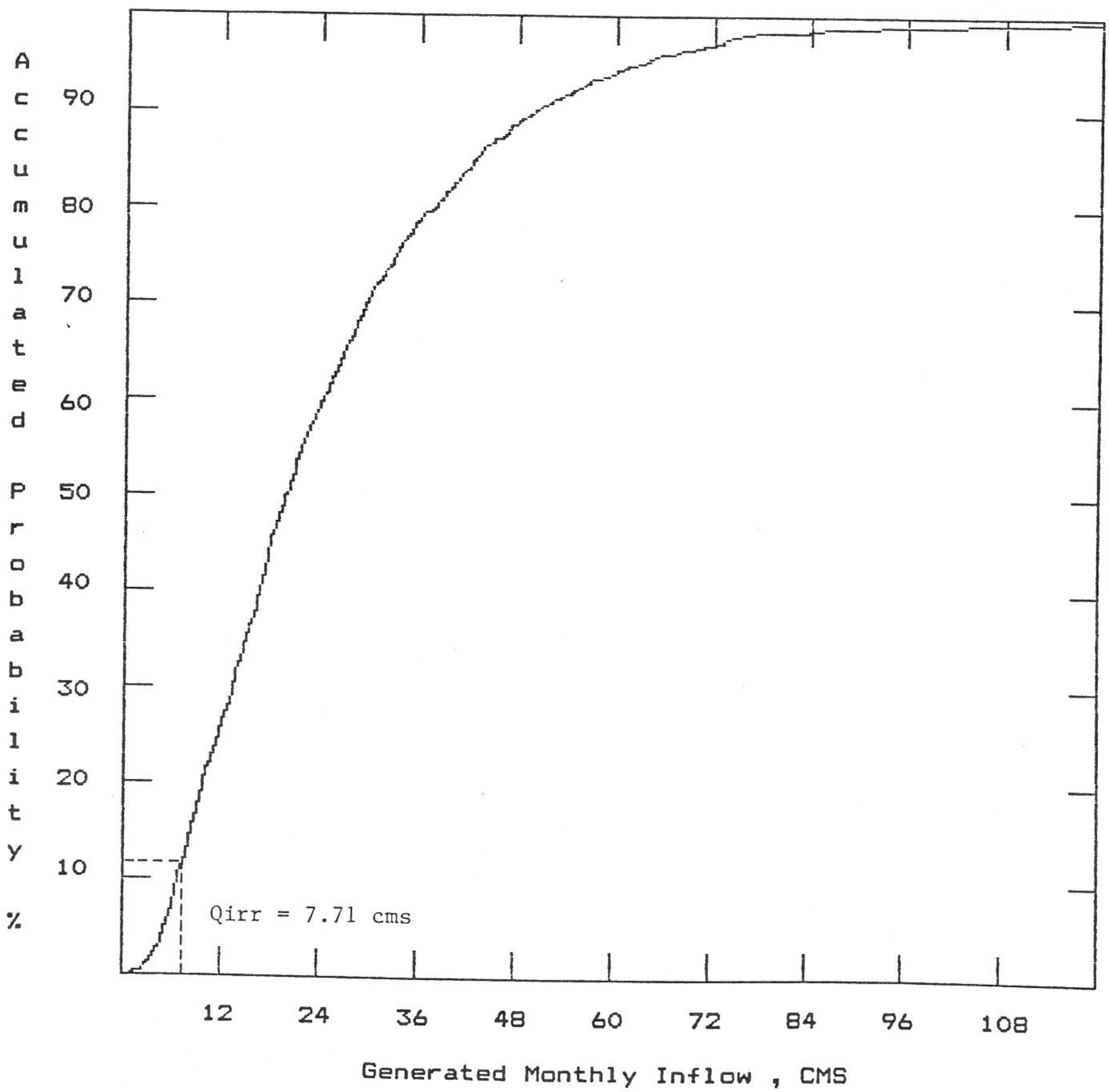

Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 11.50 cms
5
10
15
20
25
30
35
40
45
Generated Monthly Inflow , CMS

(c) March

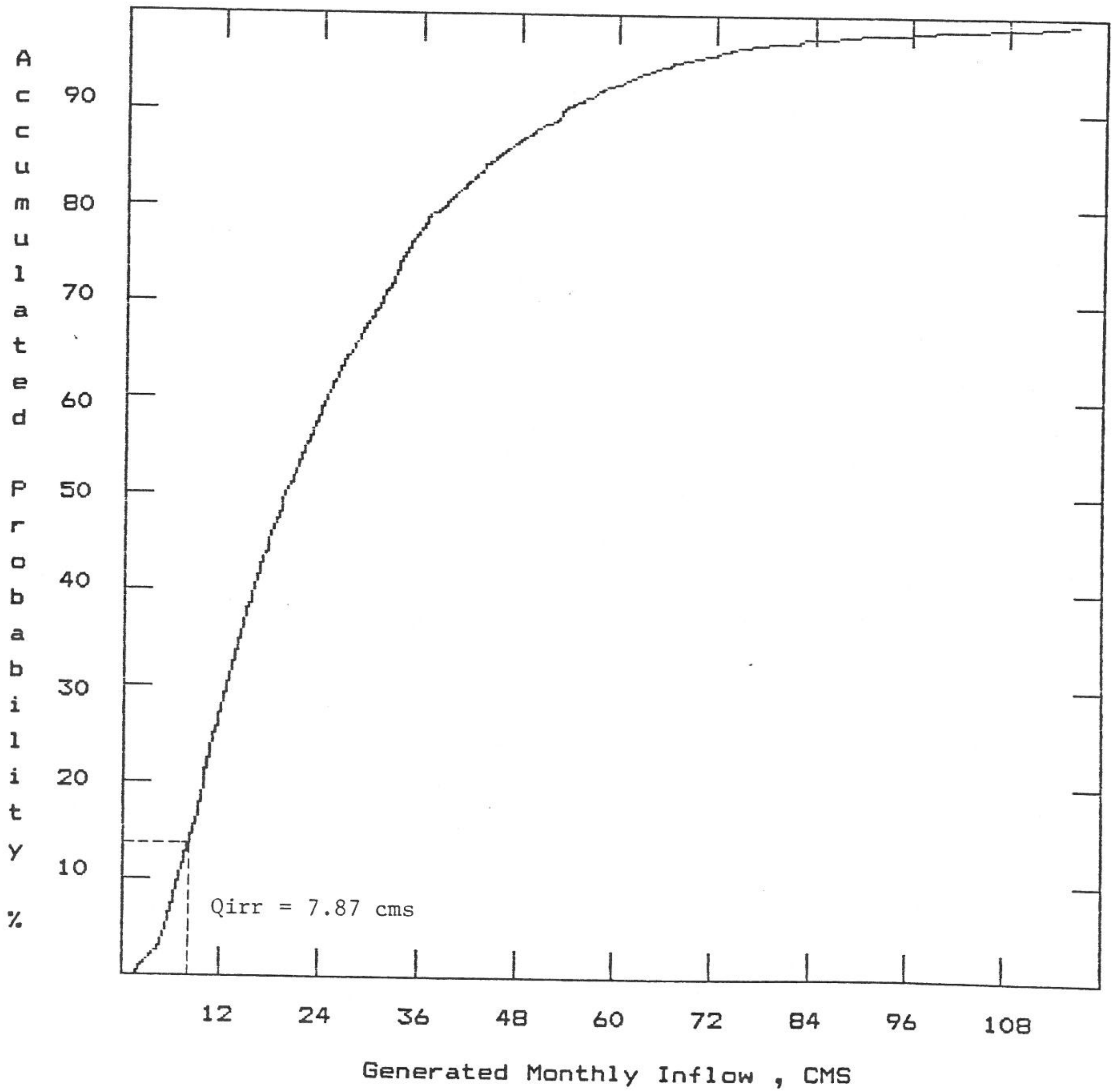


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 10.44 cms
4
8
12
16
20
24
28
32
36
Generated Monthly Inflow , CMS

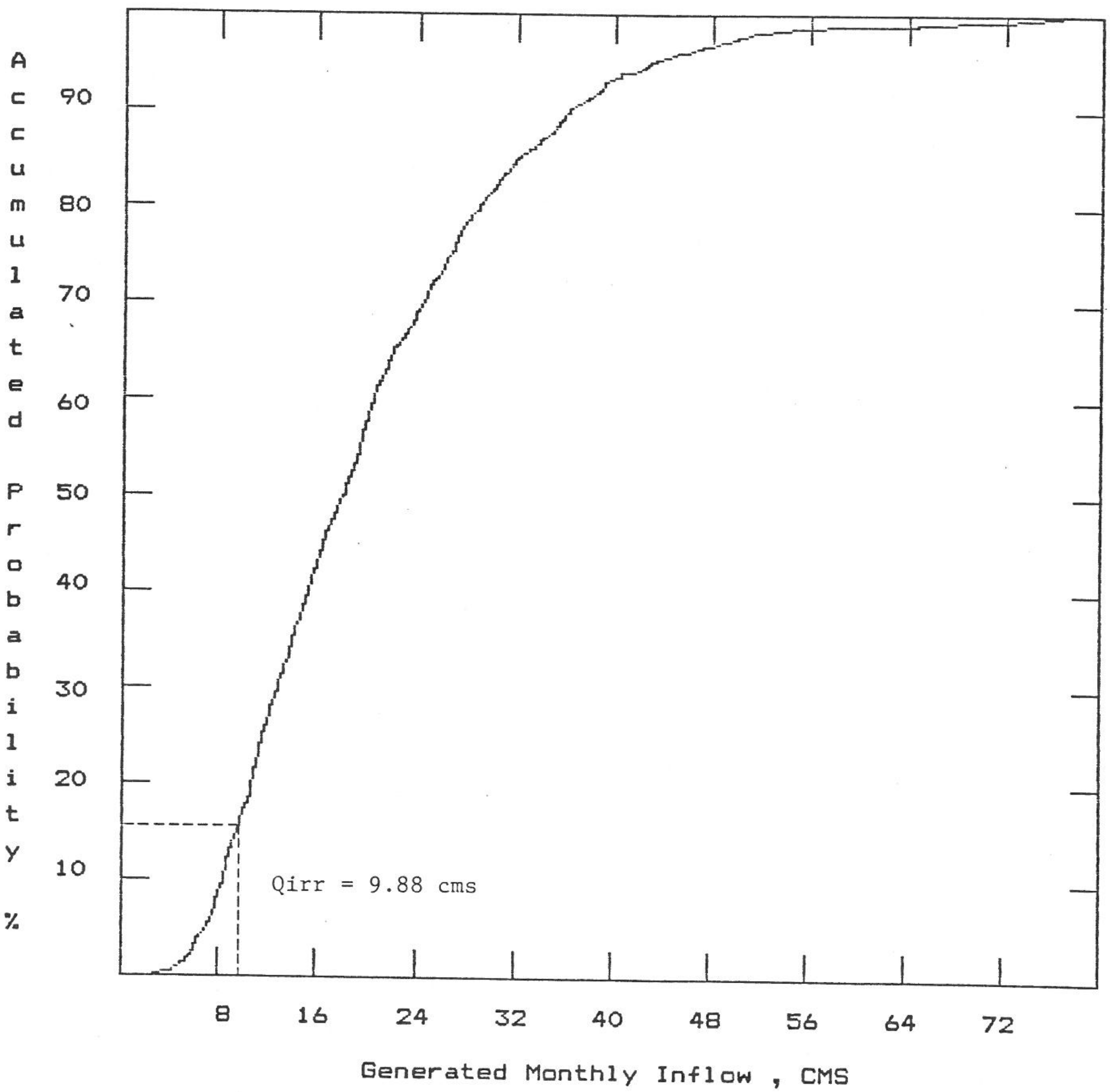
(d) April


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 7.71 cms
12
24
36
48
60
72
84
96
108
Generated Monthly Inflow , CMS

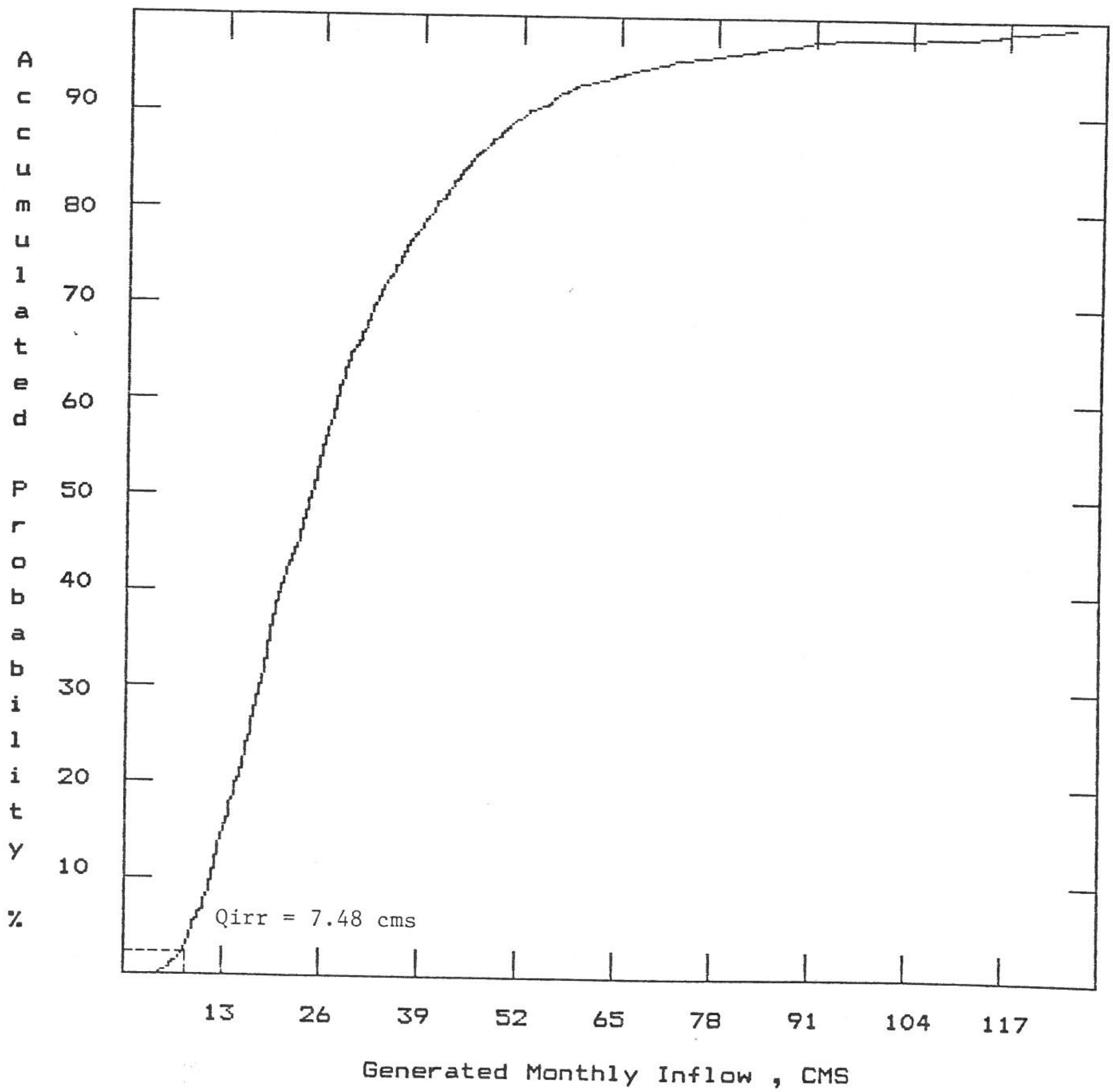
(e) May


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 7.87 cms
12
24
36
48
60
72
84
96
108
Generated Monthly Inflow , CMS

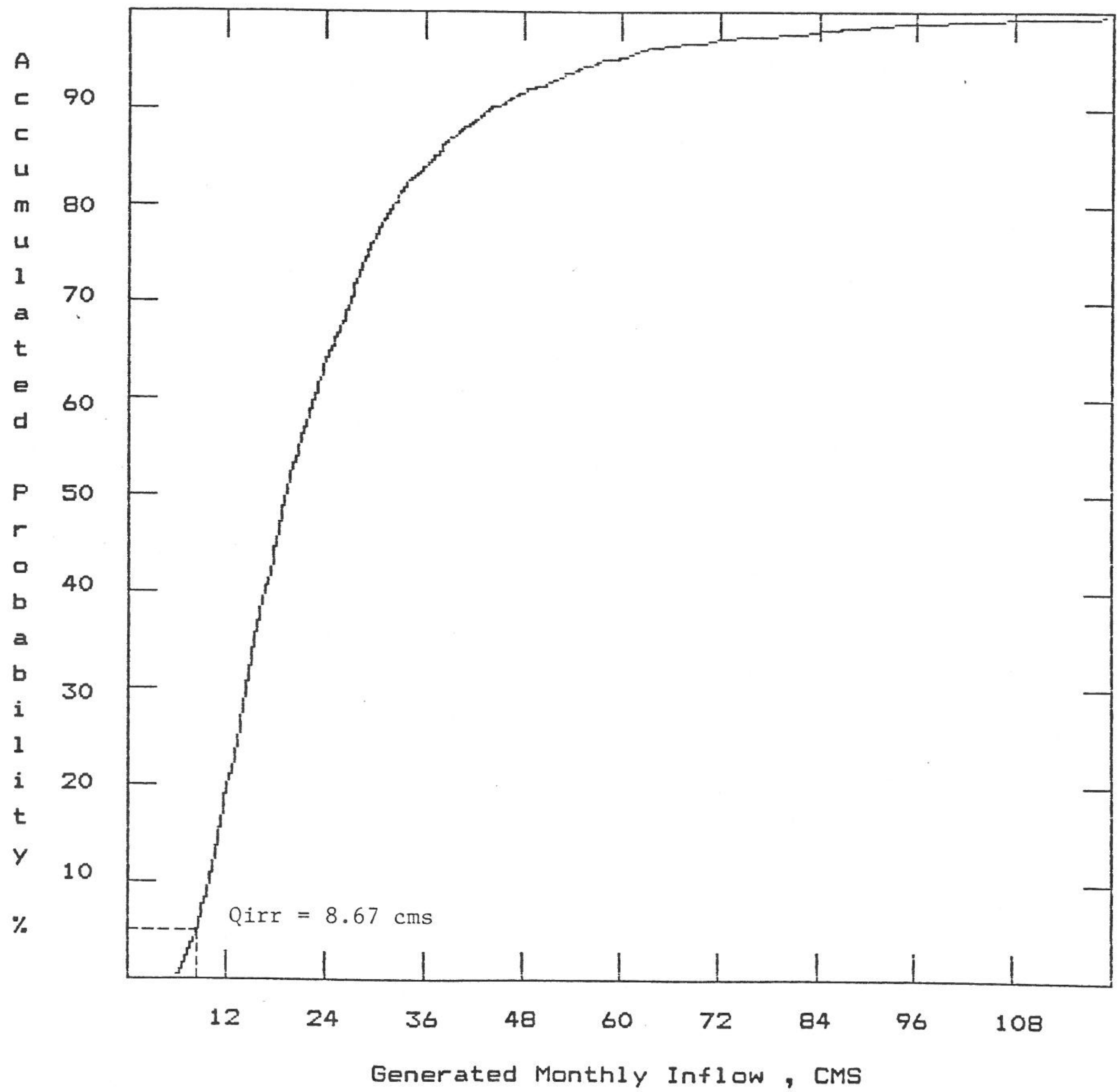
(f) June


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 9.88 cms
8
16
24
32
40
48
56
64
72
Generated Monthly Inflow , CMS

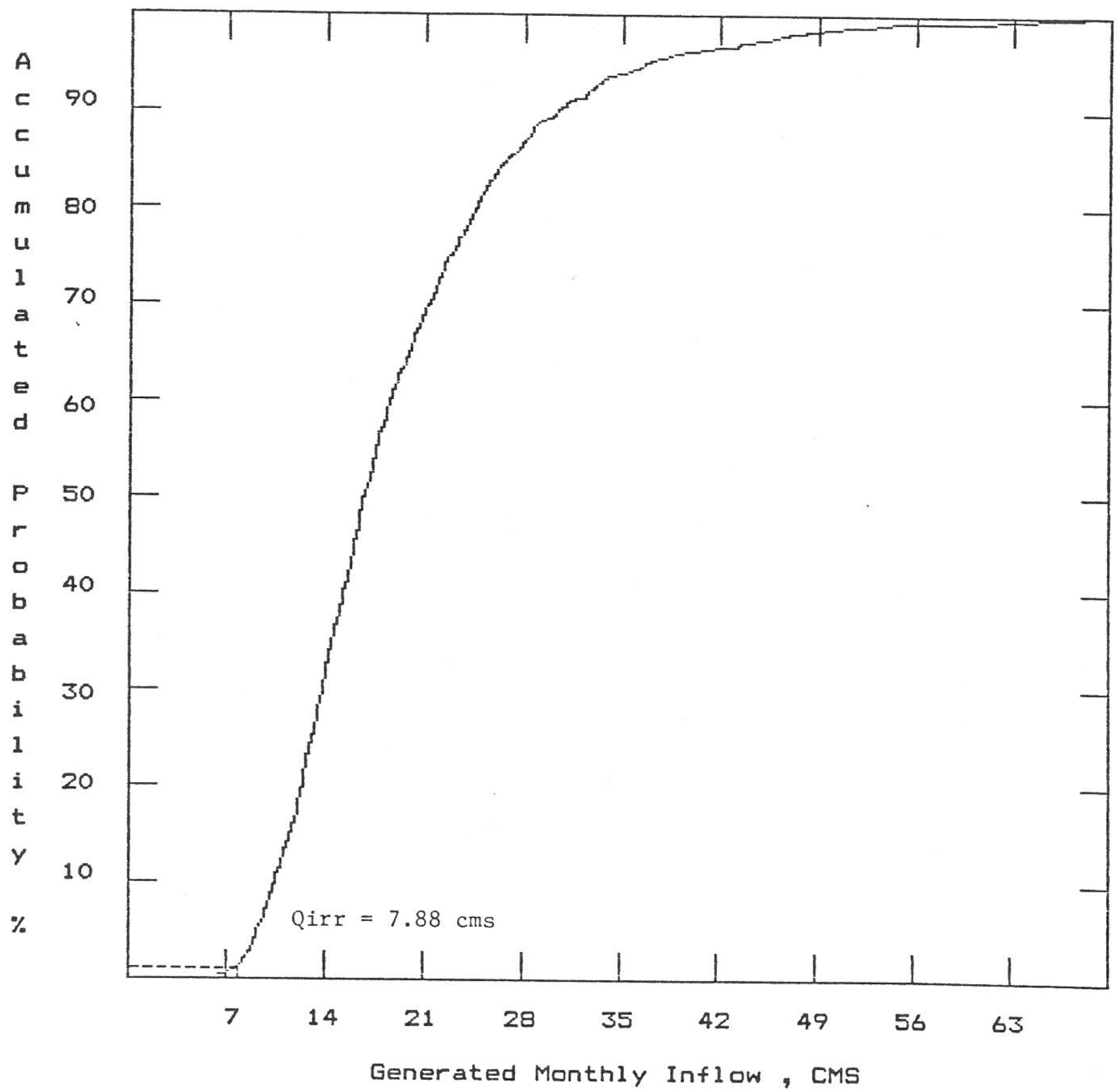
(g) July


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 7.48 cms
13
26
39
52
65
78
91
104
117
Generated Monthly Inflow , CMS

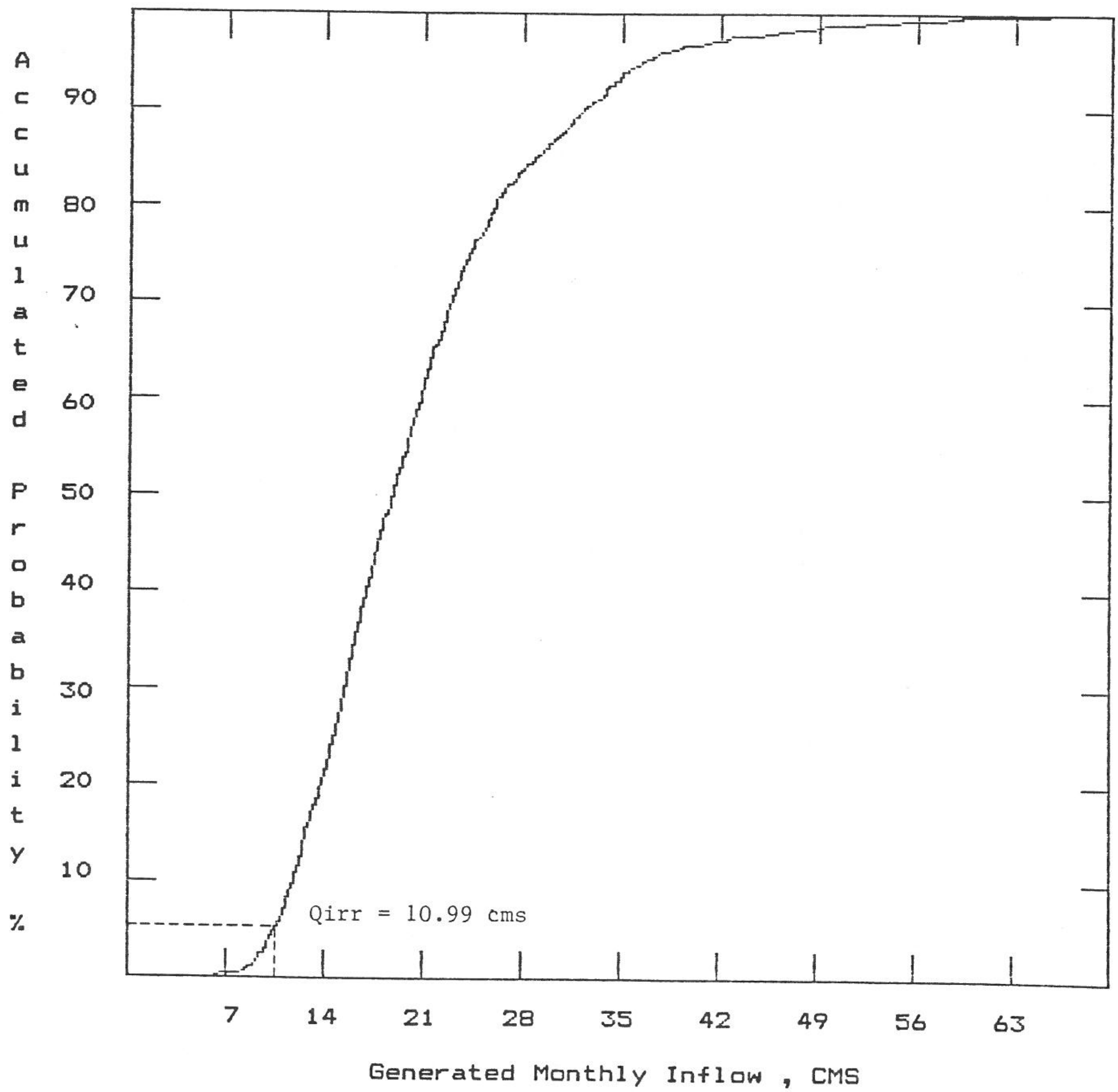
(h) August


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 8.67 cms
12
24
36
48
60
72
84
96
108
Generated Monthly Inflow , CMS

(i) September

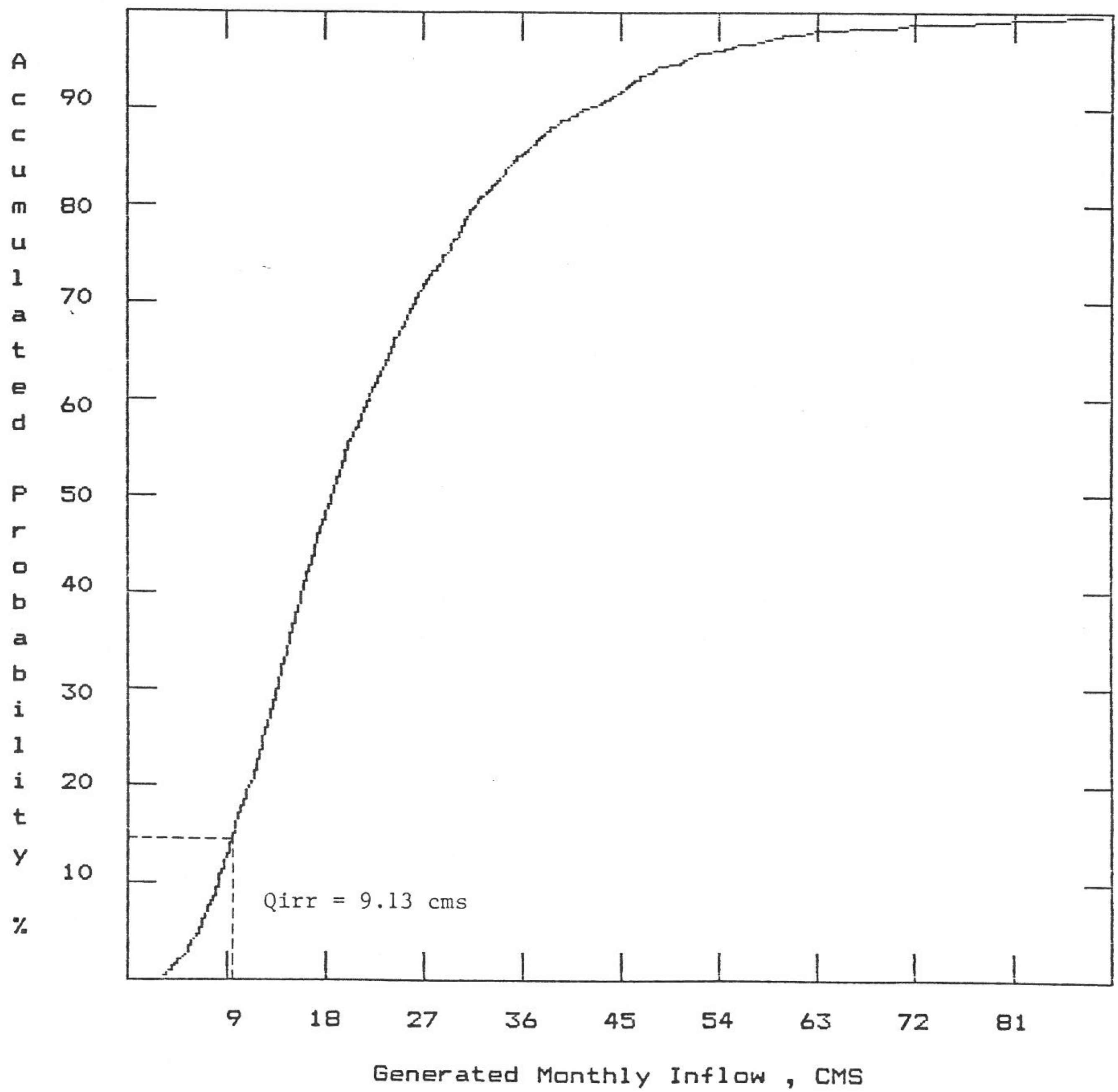

Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 7.88 cms
7
14
21
28
35
42
49
56
63
Generated Monthly Inflow , CMS

(j) October



Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 10.99 cms
7
14
21
28
35
42
49
56
63
Generated Monthly Inflow , CMS

(k) November


Accumulated Probability %
90
80
70
60
50
40
30
20
10
Qirr = 9.13 cms
9
18
27
36
45
54
63
72
81
Generated Monthly Inflow , CMS

(1) December

of inflow, if there is one, can thus be used by the operator to decide the rate of reaching the known target storage after meeting the demand. In other words, the operator can adjust releases on a weekly (or daily) basis in response to observed or forecasted weekly (or daily) inflows, so as to achieve the target storage as closely as possible by the end of month.

For the approach described in Section 2.6.2, the corresponding optimal (stationary) operation rules are shown on Figures 2.6.4 to 2.6.15 and Table 2.6.3. All policies shown form approximately a linear type relationship between beginning and end-of-month storage.

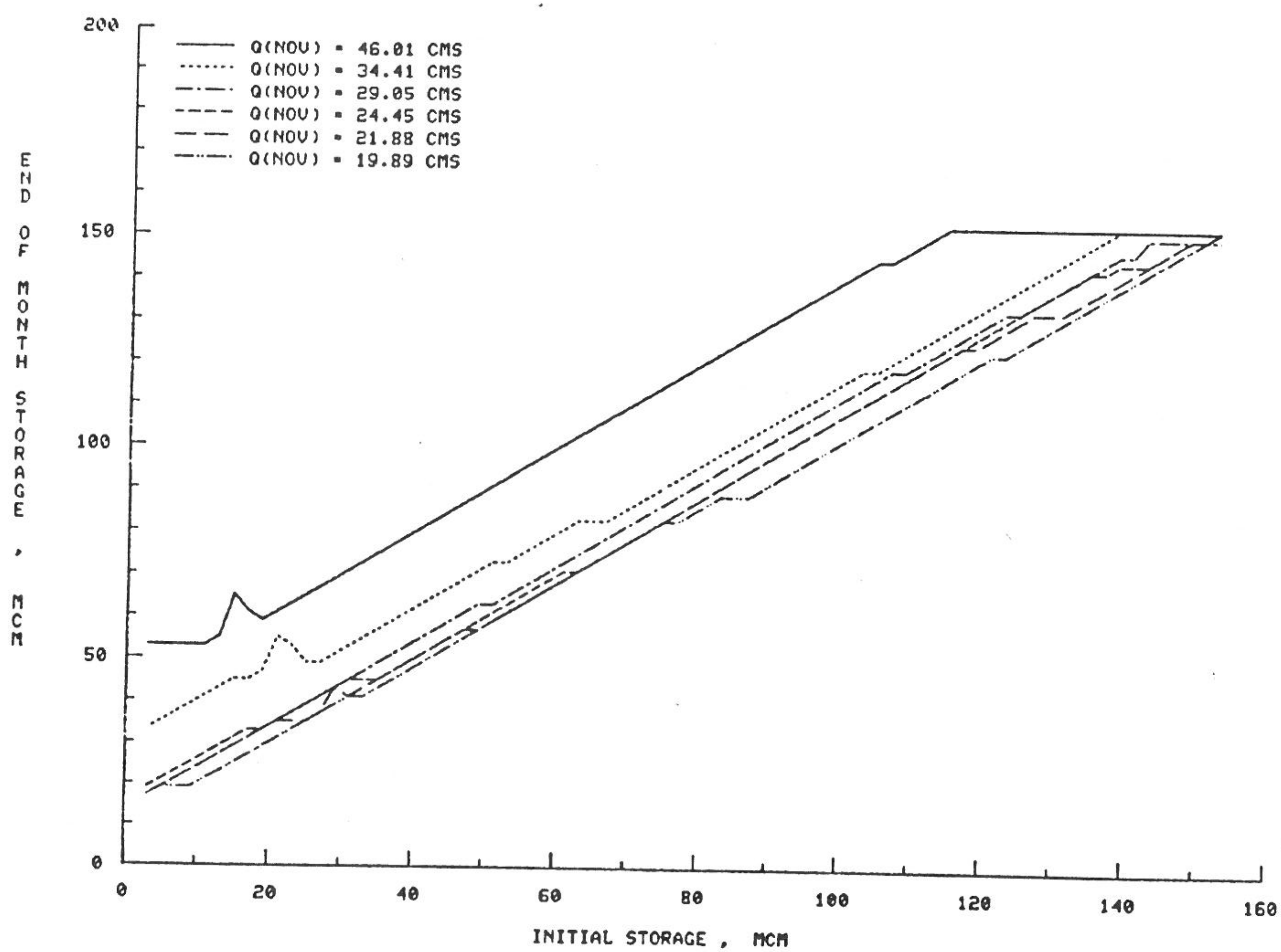


FIG 2.6.15 (B) OPERATION POLICY OF DECEMBER FOR Q(NOV) GREATER THAN 18.91 CMS

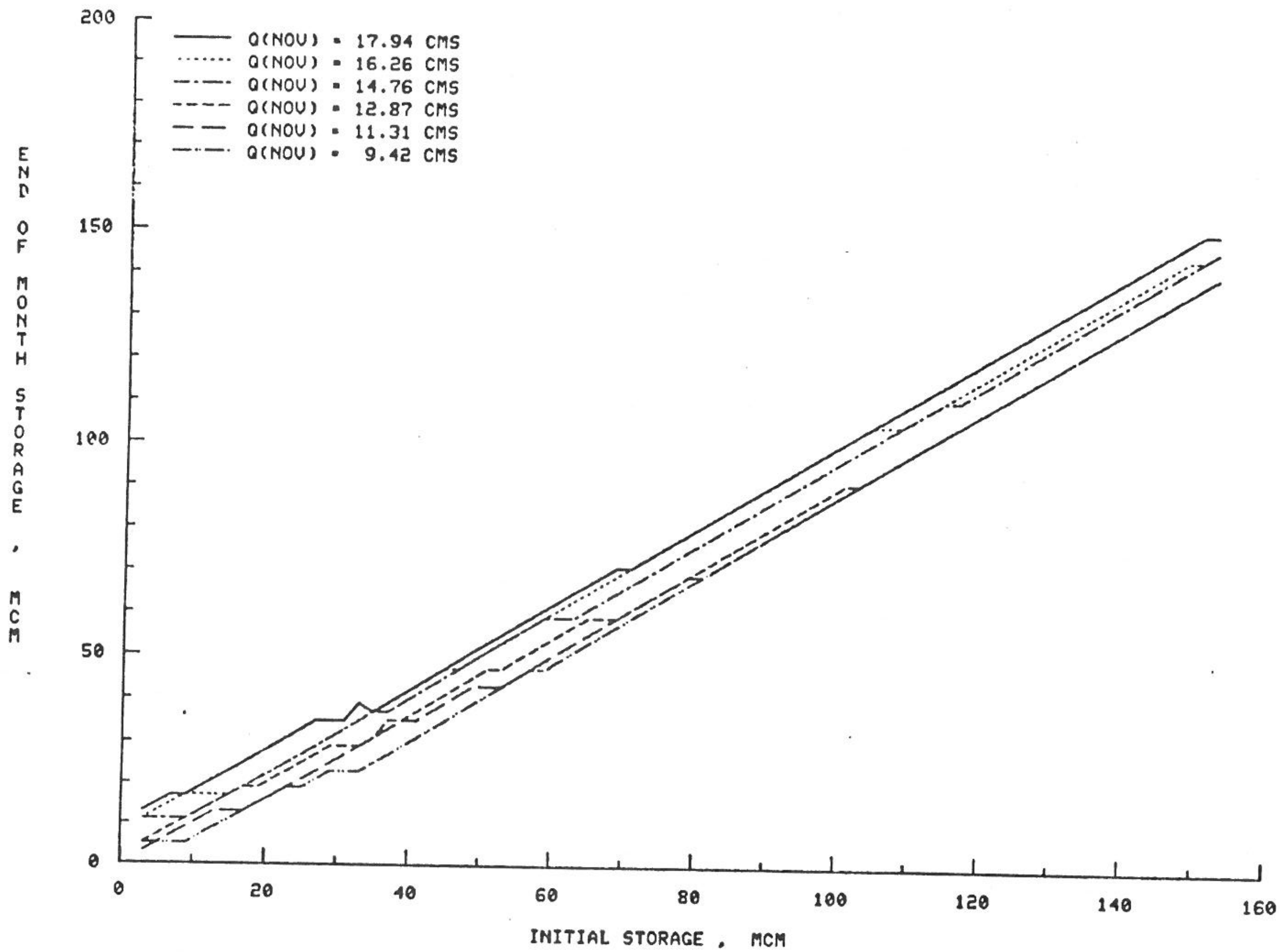


FIG 2.6.15 (A) OPERATION POLICY OF DECEMBER FOR Q(NOV) LESS THAN 18.91 CMS

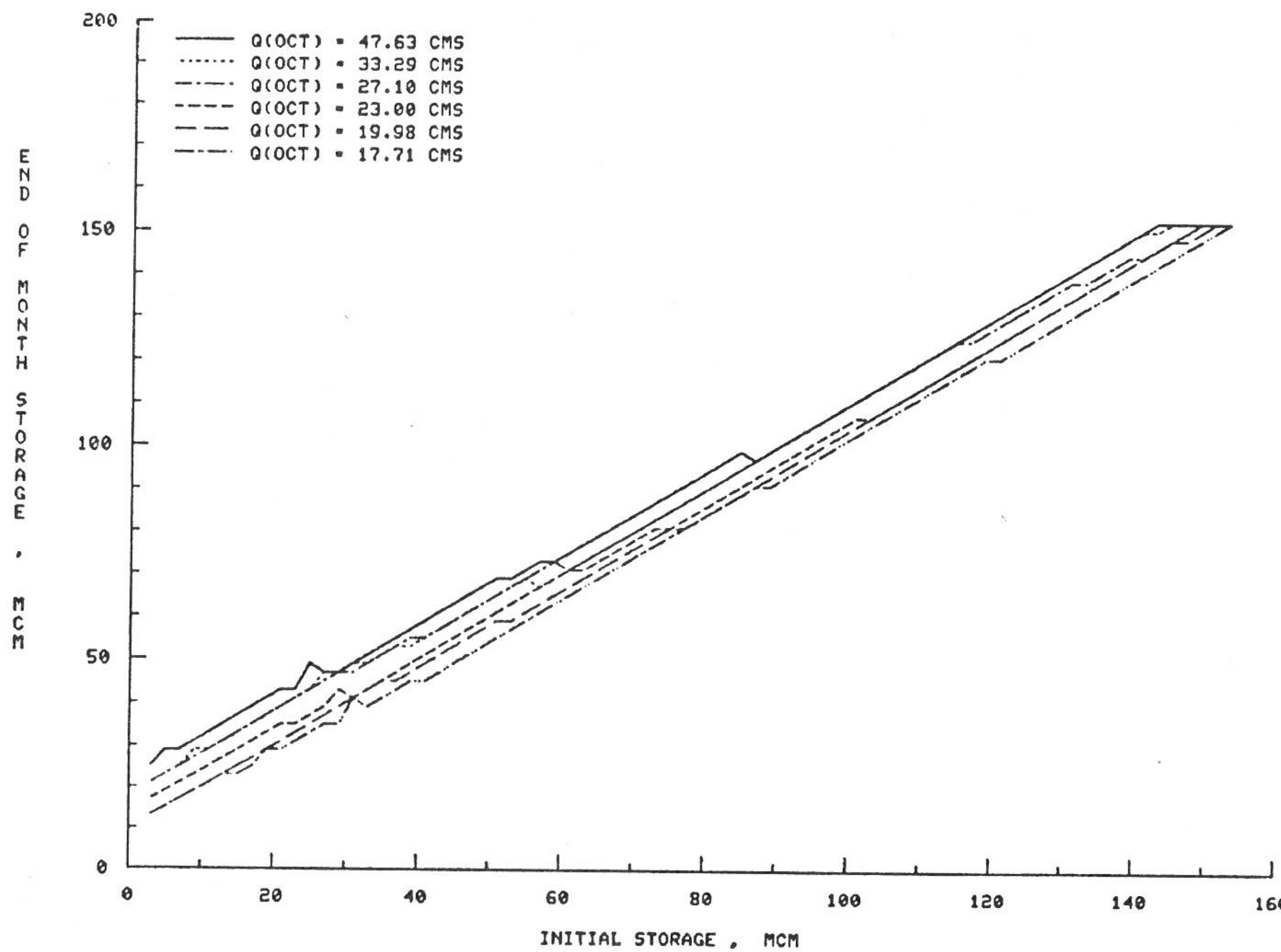


FIG 2.6.14 (B) OPERATION POLICY OF NOVEMBER FOR Q(OCT) GREATER THAN 16.74 CMS

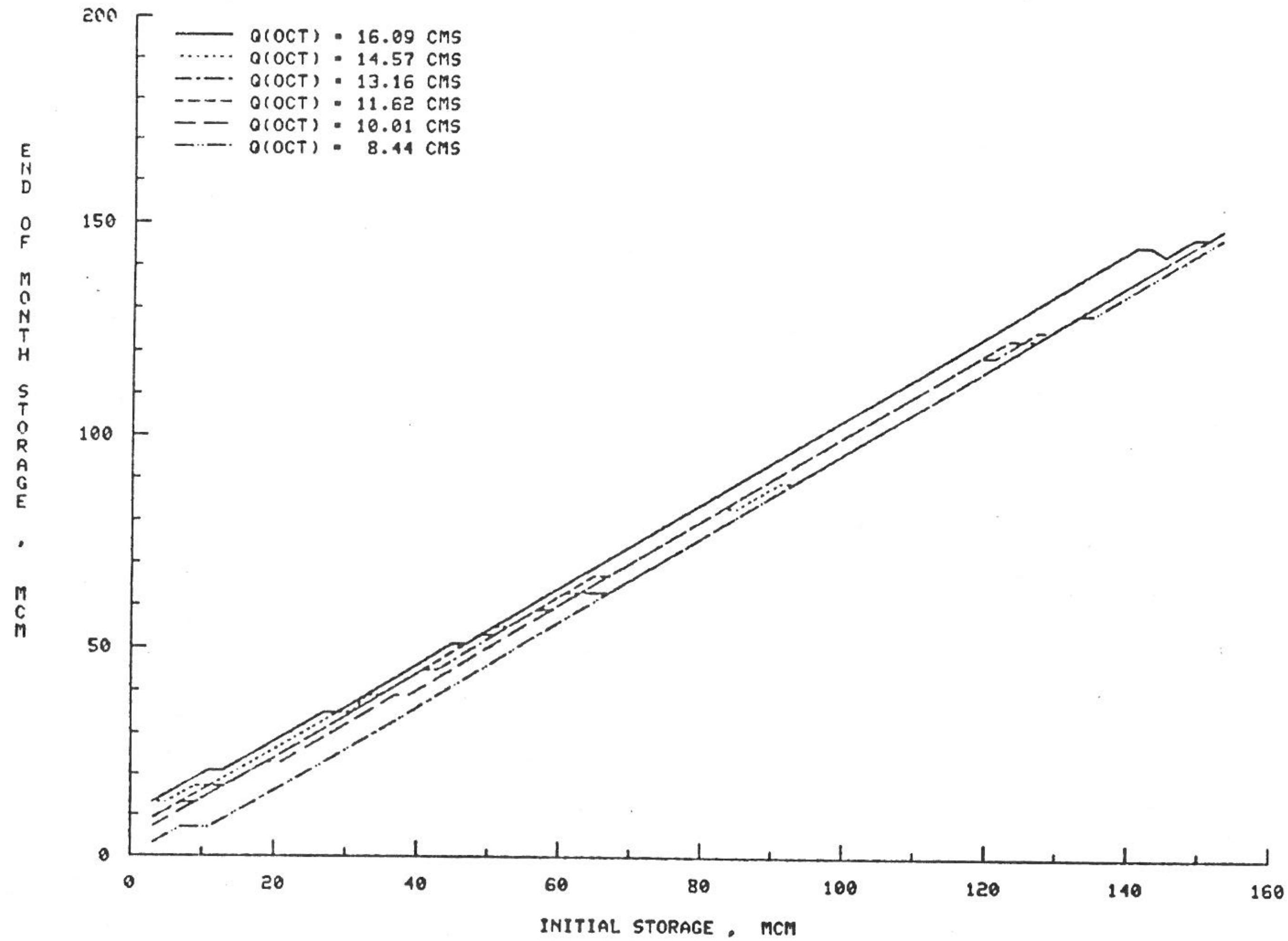


FIG 2.6.14 (A) OPERATION POLICY OF NOVEMBER FOR Q(OCT) LESS THAN 16.74 CMS

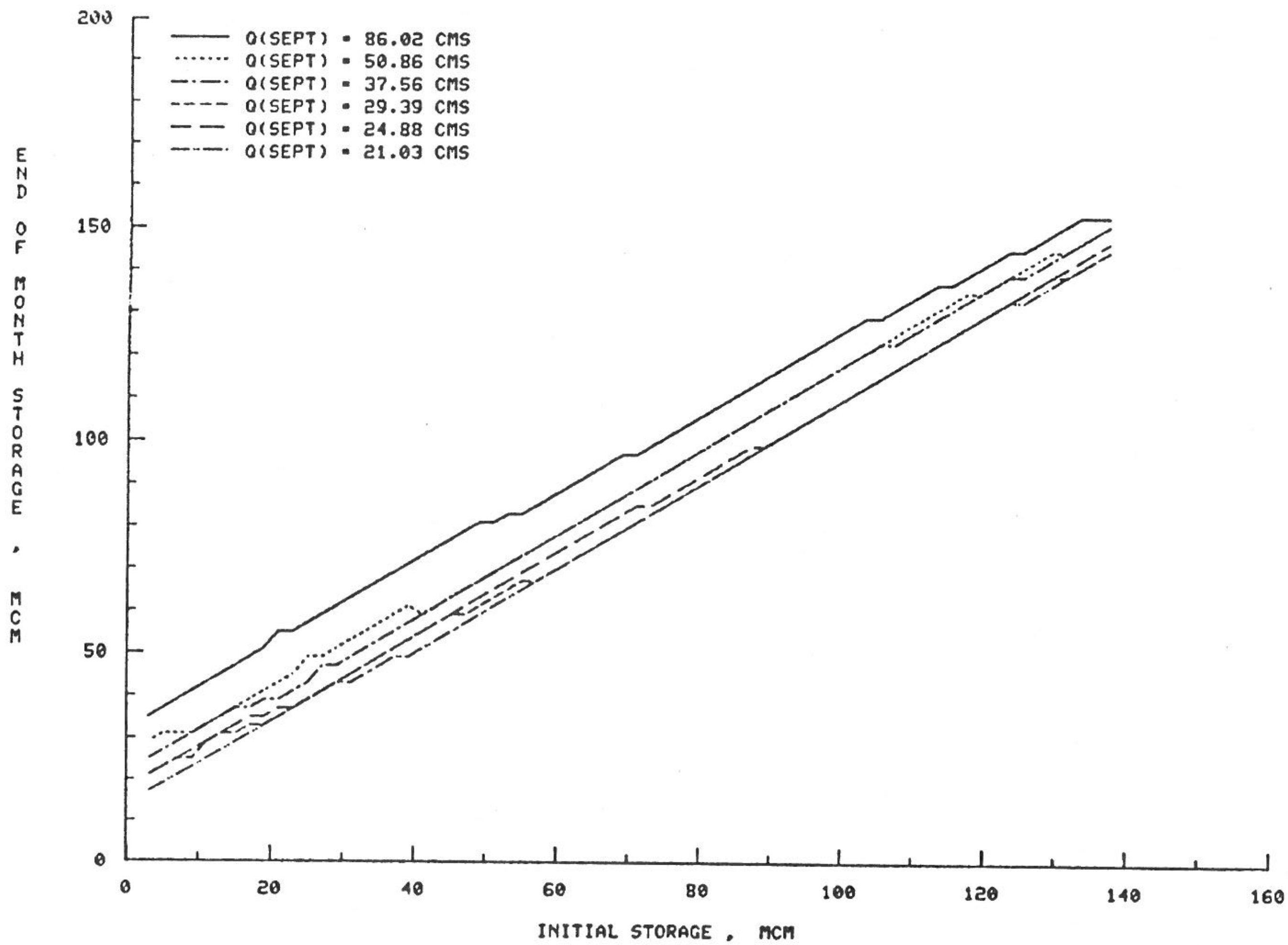


FIG 2.6.13 (B) OPERATION POLICY OF OCTOBER FOR Q(SEPT) GREATER THAN 19.04 CMS

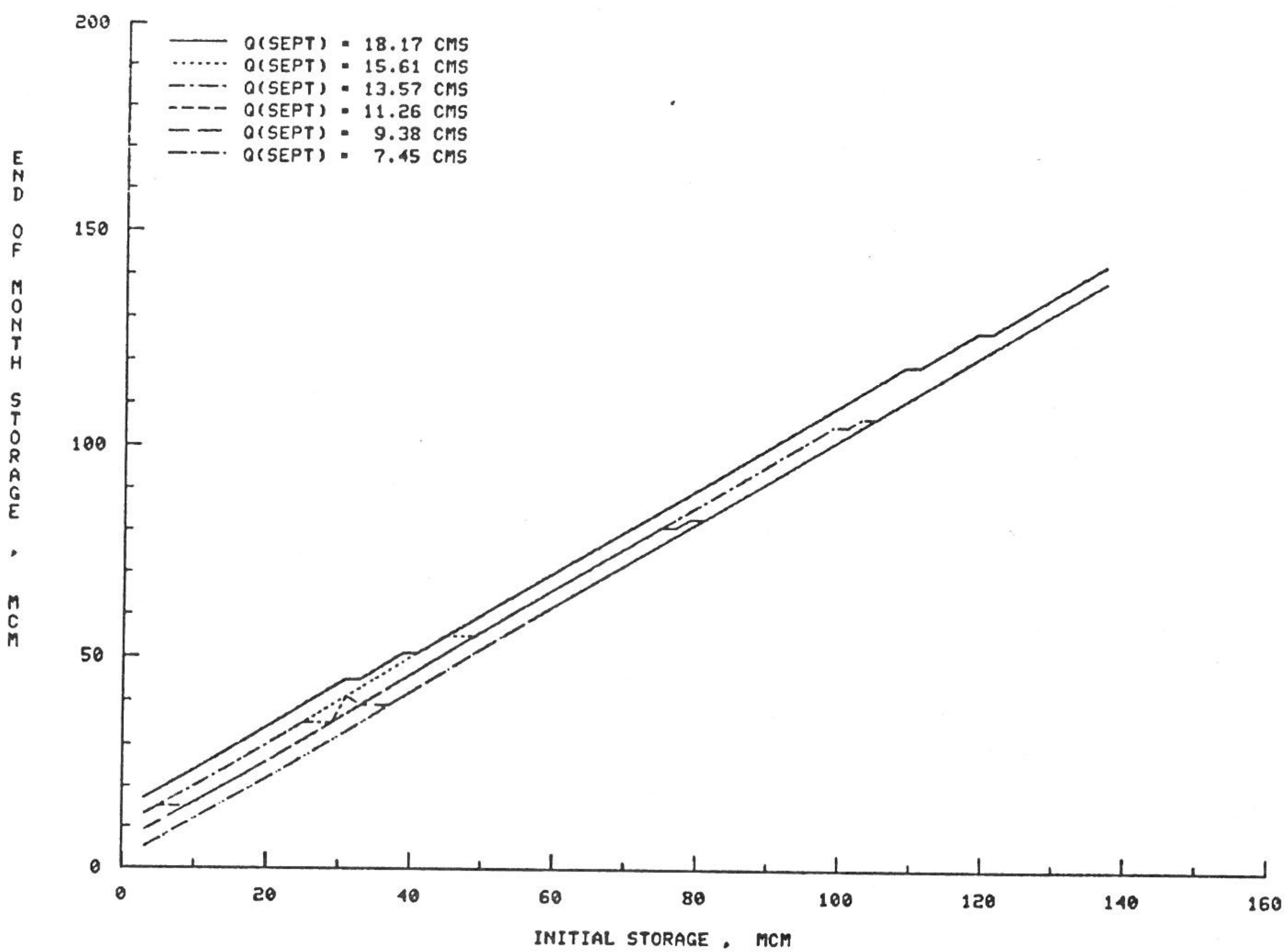


FIG 2.6.13 (A) OPERATION POLICY OF OCTOBER FOR Q(SEPT) LESS THAN 19.04 CMS

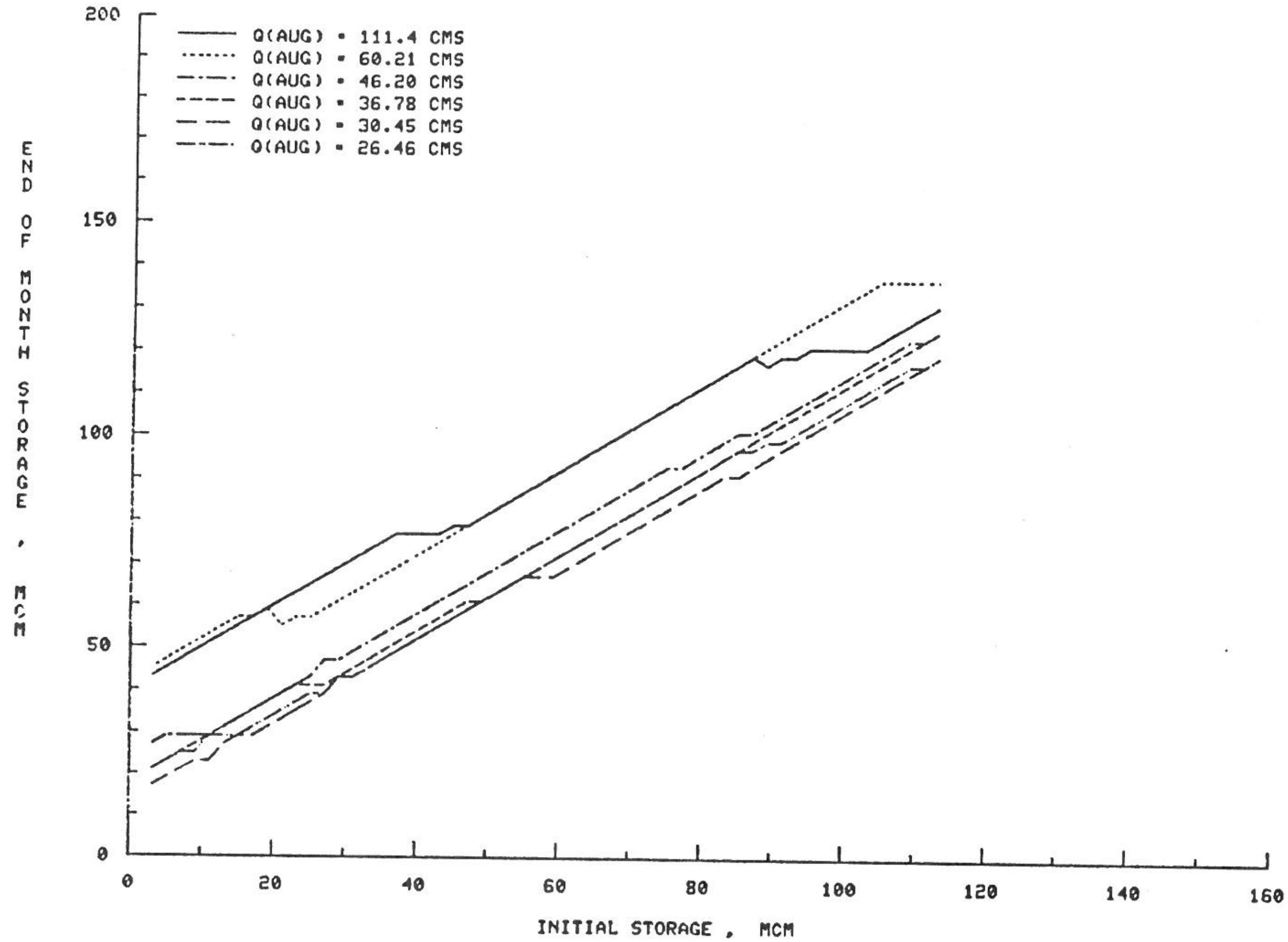


FIG 2.6.12 (B) OPERATION POLICY OF SEPTEMBER FOR Q(AUG) GREATER THAN 24.80 CMS

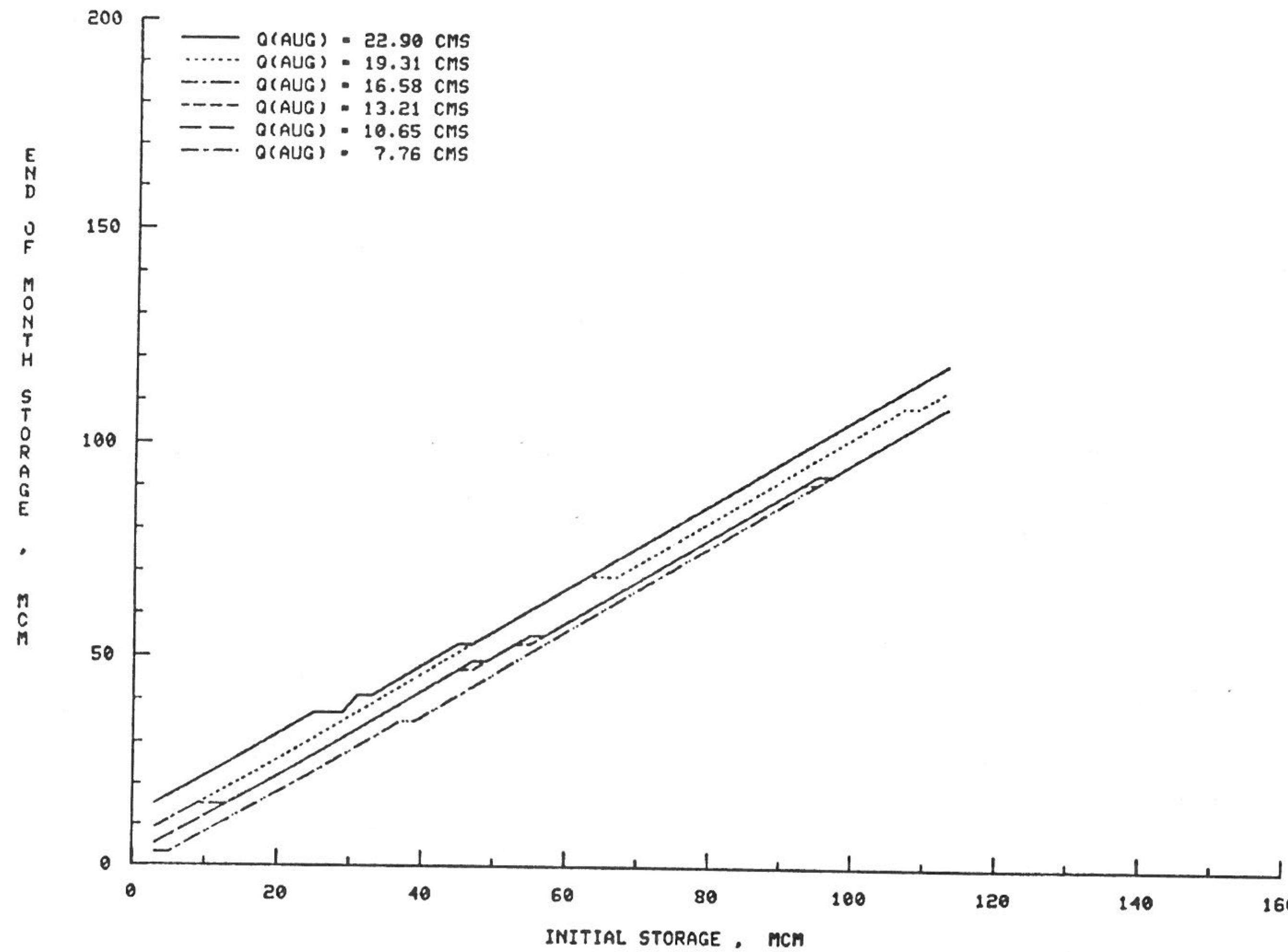


FIG 2.6.12 (A) OPERATION POLICY OF SEPTEMBER FOR Q(AUG) LESS THAN 24.80 CMS

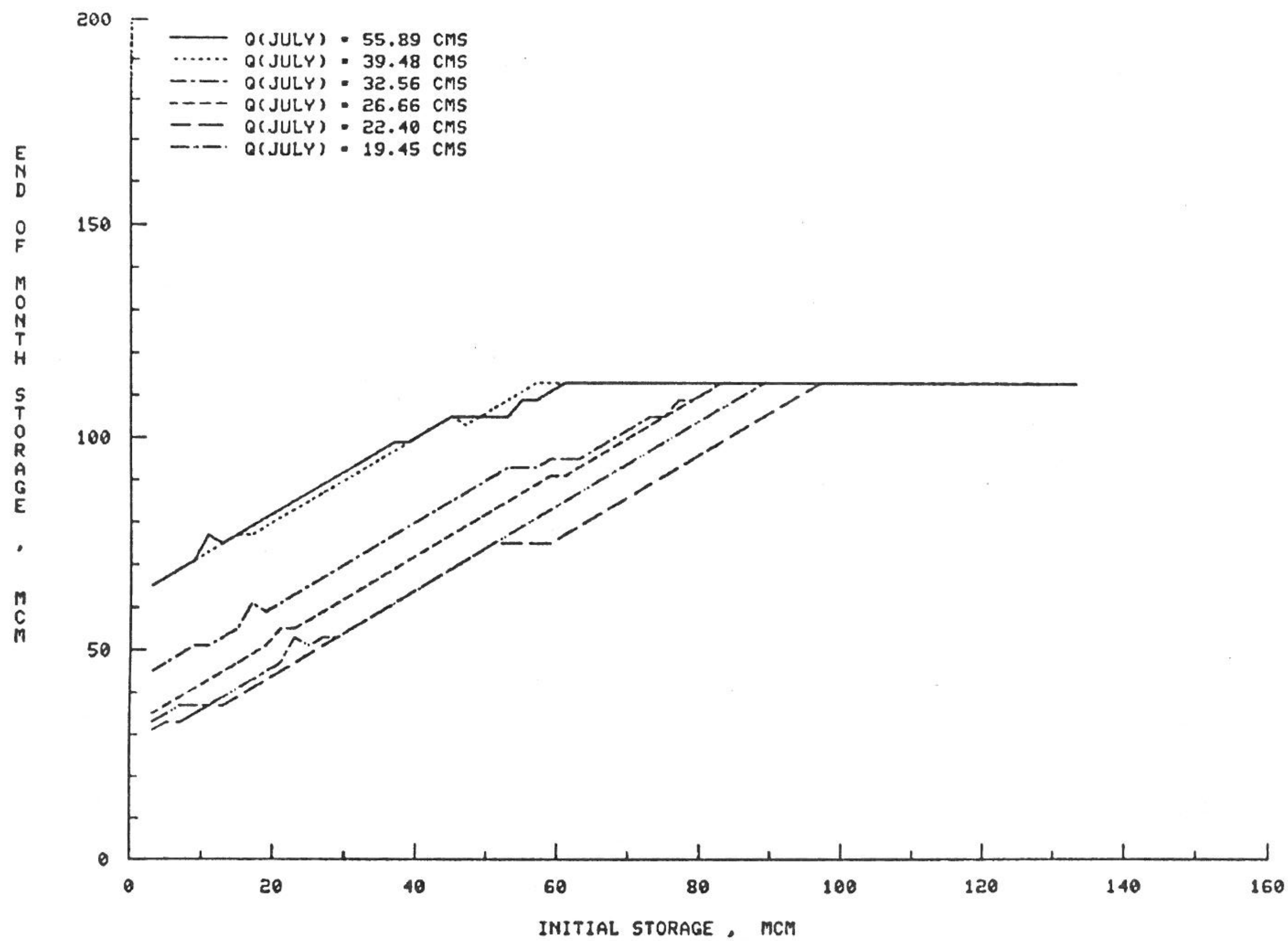


FIG 2.6.11 (B) OPERATION POLICY OF AUGUST FOR Q(JULY) GREATER THAN 18.25 CMS

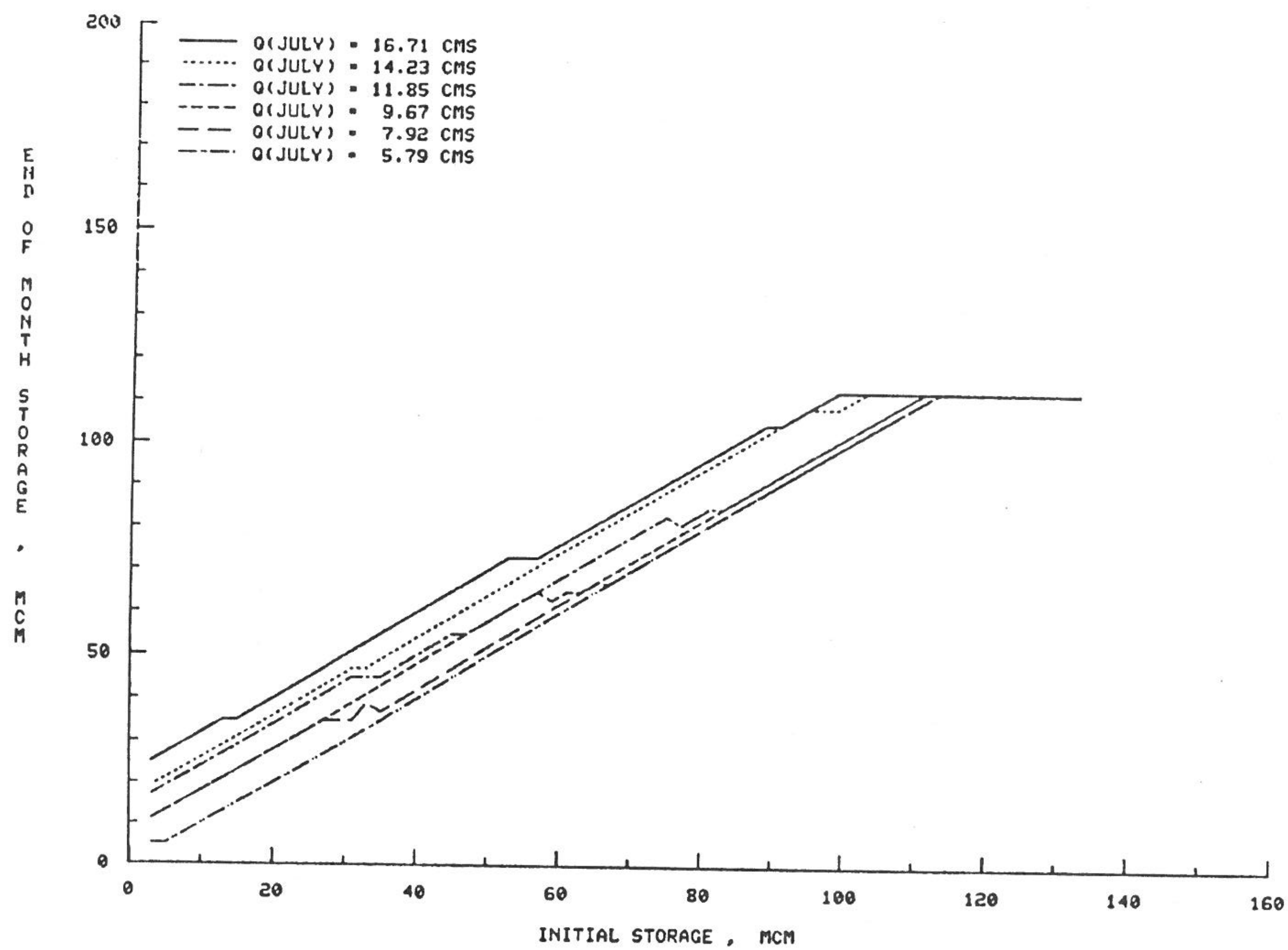


FIG 2.6.11 (A) OPERATION POLICY OF AUGUST FOR Q(JULY) LESS THAN 18.25 CMS

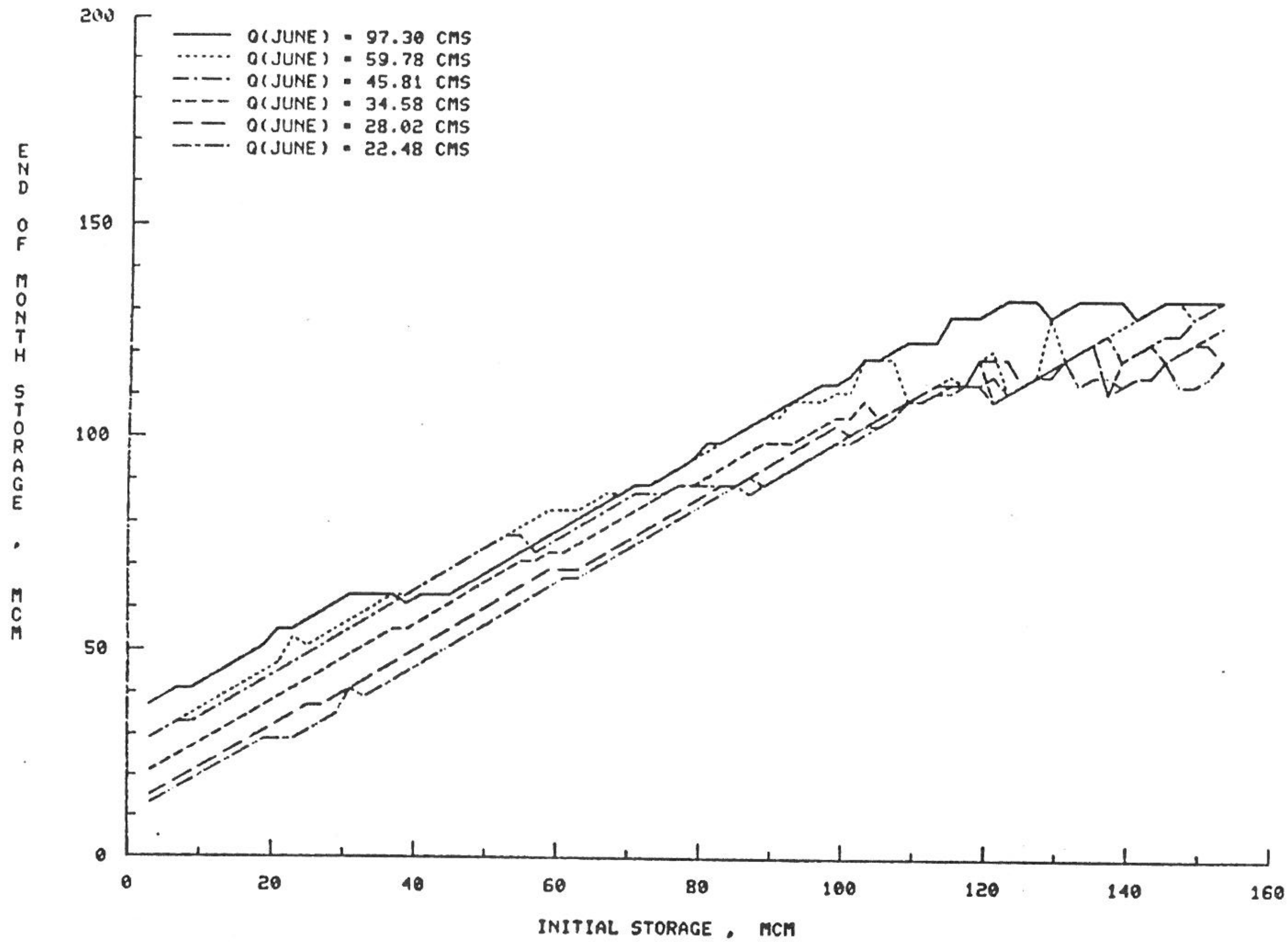


FIG 2.6.10 (B) OPERATION POLICY OF JULY FOR Q(JUNE) GREATER THAN 19.86 CMS

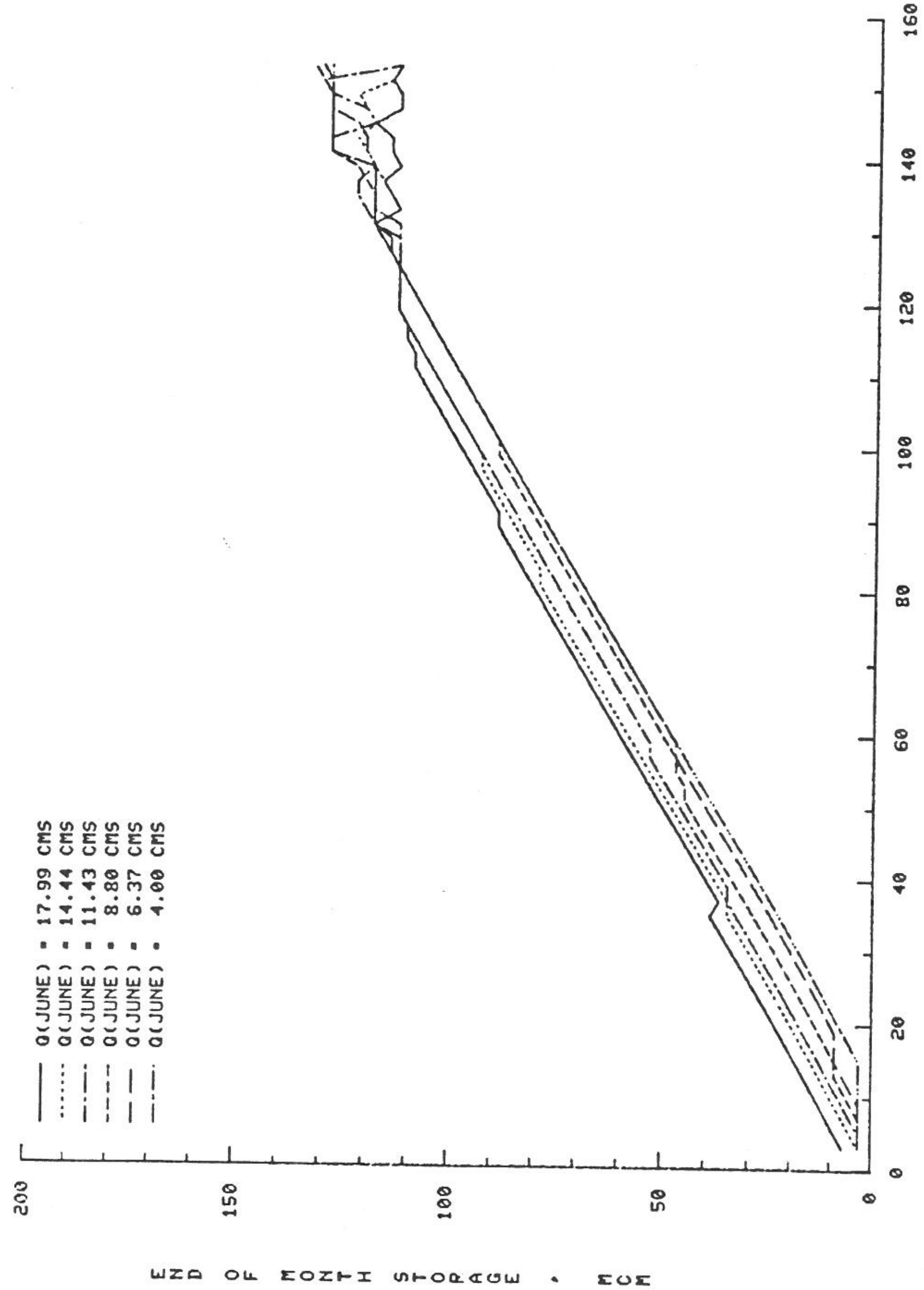


FIG 2.6.10 (A) OPERATION POLICY OF JULY FOR Q(JUNE) LESS THAN 19.86 CMS

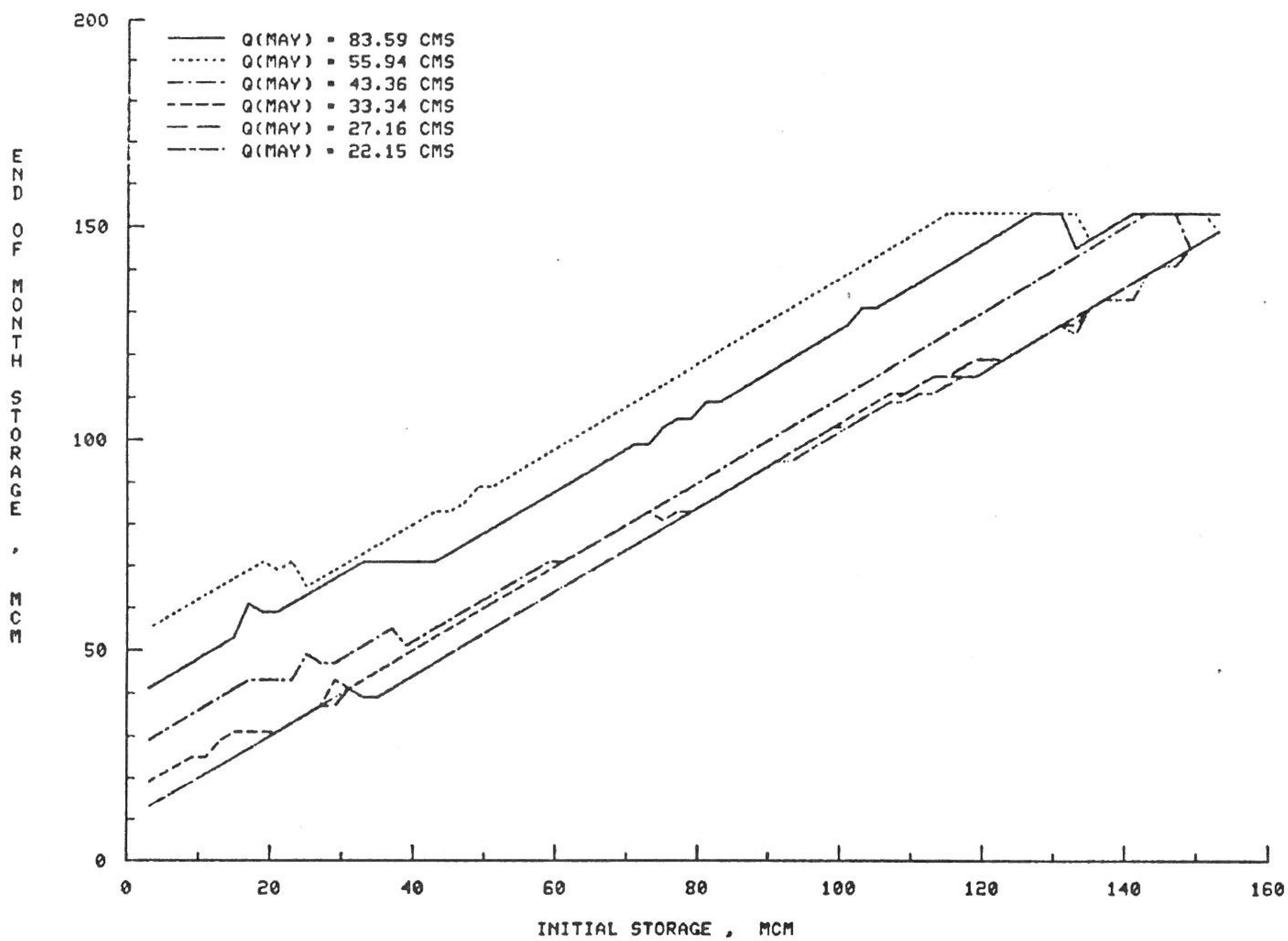


FIG 2.6.9 (B) OPERATION POLICY OF JUNE FOR Q(MAY) GREATER THAN 20.09 CMS

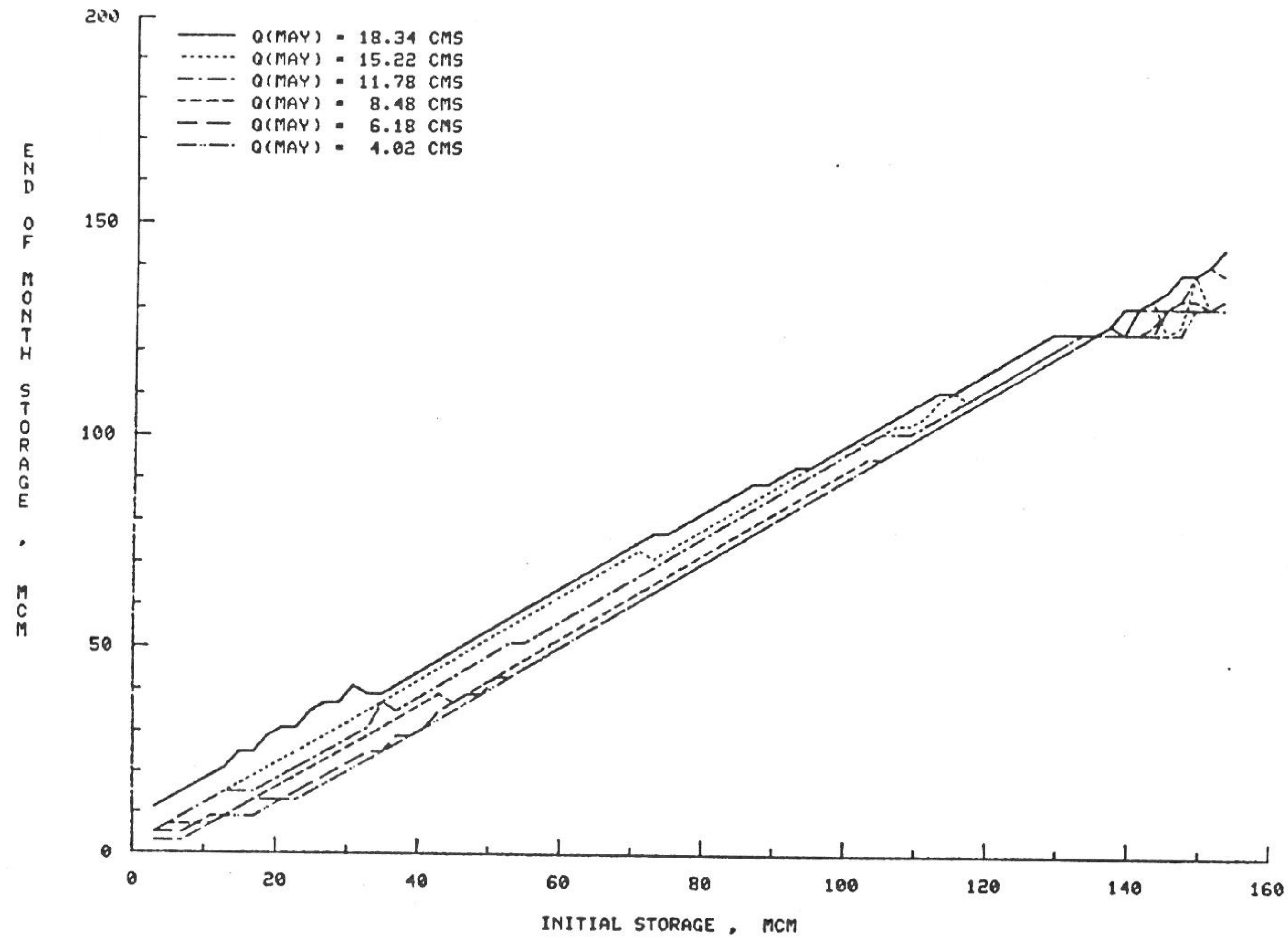


FIG 2.6.9 (A) OPERATION POLICY OF JUNE FOR Q(MAY) LESS THAN 20.09 CMS

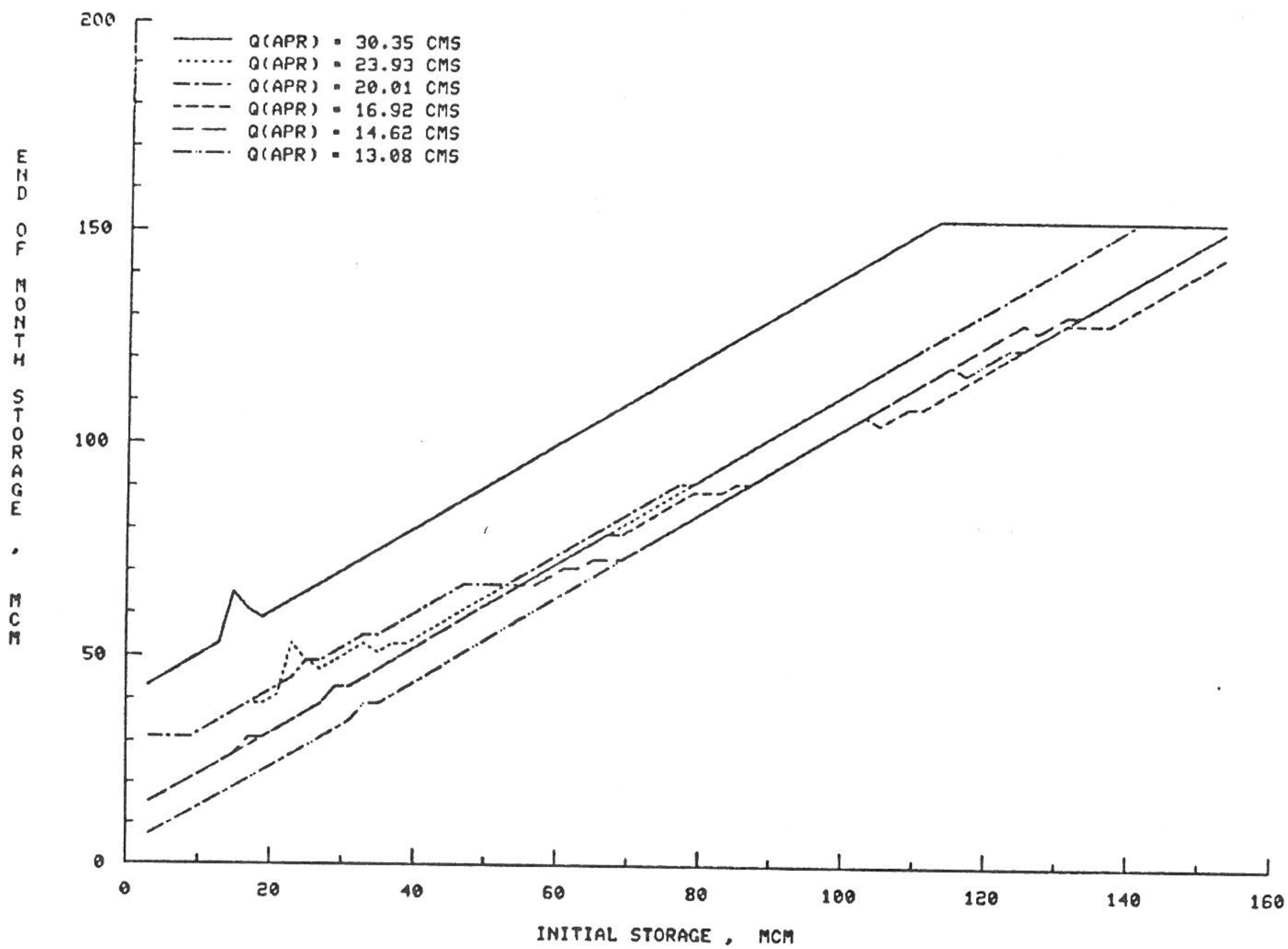


FIG 2.6.8 (B) OPERATION POLICY OF MAY FOR Q(APR) GREATER THAN 12.28 CMS

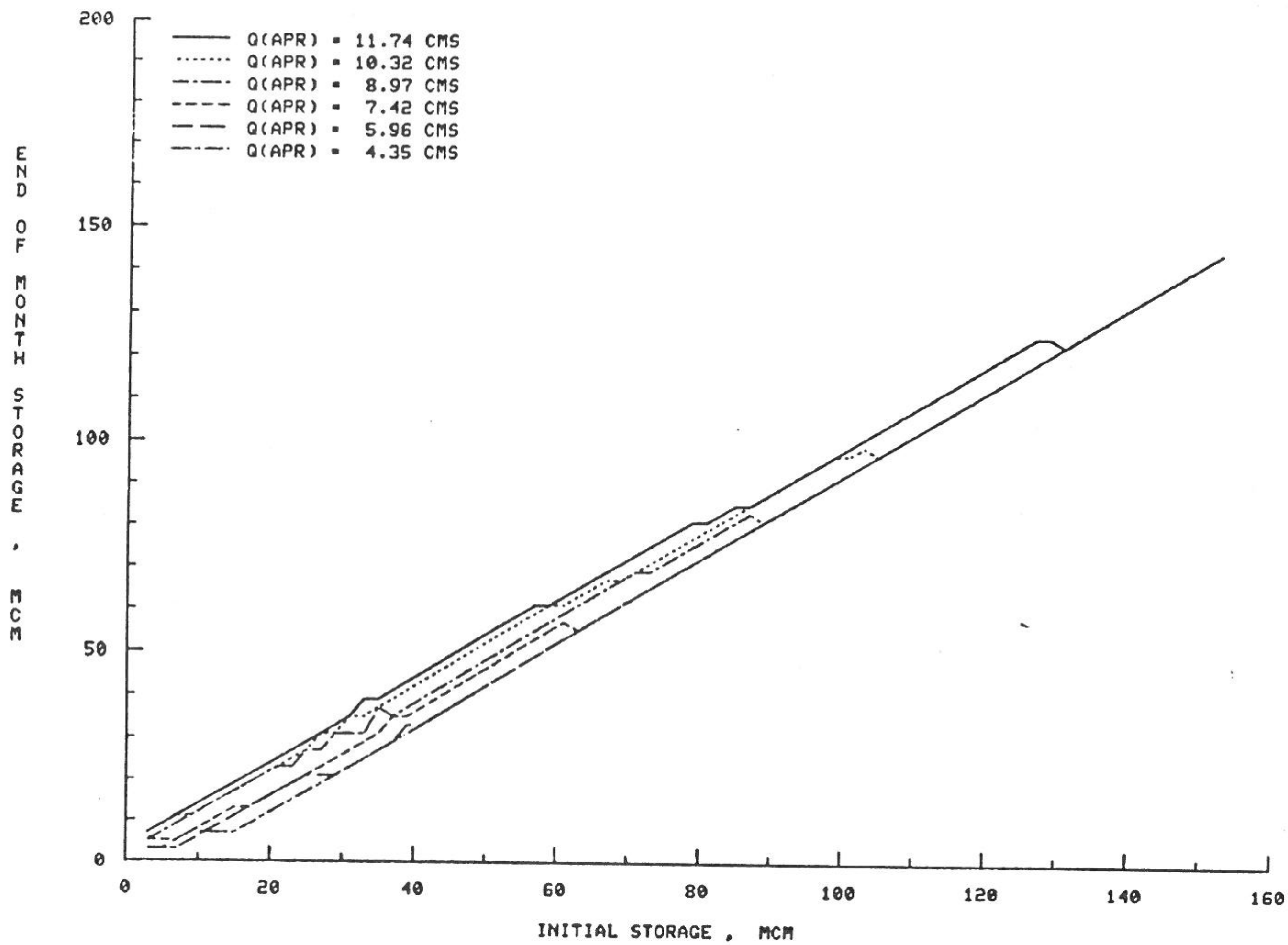


FIG 2.6.8 (A) OPERATION POLICY OF MAY FOR Q(APR) LESS THAN 12.28 CMS

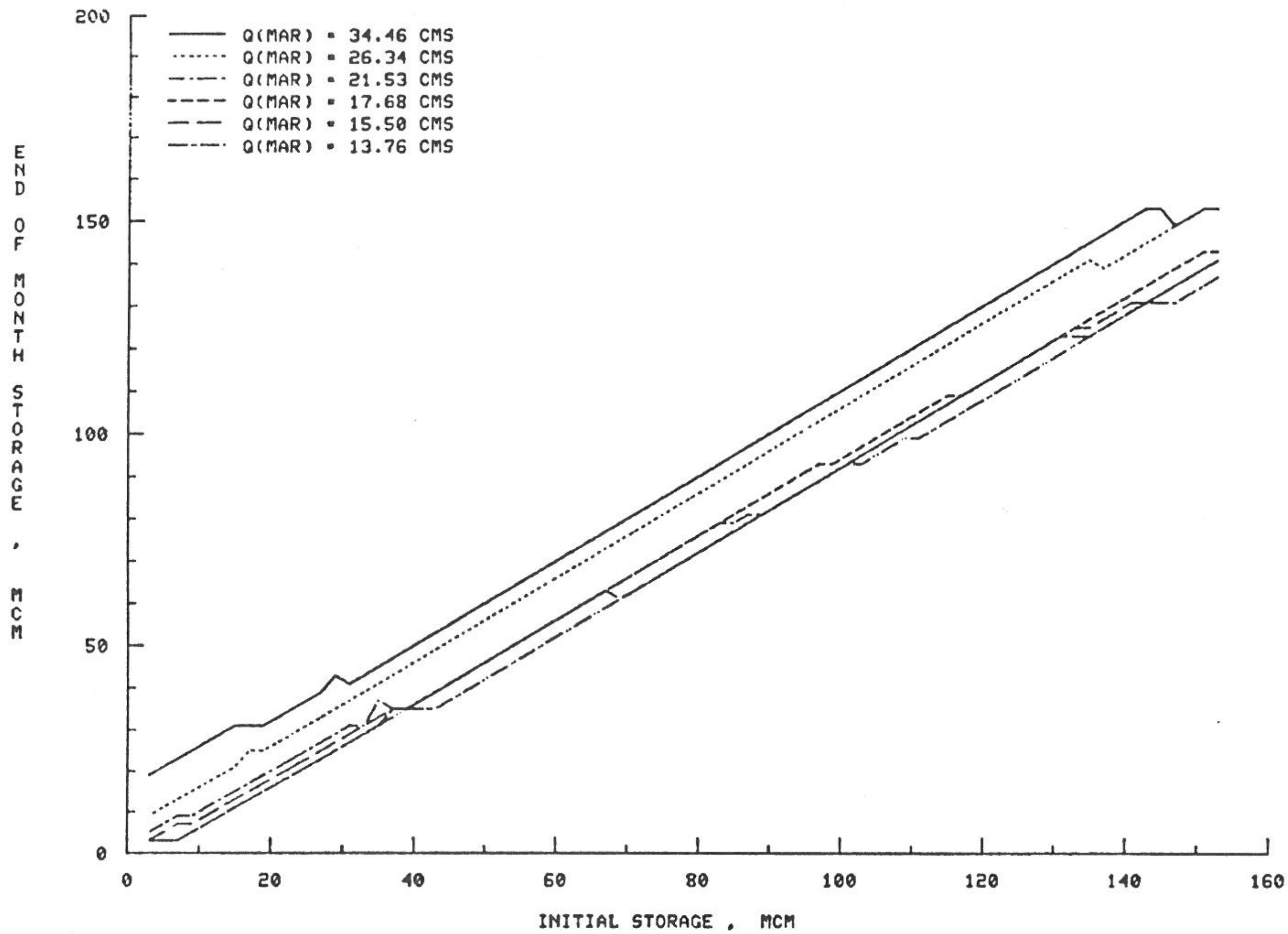


FIG 2.6.7 (B) OPERATION POLICY OF APRIL FOR Q(MAR) GREATER THAN 12.93 CMS

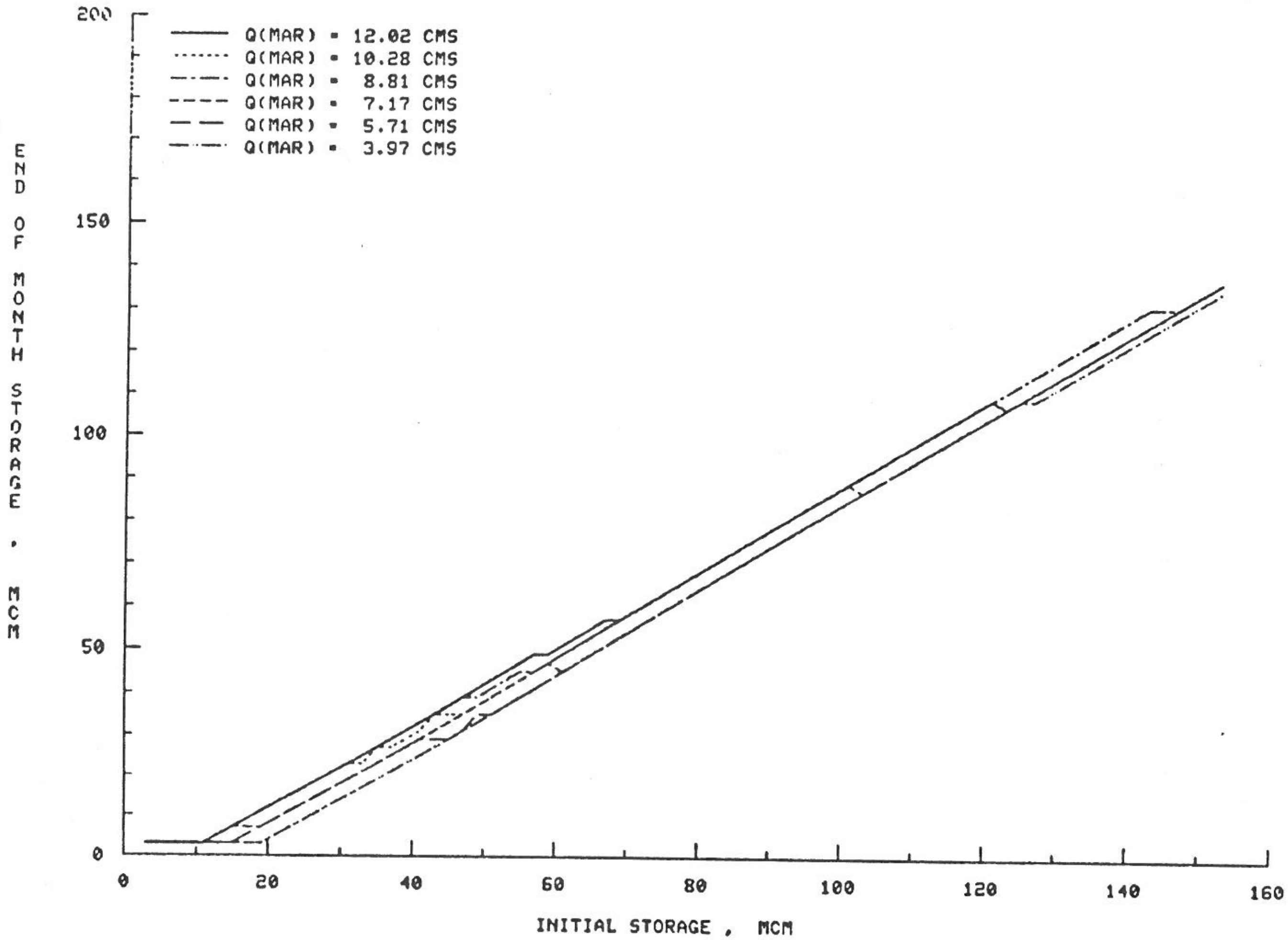


FIG 2.6.7 (A) OPERATION POLICY OF APRIL FOR Q(MAR) LESS THAN 12.93 CMS

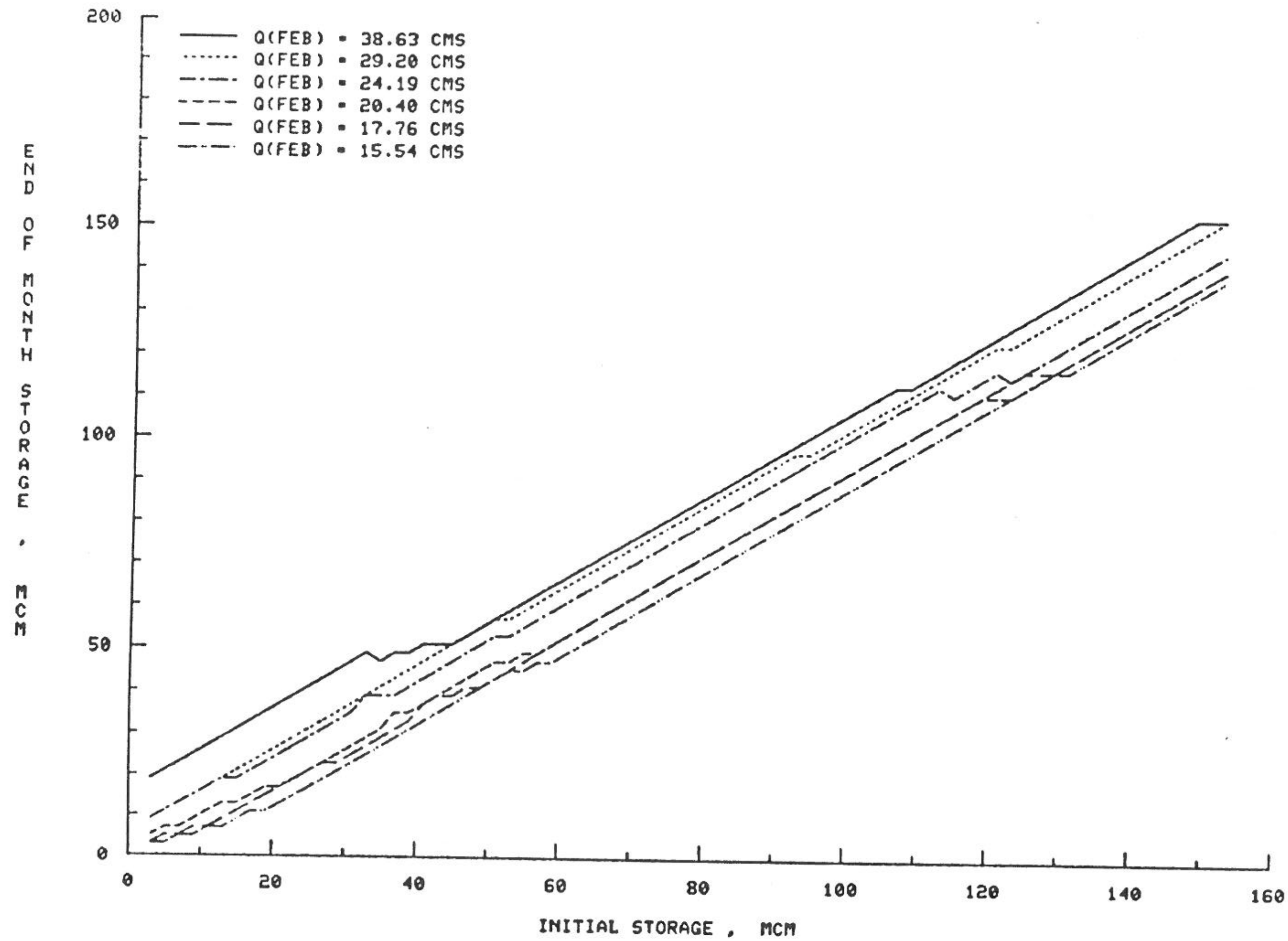


FIG 2.6.6 (B) OPERATION POLICY OF MARCH FOR Q(FEB) GREATER THAN 14.52 CMS

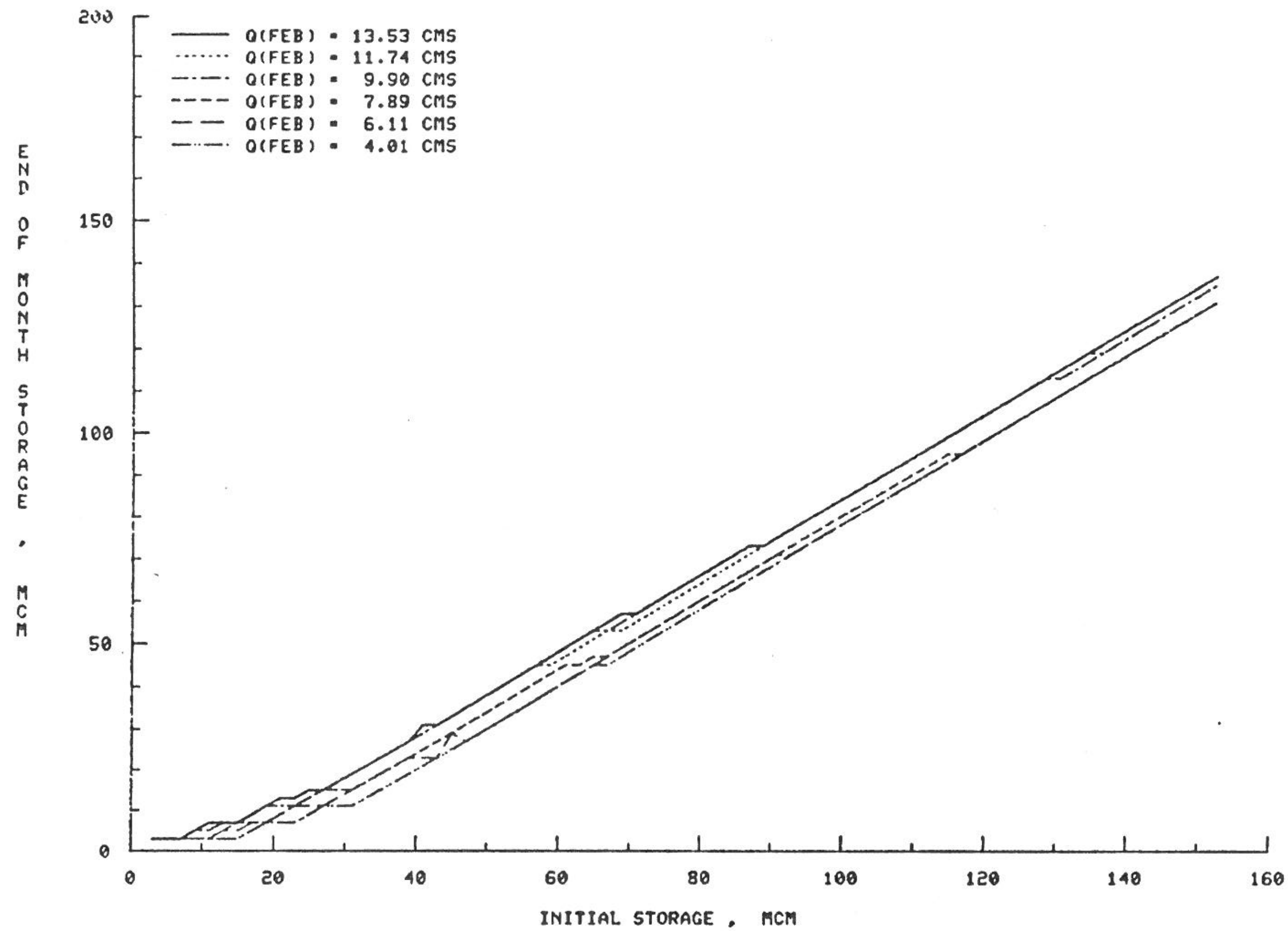


FIG 2.6.6 (A) OPERATION POLICY OF MARCH FOR Q(FEB) LESS THAN 14.52 CMS

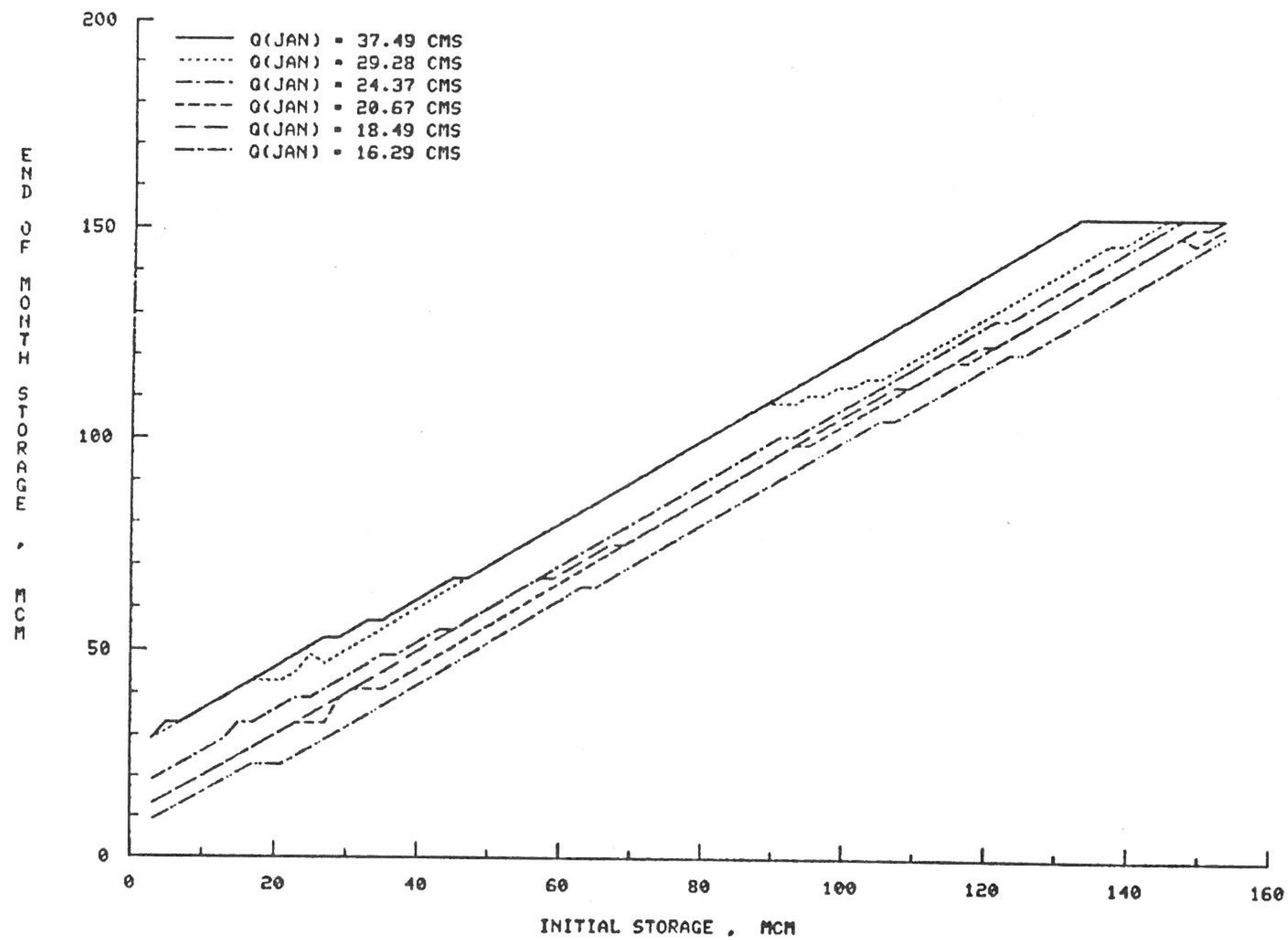


FIG 2.6.5 (B) OPERATION POLICY OF FEBRUARY FOR Q(JAN) GREATER THAN 15.30 CMS

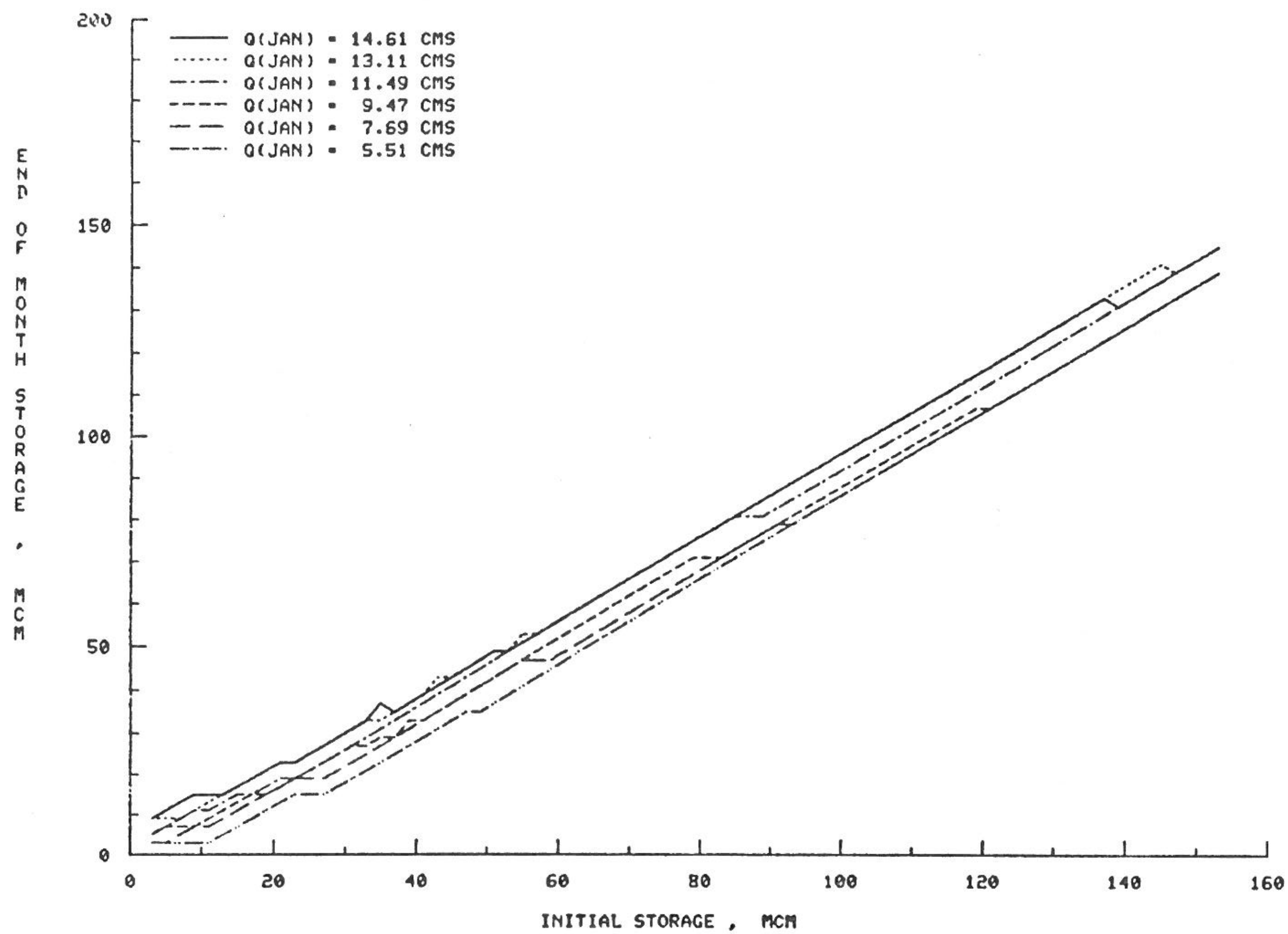


FIG 2.6.5 (A) OPERATION POLICY OF FEBRUARY FOR Q(JAN) LESS THAN 15.30 CMS

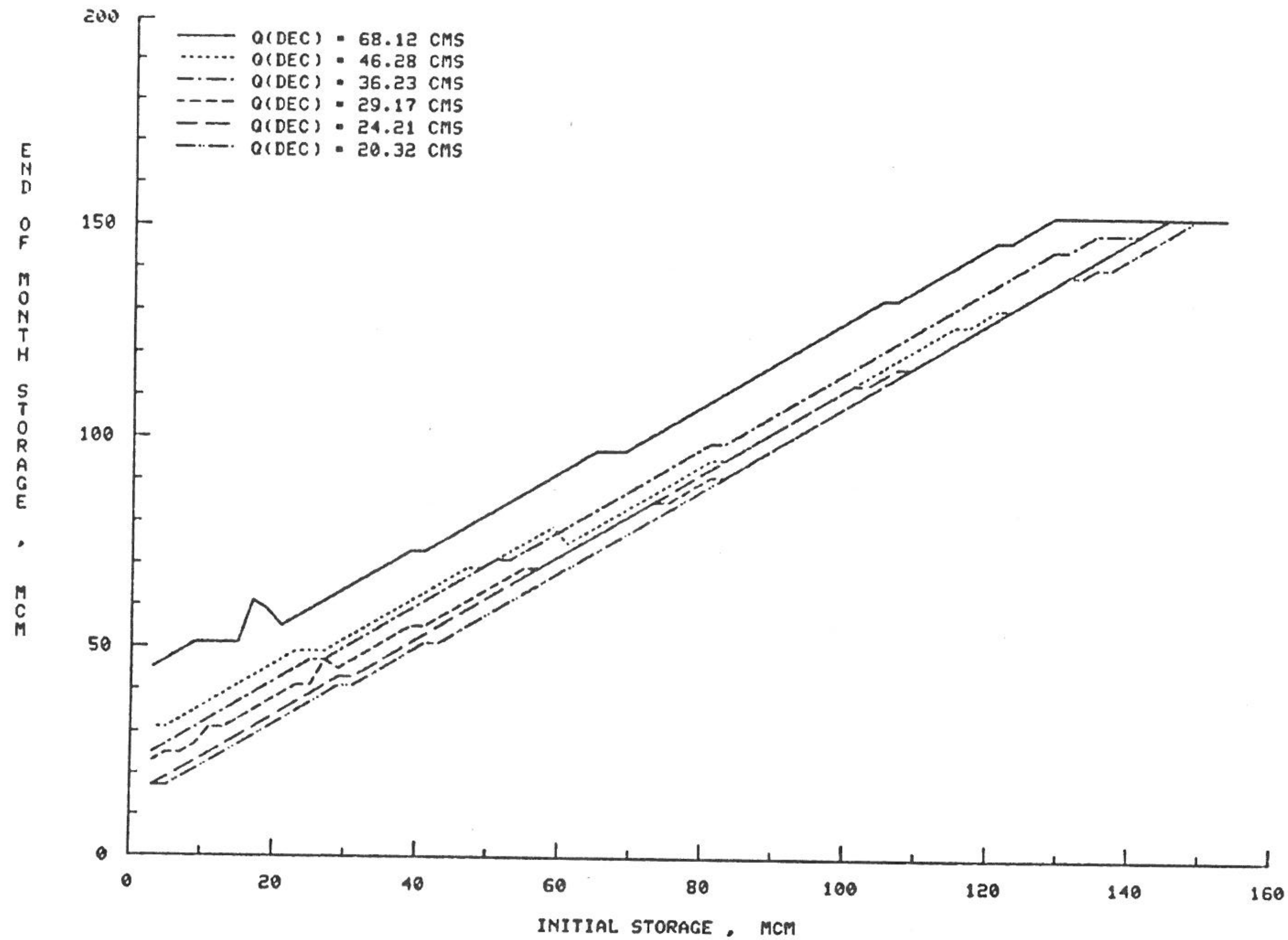


FIG 2.6.4 (B) OPERATION POLICY OF JANUARY FOR Q(DEC) GREATER THAN 18.74 CMS

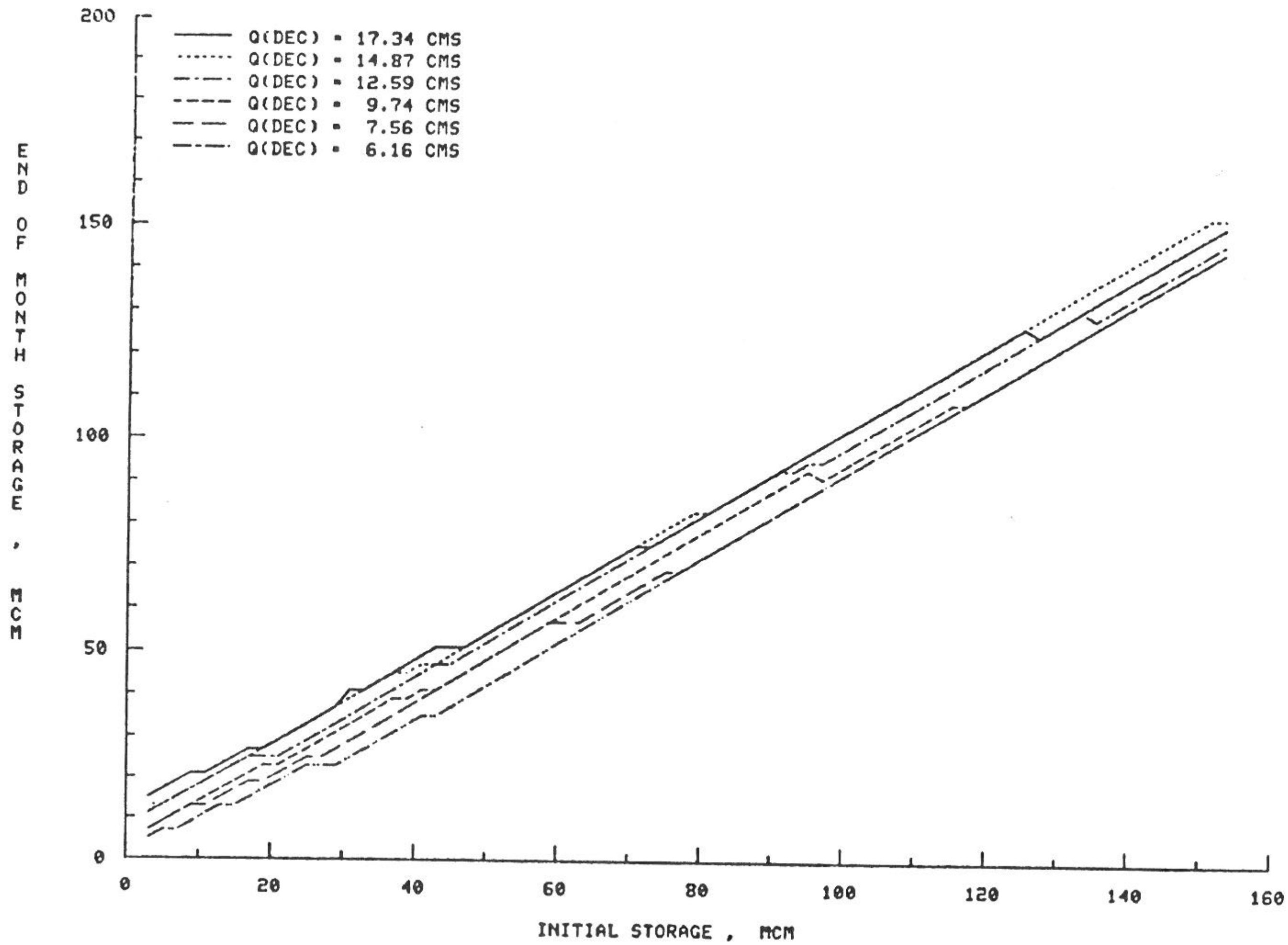


FIG 2.6.4 (A) OPERATION POLICY OF JANUARY FOR Q(DEC) LESS THAN 18.74 CMS

Table 2.6.3. Optimal Stationary Operation Policies for each Month , Inflow in CMS , Storage in MCM

(a) January

Previous Inflow limits	5.158	7.563	9.740	12.589	14.874	17.343	20.320	24.207	29.173	36.263	46.281	68.123
	6.9350	8.4200	10.654	12.370	13.890	15.300	17.510	19.441	22.240	27.220	31.829	
Initial	End-of-Month Target Storage											
3.	5.	7.	7.	11.	13.	15.	17.	17.	23.	25.	31.	45.
5.	7.	9.	9.	13.	13.	17.	17.	19.	25.	27.	31.	47.
7.	7.	11.	11.	15.	15.	19.	19.	21.	25.	29.	33.	49.
9.	9.	13.	13.	17.	17.	21.	21.	23.	27.	31.	35.	51.
11.	11.	13.	15.	19.	19.	21.	23.	25.	31.	33.	37.	51.
13.	13.	15.	17.	21.	21.	23.	25.	27.	31.	35.	39.	51.
15.	13.	17.	19.	23.	23.	25.	27.	29.	33.	37.	41.	51.
17.	15.	19.	21.	25.	25.	27.	29.	31.	35.	39.	43.	61.
19.	17.	19.	23.	25.	27.	27.	31.	33.	37.	41.	45.	59.
21.	19.	21.	23.	25.	29.	29.	33.	35.	39.	43.	47.	55.
23.	21.	23.	25.	27.	31.	31.	35.	37.	41.	45.	49.	57.
25.	23.	25.	27.	29.	33.	33.	37.	39.	41.	47.	49.	59.
27.	23.	25.	29.	31.	35.	35.	39.	41.	47.	47.	49.	61.
29.	23.	27.	31.	33.	37.	37.	41.	43.	45.	49.	51.	63.
31.	25.	29.	33.	35.	39.	41.	41.	43.	47.	51.	53.	65.
33.	27.	31.	35.	37.	41.	41.	43.	45.	49.	53.	55.	67.
35.	29.	33.	37.	39.	43.	43.	45.	47.	51.	55.	57.	69.
37.	31.	35.	39.	41.	45.	45.	47.	49.	53.	57.	59.	71.
39.	33.	37.	39.	43.	45.	47.	49.	51.	55.	59.	61.	73.
41.	35.	39.	41.	45.	47.	49.	51.	53.	55.	61.	63.	73.
43.	35.	41.	41.	47.	47.	51.	51.	55.	57.	63.	65.	75.
45.	37.	43.	43.	47.	49.	51.	53.	57.	59.	65.	67.	77.
47.	39.	45.	45.	49.	51.	51.	55.	59.	61.	67.	69.	79.
49.	41.	47.	47.	51.	53.	53.	57.	61.	63.	69.	69.	81.
51.	43.	49.	49.	53.	55.	55.	59.	63.	65.	71.	71.	83.
53.	45.	51.	51.	55.	57.	57.	61.	65.	67.	71.	73.	85.
55.	47.	53.	53.	57.	59.	59.	63.	67.	69.	73.	75.	87.
57.	49.	55.	55.	59.	61.	61.	65.	69.	69.	75.	77.	89.
59.	51.	57.	57.	61.	63.	63.	67.	71.	71.	77.	79.	91.
61.	53.	57.	59.	63.	65.	65.	69.	73.	73.	79.	75.	93.
63.	55.	57.	61.	65.	67.	67.	71.	75.	75.	81.	77.	95.
65.	57.	59.	63.	67.	69.	69.	73.	77.	77.	83.	79.	97.
67.	59.	61.	65.	69.	71.	71.	75.	79.	79.	85.	81.	97.
69.	61.	63.	67.	71.	73.	73.	77.	81.	81.	87.	83.	97.
71.	63.	65.	69.	73.	75.	75.	79.	83.	83.	89.	85.	99.
73.	65.	67.	71.	75.	77.	75.	81.	85.	85.	91.	87.	101.
75.	67.	69.	73.	77.	79.	77.	83.	87.	85.	93.	89.	103.
77.	69.	69.	75.	79.	81.	79.	85.	89.	87.	95.	91.	105.

79.	71.	71.	77.	81.	83.	81.	87.	91.	89.	97.	93.	107.
81.	73.	73.	79.	83.	83.	83.	89.	93.	91.	99.	95.	109.
83.	75.	75.	81.	85.	85.	85.	91.	95.	91.	99.	95.	111.
85.	77.	77.	83.	87.	87.	87.	93.	97.	93.	101.	97.	113.
87.	79.	79.	85.	89.	89.	89.	95.	99.	95.	103.	99.	115.
89.	81.	81.	87.	91.	91.	91.	97.	101.	97.	105.	101.	117.
91.	83.	83.	89.	93.	93.	93.	99.	103.	99.	107.	103.	119.
93.	85.	85.	91.	93.	95.	95.	101.	105.	101.	109.	105.	121.
95.	87.	87.	93.	95.	97.	97.	103.	107.	103.	111.	107.	123.
97.	89.	89.	91.	95.	99.	99.	105.	109.	105.	113.	109.	125.
99.	91.	91.	93.	97.	101.	101.	107.	111.	107.	115.	111.	127.
101.	93.	93.	95.	99.	103.	103.	109.	113.	109.	117.	113.	129.
103.	95.	95.	97.	101.	105.	105.	111.	113.	111.	119.	115.	131.
105.	97.	97.	99.	103.	107.	107.	113.	115.	113.	121.	117.	133.
107.	99.	99.	101.	105.	109.	109.	115.	117.	115.	123.	119.	133.
109.	101.	101.	103.	107.	111.	111.	117.	117.	117.	125.	121.	135.
111.	103.	103.	105.	109.	113.	113.	119.	119.	119.	127.	123.	137.
113.	105.	105.	107.	111.	115.	115.	121.	121.	121.	129.	125.	139.
115.	107.	107.	109.	113.	117.	117.	123.	123.	123.	131.	127.	141.
117.	109.	109.	109.	115.	119.	119.	125.	125.	125.	133.	127.	143.
119.	111.	111.	111.	117.	121.	121.	127.	127.	127.	135.	129.	145.
121.	113.	113.	113.	119.	123.	123.	129.	129.	129.	137.	131.	147.
123.	115.	115.	115.	121.	125.	125.	131.	131.	131.	139.	131.	147.
125.	117.	117.	117.	123.	127.	127.	133.	133.	133.	141.	133.	149.
127.	119.	119.	119.	125.	129.	125.	135.	135.	135.	143.	135.	151.
129.	121.	121.	121.	127.	131.	127.	137.	137.	137.	145.	137.	153.
131.	123.	123.	123.	129.	133.	129.	139.	139.	139.	145.	139.	153.
133.	125.	125.	125.	131.	135.	131.	139.	141.	141.	147.	141.	153.
135.	127.	127.	127.	129.	137.	133.	141.	143.	143.	149.	143.	153.
137.	129.	129.	129.	131.	139.	135.	141.	145.	145.	149.	145.	153.
139.	131.	131.	131.	133.	141.	137.	143.	147.	147.	149.	147.	153.
141.	133.	133.	133.	135.	143.	139.	145.	149.	149.	149.	149.	153.
143.	135.	135.	135.	137.	145.	141.	147.	151.	151.	151.	151.	153.
145.	137.	137.	137.	139.	147.	143.	149.	153.	153.	153.	153.	153.
147.	139.	139.	139.	141.	149.	145.	151.	153.	153.	153.	153.	153.
149.	141.	141.	141.	143.	151.	147.	153.	153.	153.	153.	153.	153.
151.	143.	143.	143.	145.	153.	149.	153.	153.	153.	153.	153.	153.
153.	145.	145.	145.	147.	153.	151.	153.	153.	153.	153.	153.	153.

Table 2.6.3. (Cont.)

(b) February

Previous Inflow	5.510	7.690	9.471	11.486	13.111	14.608	16.288	18.488	20.666	24.367	29.279	37.493
limits	5.2930	6.7930	8.8600	10.771	12.600	14.516	16.617	19.089	21.967	27.168	31.841	
Initial	End-of-Month Target Storage											
3.	3.	3.	5.	5.	9.	9.	9.	13.	13.	19.	29.	29.
5.	3.	3.	7.	7.	9.	11.	11.	15.	15.	21.	31.	33.
7.	3.	5.	7.	9.	9.	13.	13.	17.	17.	23.	33.	33.
9.	3.	7.	7.	11.	11.	15.	15.	19.	19.	25.	35.	35.
11.	3.	7.	9.	11.	13.	15.	17.	21.	21.	27.	37.	37.
13.	5.	9.	11.	13.	15.	15.	19.	23.	23.	29.	39.	39.
15.	7.	11.	13.	15.	17.	17.	21.	25.	25.	33.	41.	41.
17.	9.	13.	15.	15.	19.	19.	23.	27.	27.	33.	43.	43.
19.	11.	15.	15.	17.	21.	21.	23.	29.	29.	35.	43.	45.
21.	13.	17.	17.	19.	23.	23.	23.	31.	31.	37.	43.	47.
23.	15.	19.	19.	19.	23.	23.	25.	33.	33.	39.	45.	49.
25.	15.	19.	21.	21.	25.	25.	27.	35.	33.	39.	49.	51.
27.	15.	19.	23.	23.	27.	27.	29.	37.	33.	41.	47.	53.
29.	17.	21.	25.	25.	29.	29.	31.	39.	39.	43.	49.	53.
31.	19.	23.	27.	27.	31.	31.	33.	41.	41.	45.	51.	55.
33.	21.	25.	27.	29.	33.	33.	35.	43.	41.	47.	53.	57.
35.	23.	27.	29.	31.	33.	37.	37.	45.	41.	49.	55.	57.
37.	25.	29.	29.	33.	35.	35.	39.	47.	43.	49.	57.	59.
39.	27.	31.	33.	35.	37.	37.	41.	49.	45.	51.	59.	61.
41.	29.	33.	33.	37.	39.	39.	43.	51.	47.	53.	61.	63.
43.	31.	35.	35.	39.	43.	41.	45.	53.	49.	55.	63.	65.
45.	33.	37.	37.	41.	43.	43.	47.	55.	51.	55.	65.	67.
47.	35.	39.	39.	43.	45.	45.	49.	57.	53.	57.	67.	67.
49.	35.	41.	41.	45.	47.	47.	51.	59.	55.	59.	69.	69.
51.	37.	43.	43.	47.	49.	49.	53.	61.	57.	61.	71.	71.
53.	39.	45.	45.	49.	49.	49.	55.	63.	59.	63.	73.	73.
55.	41.	47.	47.	51.	53.	51.	57.	65.	61.	65.	75.	75.
57.	43.	47.	49.	53.	53.	53.	59.	67.	63.	67.	77.	77.
59.	45.	47.	51.	55.	55.	55.	61.	67.	65.	69.	79.	79.
61.	47.	49.	53.	57.	57.	57.	63.	69.	67.	71.	81.	81.
63.	49.	51.	55.	59.	59.	59.	65.	71.	69.	73.	83.	83.
65.	51.	53.	57.	61.	61.	61.	65.	73.	71.	75.	85.	85.
67.	53.	55.	59.	63.	63.	63.	67.	75.	73.	77.	87.	87.
69.	55.	57.	61.	65.	65.	65.	69.	75.	75.	79.	89.	89.
71.	57.	59.	63.	67.	67.	67.	71.	77.	77.	81.	91.	91.
73.	59.	61.	65.	69.	69.	69.	73.	79.	79.	83.	93.	93.
75.	61.	63.	67.	71.	71.	71.	75.	81.	81.	85.	95.	95.
77.	63.	65.	69.	73.	73.	73.	77.	83.	83.	87.	97.	97.
79.	65.	67.	71.	75.	75.	75.	79.	85.	85.	89.	99.	99.

81.	67.	69.	71.	77.	77.	77.	81.	87.	87.	91.	101.	101.
83.	69.	71.	71.	79.	79.	79.	83.	89.	89.	93.	103.	103.
85.	71.	73.	73.	81.	81.	81.	85.	91.	91.	95.	105.	105.
87.	73.	75.	75.	81.	83.	83.	87.	93.	93.	97.	107.	107.
89.	75.	77.	77.	81.	85.	85.	89.	95.	95.	99.	109.	109.
91.	77.	79.	79.	83.	87.	87.	91.	97.	97.	101.	109.	111.
93.	79.	79.	81.	85.	89.	89.	93.	99.	99.	101.	109.	113.
95.	81.	81.	83.	87.	91.	91.	95.	101.	99.	103.	111.	115.
97.	83.	83.	85.	89.	93.	93.	97.	103.	101.	105.	111.	117.
99.	85.	85.	87.	91.	95.	95.	99.	105.	103.	107.	113.	119.
101.	87.	87.	89.	93.	97.	97.	101.	107.	105.	109.	113.	121.
103.	89.	89.	91.	95.	99.	99.	103.	109.	107.	111.	115.	123.
105.	91.	91.	93.	97.	101.	101.	105.	111.	109.	113.	115.	125.
107.	93.	93.	95.	99.	103.	103.	105.	113.	111.	115.	117.	127.
109.	95.	95.	97.	101.	105.	105.	107.	113.	113.	117.	119.	129.
111.	97.	97.	99.	103.	107.	107.	109.	115.	115.	119.	121.	131.
113.	99.	99.	101.	105.	109.	109.	111.	117.	117.	121.	123.	133.
115.	101.	101.	103.	107.	111.	111.	113.	119.	119.	123.	125.	135.
117.	103.	103.	105.	109.	113.	113.	115.	121.	119.	125.	127.	137.
119.	105.	105.	107.	111.	115.	115.	117.	123.	121.	127.	129.	139.
121.	107.	107.	107.	113.	117.	117.	119.	123.	123.	129.	131.	141.
123.	109.	109.	109.	115.	119.	119.	121.	125.	125.	129.	133.	143.
125.	111.	111.	111.	117.	121.	121.	121.	127.	127.	131.	135.	145.
127.	113.	113.	113.	119.	123.	123.	123.	129.	129.	133.	137.	147.
129.	115.	115.	115.	121.	125.	125.	125.	131.	131.	135.	139.	149.
131.	117.	117.	117.	123.	127.	127.	127.	133.	133.	137.	141.	151.
133.	119.	119.	119.	125.	129.	129.	129.	135.	135.	139.	143.	153.
135.	121.	121.	121.	127.	131.	131.	131.	137.	137.	141.	145.	153.
137.	123.	123.	123.	129.	133.	133.	133.	139.	139.	143.	147.	153.
139.	125.	125.	125.	131.	135.	131.	135.	141.	141.	145.	147.	153.
141.	127.	127.	127.	133.	137.	133.	137.	143.	143.	147.	149.	153.
143.	129.	129.	129.	135.	139.	135.	139.	145.	145.	149.	151.	153.
145.	131.	131.	131.	137.	141.	137.	141.	147.	147.	151.	153.	153.
147.	133.	133.	133.	139.	139.	139.	143.	149.	149.	153.	153.	153.
149.	135.	135.	135.	141.	141.	141.	145.	151.	147.	153.	153.	153.
151.	137.	137.	137.	143.	143.	143.	147.	151.	149.	153.	153.	153.
153.	139.	139.	139.	145.	145.	145.	149.	153.	151.	153.	153.	153.

Table 2.6.3. (Cont.)

(c) March

Previous Inflow limits	4.009	6.111	7.889	9.897	11.740	13.528	15.542	17.757	20.398	24.194	29.196	38.625
	5.1490	6.1740	8.0050	9.5120	11.034	12.925	14.606	16.387	19.218	24.387	28.491	
Initial	End-of-Month Target Storage											
3.	3.	3.	3.	3.	3.	3.	3.	3.	5.	9.	9.	19.
5.	3.	3.	3.	3.	3.	3.	3.	5.	7.	11.	11.	21.
7.	3.	3.	3.	3.	3.	3.	5.	5.	7.	13.	13.	23.
9.	3.	3.	3.	5.	5.	5.	5.	7.	9.	15.	15.	25.
11.	3.	3.	3.	5.	7.	7.	7.	7.	11.	17.	17.	27.
13.	3.	5.	5.	7.	7.	7.	7.	9.	13.	19.	19.	29.
15.	3.	5.	7.	7.	7.	7.	9.	11.	13.	19.	21.	31.
17.	5.	7.	7.	9.	9.	9.	11.	13.	15.	21.	23.	33.
19.	7.	7.	7.	11.	11.	11.	11.	15.	17.	23.	25.	35.
21.	7.	9.	9.	11.	11.	13.	13.	17.	17.	25.	27.	37.
23.	7.	11.	11.	11.	11.	13.	15.	19.	19.	27.	29.	39.
25.	9.	11.	13.	13.	13.	15.	17.	21.	21.	29.	31.	41.
27.	11.	11.	15.	15.	15.	15.	19.	23.	23.	31.	33.	43.
29.	11.	13.	15.	17.	17.	17.	21.	23.	25.	33.	35.	45.
31.	11.	15.	15.	19.	19.	19.	23.	25.	27.	35.	37.	47.
33.	13.	17.	17.	21.	21.	21.	25.	27.	29.	39.	39.	49.
35.	15.	19.	19.	23.	23.	23.	27.	29.	31.	39.	41.	47.
37.	17.	21.	21.	25.	25.	25.	29.	31.	35.	39.	43.	49.
39.	19.	23.	23.	27.	27.	27.	31.	33.	35.	41.	45.	49.
41.	21.	23.	25.	29.	29.	31.	33.	37.	37.	43.	47.	51.
43.	23.	23.	27.	31.	31.	31.	35.	39.	39.	45.	49.	51.
45.	25.	29.	29.	33.	33.	33.	37.	39.	41.	47.	51.	51.
47.	27.	27.	31.	35.	35.	35.	39.	41.	43.	49.	53.	53.
49.	29.	29.	33.	37.	37.	37.	41.	41.	45.	51.	55.	55.
51.	31.	31.	35.	39.	39.	39.	43.	43.	47.	53.	57.	57.
53.	33.	33.	37.	41.	41.	41.	45.	45.	47.	53.	57.	59.
55.	35.	35.	39.	43.	43.	43.	45.	47.	49.	55.	59.	61.
57.	37.	37.	41.	45.	45.	45.	47.	49.	49.	57.	61.	63.
59.	39.	39.	43.	47.	45.	47.	47.	51.	51.	59.	63.	65.
61.	41.	41.	45.	49.	47.	49.	49.	53.	53.	61.	65.	67.
63.	43.	43.	45.	51.	49.	51.	51.	55.	55.	63.	67.	69.
65.	45.	45.	47.	53.	51.	53.	53.	57.	57.	65.	69.	71.
67.	45.	47.	47.	53.	53.	55.	55.	59.	59.	67.	71.	73.
69.	47.	49.	49.	55.	53.	57.	57.	61.	61.	69.	73.	75.
71.	49.	51.	51.	57.	55.	57.	59.	63.	63.	71.	75.	77.
73.	51.	53.	53.	59.	57.	59.	61.	65.	65.	73.	77.	79.
75.	53.	55.	55.	61.	59.	61.	63.	67.	67.	75.	79.	81.
77.	55.	57.	57.	63.	61.	63.	65.	69.	69.	77.	81.	83.
79.	57.	59.	59.	65.	63.	65.	67.	71.	71.	79.	83.	85.

81.	59.	61.	61.	67.	65.	67.	69.	73.	73.	81.	85.	87.
83.	61.	63.	63.	69.	67.	69.	71.	75.	75.	83.	87.	89.
85.	63.	65.	65.	71.	69.	71.	73.	77.	77.	85.	89.	91.
87.	65.	67.	67.	73.	71.	73.	75.	79.	79.	87.	91.	93.
89.	67.	69.	69.	73.	73.	73.	77.	81.	81.	89.	93.	95.
91.	69.	71.	71.	75.	75.	75.	79.	83.	83.	91.	95.	97.
93.	71.	71.	73.	77.	77.	77.	81.	85.	85.	93.	97.	99.
95.	73.	73.	75.	79.	79.	79.	83.	87.	87.	95.	97.	101.
97.	75.	75.	77.	81.	81.	81.	85.	89.	89.	97.	99.	103.
99.	77.	77.	79.	83.	83.	83.	87.	91.	91.	99.	101.	105.
101.	79.	79.	81.	85.	85.	85.	89.	93.	93.	101.	103.	107.
103.	81.	81.	83.	87.	87.	87.	91.	95.	95.	103.	105.	109.
105.	83.	83.	85.	89.	89.	89.	93.	97.	97.	105.	107.	111.
107.	85.	85.	87.	91.	91.	91.	95.	99.	99.	107.	109.	113.
109.	87.	87.	89.	93.	93.	93.	97.	101.	101.	109.	111.	113.
111.	89.	89.	91.	95.	95.	95.	99.	103.	103.	111.	113.	115.
113.	91.	91.	93.	97.	97.	97.	101.	105.	105.	113.	115.	117.
115.	93.	93.	95.	99.	99.	99.	103.	107.	107.	111.	117.	119.
117.	95.	95.	95.	101.	101.	101.	105.	109.	109.	113.	119.	121.
119.	97.	97.	97.	103.	103.	103.	107.	111.	111.	115.	121.	123.
121.	99.	99.	99.	105.	105.	105.	109.	113.	111.	117.	123.	125.
123.	101.	101.	101.	107.	107.	107.	111.	115.	111.	115.	123.	127.
125.	103.	103.	103.	109.	109.	109.	113.	117.	113.	117.	125.	129.
127.	105.	105.	105.	111.	111.	111.	115.	117.	115.	119.	127.	131.
129.	107.	107.	107.	113.	113.	113.	117.	117.	117.	121.	129.	133.
131.	109.	109.	109.	113.	115.	115.	117.	119.	119.	123.	131.	135.
133.	111.	111.	111.	115.	117.	117.	119.	121.	121.	125.	133.	137.
135.	113.	113.	113.	117.	119.	119.	121.	123.	123.	127.	135.	139.
137.	115.	115.	115.	119.	119.	121.	123.	125.	125.	129.	137.	141.
139.	117.	117.	117.	121.	121.	123.	125.	127.	127.	131.	139.	143.
141.	119.	119.	119.	123.	123.	125.	127.	129.	129.	133.	141.	145.
143.	121.	121.	121.	125.	125.	127.	129.	131.	131.	135.	143.	147.
145.	123.	123.	123.	127.	127.	129.	131.	133.	133.	137.	145.	149.
147.	125.	125.	125.	129.	129.	131.	133.	135.	135.	139.	147.	151.
149.	127.	127.	127.	131.	131.	133.	135.	137.	137.	141.	149.	153.
151.	129.	129.	129.	133.	133.	135.	137.	139.	139.	143.	151.	153.
153.	131.	131.	131.	135.	135.	137.	139.	141.	141.	145.	153.	153.

Table 2.6.3. (Cont.)

(d) April

Previous Inflow limits	3.973 / 5.3470	5.711 / 6.5040	7.166 / 8.2510	8.812 / 9.6860	10.275 / 11.035	12.016 / 12.284	13.763 / 13.846	15.501 / 15.650	17.678 / 18.196	21.527 / 22.292	26.341 / 26.061	34.457
Initial	End-of-Month Target Storage											
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	5.	9.	19.
5.	3.	3.	3.	3.	3.	3.	3.	5.	3.	7.	11.	21.
7.	3.	3.	3.	3.	3.	3.	3.	7.	3.	9.	13.	23.
9.	3.	3.	3.	3.	3.	3.	5.	7.	5.	9.	15.	25.
11.	3.	3.	3.	3.	3.	3.	7.	9.	7.	11.	17.	27.
13.	3.	3.	5.	5.	5.	5.	9.	11.	9.	13.	19.	29.
15.	3.	3.	7.	7.	7.	7.	11.	13.	11.	15.	21.	31.
17.	3.	5.	7.	9.	9.	9.	13.	15.	13.	17.	25.	31.
19.	3.	7.	7.	11.	11.	11.	15.	17.	15.	19.	25.	31.
21.	5.	9.	9.	13.	13.	13.	17.	19.	17.	21.	27.	33.
23.	7.	11.	11.	15.	15.	15.	19.	21.	19.	23.	29.	35.
25.	9.	13.	13.	17.	17.	17.	21.	23.	21.	25.	31.	37.
27.	11.	15.	15.	19.	19.	19.	23.	25.	23.	27.	33.	39.
29.	13.	17.	17.	21.	21.	21.	25.	27.	25.	29.	35.	43.
31.	15.	19.	19.	23.	23.	23.	27.	29.	27.	31.	37.	41.
33.	17.	21.	21.	25.	23.	25.	29.	31.	29.	31.	39.	43.
35.	19.	23.	23.	27.	27.	27.	31.	33.	31.	37.	41.	45.
37.	21.	25.	25.	29.	27.	29.	33.	35.	35.	35.	43.	47.
39.	23.	27.	27.	31.	29.	31.	35.	35.	35.	35.	45.	49.
41.	25.	29.	29.	33.	31.	33.	35.	37.	37.	37.	47.	51.
43.	27.	29.	31.	35.	35.	35.	35.	39.	39.	39.	49.	53.
45.	29.	29.	33.	37.	35.	37.	37.	41.	41.	41.	51.	55.
47.	31.	31.	35.	39.	35.	39.	39.	43.	43.	43.	53.	57.
49.	33.	35.	37.	39.	37.	41.	41.	45.	45.	45.	55.	59.
51.	35.	35.	39.	41.	39.	43.	43.	47.	47.	47.	57.	61.
53.	37.	37.	41.	43.	41.	45.	45.	49.	49.	49.	59.	63.
55.	39.	39.	43.	45.	43.	47.	47.	51.	51.	51.	61.	65.
57.	41.	41.	45.	45.	45.	49.	49.	53.	53.	53.	63.	67.
59.	43.	43.	47.	47.	47.	49.	51.	55.	55.	55.	65.	69.
61.	45.	45.	45.	49.	49.	51.	53.	57.	57.	57.	67.	71.
63.	47.	47.	47.	51.	51.	53.	55.	59.	59.	59.	69.	73.
65.	49.	49.	49.	53.	53.	55.	57.	61.	61.	61.	71.	75.
67.	51.	51.	51.	55.	55.	57.	59.	63.	63.	63.	73.	77.
69.	53.	53.	53.	57.	57.	57.	61.	61.	65.	65.	75.	79.
71.	55.	55.	55.	59.	59.	59.	63.	63.	67.	67.	77.	81.
73.	57.	57.	57.	61.	61.	61.	65.	65.	69.	69.	79.	83.
75.	59.	59.	59.	63.	63.	63.	67.	67.	71.	71.	81.	85.
77.	61.	61.	61.	65.	65.	65.	69.	69.	73.	73.	83.	87.
79.	63.	63.	63.	67.	67.	67.	71.	71.	75.	75.	85.	89.

81.	65.	65.	65.	69.	69.	69.	73.	73.	77.	77.	87.	91.
83.	67.	67.	67.	71.	71.	71.	75.	75.	79.	79.	89.	93.
85.	69.	69.	69.	73.	73.	73.	77.	77.	81.	79.	91.	95.
87.	71.	71.	71.	75.	75.	75.	79.	79.	83.	81.	93.	97.
89.	73.	73.	73.	77.	77.	77.	81.	81.	85.	81.	95.	99.
91.	75.	75.	75.	79.	79.	79.	83.	83.	87.	83.	97.	101.
93.	77.	77.	77.	81.	81.	81.	85.	85.	89.	85.	99.	103.
95.	79.	79.	79.	83.	83.	83.	87.	87.	91.	87.	101.	105.
97.	81.	81.	81.	85.	85.	85.	89.	89.	93.	89.	103.	107.
99.	83.	83.	83.	87.	87.	87.	91.	91.	93.	91.	105.	109.
101.	85.	85.	85.	89.	89.	89.	93.	93.	95.	93.	107.	111.
103.	87.	87.	87.	91.	87.	91.	93.	95.	97.	95.	109.	113.
105.	89.	89.	89.	93.	89.	93.	95.	97.	99.	97.	111.	115.
107.	91.	91.	91.	95.	91.	95.	97.	99.	101.	99.	113.	117.
109.	93.	93.	93.	97.	93.	97.	99.	101.	103.	101.	115.	119.
111.	95.	95.	95.	99.	95.	99.	99.	103.	105.	103.	117.	121.
113.	97.	97.	97.	101.	97.	101.	101.	105.	107.	105.	119.	123.
115.	99.	99.	99.	103.	99.	103.	103.	107.	109.	107.	121.	125.
117.	101.	101.	101.	105.	101.	105.	105.	109.	109.	109.	123.	127.
119.	103.	103.	103.	107.	103.	107.	107.	111.	111.	111.	125.	129.
121.	105.	105.	105.	109.	105.	109.	109.	113.	113.	113.	127.	131.
123.	107.	107.	107.	111.	107.	107.	111.	115.	115.	115.	129.	133.
125.	109.	109.	109.	113.	109.	109.	113.	117.	117.	117.	131.	135.
127.	109.	111.	111.	115.	111.	111.	115.	119.	119.	119.	133.	137.
129.	111.	113.	113.	117.	113.	113.	117.	121.	121.	121.	135.	139.
131.	113.	115.	115.	119.	115.	115.	119.	123.	123.	123.	137.	141.
133.	115.	117.	117.	121.	117.	117.	121.	125.	125.	123.	139.	143.
135.	117.	119.	119.	123.	119.	119.	123.	125.	127.	123.	141.	145.
137.	119.	121.	121.	125.	121.	121.	125.	127.	129.	125.	139.	147.
139.	121.	123.	123.	127.	123.	123.	127.	129.	131.	127.	141.	149.
141.	123.	125.	125.	129.	125.	125.	129.	131.	133.	129.	143.	151.
143.	125.	127.	127.	131.	127.	127.	131.	131.	135.	131.	145.	153.
145.	127.	129.	129.	131.	129.	129.	133.	133.	137.	131.	147.	153.
147.	129.	131.	131.	131.	131.	131.	135.	135.	139.	131.	149.	149.
149.	131.	133.	133.	133.	133.	133.	137.	137.	141.	133.	151.	151.
151.	133.	135.	135.	135.	135.	135.	139.	139.	143.	135.	153.	153.
153.	135.	137.	137.	137.	137.	137.	141.	141.	143.	137.	153.	153.

Table 2.6.3. (Cont.)

(e) May

Previous Inflow limits	4.351	5.956	7.418	8.974	10.322	11.737	13.075	14.619	16.921	20.014	23.931	30.353
	5.3660	6.8950	9.9660	13.533	16.773	20.087	24.552	29.811	38.052	50.282	63.229	
Initial	End-of-Month Target Storage											
3.	3.	3.	5.	5.	7.	7.	7.	15.	15.	31.	31.	43.
5.	3.	3.	5.	7.	9.	9.	9.	17.	17.	31.	31.	45.
7.	3.	5.	5.	9.	11.	11.	11.	19.	19.	31.	31.	47.
9.	5.	7.	7.	11.	11.	13.	13.	21.	21.	31.	31.	49.
11.	7.	7.	9.	13.	13.	15.	15.	23.	23.	33.	33.	51.
13.	7.	9.	11.	15.	15.	17.	17.	25.	25.	35.	35.	53.
15.	7.	11.	13.	17.	17.	19.	19.	27.	27.	37.	37.	65.
17.	9.	13.	13.	19.	19.	21.	21.	31.	29.	39.	39.	61.
19.	11.	15.	15.	21.	21.	23.	23.	31.	31.	41.	39.	59.
21.	13.	17.	17.	23.	23.	25.	25.	33.	33.	43.	41.	61.
23.	15.	19.	19.	23.	25.	27.	27.	35.	35.	45.	53.	63.
25.	17.	21.	21.	27.	27.	29.	29.	37.	37.	49.	49.	65.
27.	19.	21.	23.	27.	31.	31.	31.	39.	39.	49.	47.	67.
29.	21.	21.	25.	31.	31.	33.	33.	43.	43.	51.	49.	69.
31.	23.	23.	27.	31.	35.	35.	35.	43.	43.	53.	51.	71.
33.	25.	25.	29.	31.	35.	39.	39.	45.	45.	55.	53.	73.
35.	27.	27.	31.	37.	37.	39.	39.	47.	47.	55.	51.	75.
37.	29.	29.	35.	35.	39.	41.	41.	49.	49.	57.	53.	77.
39.	31.	33.	35.	37.	41.	43.	43.	51.	51.	59.	53.	79.
41.	33.	33.	37.	39.	43.	45.	45.	53.	53.	61.	55.	81.
43.	35.	35.	39.	41.	45.	47.	47.	55.	55.	63.	57.	83.
45.	37.	37.	41.	43.	47.	49.	49.	57.	57.	65.	59.	85.
47.	39.	39.	43.	45.	49.	51.	51.	59.	59.	67.	61.	87.
49.	41.	41.	45.	47.	51.	53.	53.	61.	61.	67.	63.	89.
51.	43.	43.	47.	49.	53.	55.	55.	63.	63.	67.	65.	91.
53.	45.	45.	49.	51.	55.	57.	57.	65.	65.	67.	67.	93.
55.	47.	47.	51.	53.	57.	59.	59.	67.	67.	69.	67.	95.
57.	49.	49.	53.	55.	59.	61.	61.	67.	69.	71.	69.	97.
59.	51.	51.	55.	57.	61.	61.	63.	69.	71.	73.	71.	99.
61.	53.	53.	57.	59.	61.	63.	65.	71.	73.	75.	73.	101.
63.	55.	55.	55.	61.	63.	65.	67.	71.	75.	77.	75.	103.
65.	57.	57.	57.	63.	65.	67.	69.	73.	77.	79.	77.	105.
67.	59.	59.	59.	65.	67.	69.	71.	73.	79.	81.	79.	107.
69.	61.	61.	61.	67.	67.	71.	73.	73.	79.	83.	81.	109.
71.	63.	63.	63.	69.	69.	73.	75.	75.	81.	85.	83.	111.
73.	65.	65.	65.	69.	71.	75.	77.	77.	83.	87.	85.	113.
75.	67.	67.	67.	71.	73.	77.	79.	79.	85.	89.	87.	115.
77.	69.	69.	69.	73.	75.	79.	81.	81.	87.	91.	89.	117.
79.	71.	71.	71.	75.	77.	81.	83.	83.	89.	91.	91.	119.

81.	73.	73.	73.	77.	79.	81.	85.	85.	89.	93.	93.	121.
83.	75.	75.	75.	79.	81.	83.	87.	87.	89.	95.	95.	123.
85.	77.	77.	77.	81.	83.	85.	89.	89.	91.	97.	97.	125.
87.	79.	79.	79.	83.	85.	85.	91.	91.	91.	99.	99.	127.
89.	81.	81.	81.	81.	87.	87.	93.	93.	93.	101.	101.	129.
91.	83.	83.	83.	83.	89.	89.	95.	95.	95.	103.	103.	131.
93.	85.	85.	85.	85.	91.	91.	97.	97.	97.	105.	105.	133.
95.	87.	87.	87.	87.	93.	93.	99.	99.	99.	107.	107.	135.
97.	89.	89.	89.	89.	95.	95.	101.	101.	101.	109.	109.	137.
99.	91.	91.	91.	91.	97.	97.	103.	103.	103.	111.	111.	139.
101.	93.	93.	93.	93.	97.	99.	105.	105.	105.	113.	113.	141.
103.	95.	95.	95.	95.	99.	101.	107.	107.	107.	115.	115.	143.
105.	97.	97.	97.	97.	97.	103.	109.	109.	105.	117.	117.	145.
107.	99.	99.	99.	99.	99.	105.	111.	111.	107.	119.	119.	147.
109.	101.	101.	101.	101.	101.	107.	113.	113.	109.	121.	121.	149.
111.	103.	103.	103.	103.	103.	109.	115.	115.	109.	123.	123.	151.
113.	105.	105.	105.	105.	105.	111.	117.	117.	111.	125.	125.	153.
115.	107.	107.	107.	107.	107.	113.	119.	119.	113.	127.	127.	153.
117.	109.	109.	109.	109.	109.	115.	117.	121.	115.	129.	129.	153.
119.	111.	111.	111.	111.	111.	117.	119.	123.	117.	131.	131.	153.
121.	113.	113.	113.	113.	113.	119.	121.	125.	119.	133.	133.	153.
123.	115.	115.	115.	115.	115.	121.	123.	127.	121.	135.	135.	153.
125.	117.	117.	117.	117.	117.	123.	123.	129.	123.	137.	137.	153.
127.	119.	119.	119.	119.	119.	125.	125.	127.	125.	139.	139.	153.
129.	121.	121.	121.	121.	121.	125.	127.	129.	127.	141.	141.	153.
131.	123.	123.	123.	123.	123.	123.	129.	131.	129.	143.	143.	153.
133.	125.	125.	125.	125.	125.	125.	131.	131.	129.	145.	145.	153.
135.	127.	127.	127.	127.	127.	127.	133.	133.	129.	147.	147.	153.
137.	129.	129.	129.	129.	129.	129.	135.	135.	129.	149.	149.	153.
139.	131.	131.	131.	131.	131.	131.	137.	137.	131.	151.	151.	153.
141.	133.	133.	133.	133.	133.	133.	139.	139.	133.	153.	153.	153.
143.	135.	135.	135.	135.	135.	135.	141.	141.	135.	153.	153.	153.
145.	137.	137.	137.	137.	137.	137.	143.	143.	137.	153.	153.	153.
147.	139.	139.	139.	139.	139.	139.	145.	145.	139.	153.	153.	153.
149.	141.	141.	141.	141.	141.	141.	147.	147.	141.	153.	153.	153.
151.	143.	143.	143.	143.	143.	143.	149.	149.	143.	153.	153.	153.
153.	145.	145.	145.	145.	145.	145.	151.	151.	145.	153.	153.	153.

Table 2.6.3. (Cont.)

(f) June

Previous Inflow limits: 4.024 6.182 8.484 11.781 15.218 18.337 22.153 27.156 33.337 43.358 55.936 83.589

5.5670 7.1740 10.138 12.898 16.113 19.859 24.962 31.513 39.128 53.552 67.877

Initial	End-of-Month Target Storage											
3.	3.	5.	5.	5.	5.	11.	13.	13.	19.	29.	55.	41.
5.	3.	5.	7.	7.	7.	13.	15.	15.	21.	31.	57.	43.
7.	3.	5.	7.	9.	9.	15.	17.	17.	23.	33.	59.	45.
9.	5.	7.	7.	11.	11.	17.	19.	19.	25.	35.	61.	47.
11.	7.	7.	9.	13.	13.	19.	21.	21.	25.	37.	63.	49.
13.	9.	9.	9.	15.	15.	21.	23.	23.	29.	39.	65.	51.
15.	9.	11.	11.	15.	17.	25.	25.	25.	31.	41.	67.	53.
17.	9.	13.	13.	15.	19.	25.	27.	27.	31.	43.	69.	61.
19.	11.	13.	15.	17.	21.	29.	29.	29.	31.	43.	71.	59.
21.	13.	13.	17.	19.	23.	31.	31.	31.	31.	43.	69.	59.
23.	13.	15.	19.	21.	25.	31.	33.	33.	33.	43.	71.	61.
25.	15.	17.	21.	23.	27.	35.	35.	35.	35.	49.	65.	63.
27.	17.	19.	23.	25.	29.	37.	37.	37.	37.	47.	67.	65.
29.	19.	21.	25.	27.	31.	37.	39.	37.	43.	47.	69.	67.
31.	21.	23.	27.	29.	33.	41.	41.	41.	41.	49.	71.	69.
33.	23.	25.	29.	31.	35.	39.	39.	39.	43.	51.	73.	71.
35.	25.	25.	31.	37.	37.	39.	39.	39.	45.	53.	75.	71.
37.	27.	29.	33.	35.	39.	41.	41.	41.	47.	55.	77.	71.
39.	29.	29.	35.	37.	41.	43.	43.	43.	49.	51.	79.	71.
41.	31.	31.	37.	39.	43.	45.	45.	45.	51.	53.	81.	71.
43.	33.	35.	39.	41.	45.	47.	47.	47.	53.	55.	83.	71.
45.	35.	37.	37.	43.	47.	49.	49.	49.	55.	57.	83.	73.
47.	37.	39.	39.	45.	49.	51.	51.	51.	57.	59.	85.	75.
49.	39.	39.	41.	47.	51.	53.	53.	53.	59.	61.	89.	77.
51.	41.	43.	43.	49.	53.	55.	55.	55.	61.	63.	89.	79.
53.	43.	43.	45.	51.	55.	57.	57.	57.	63.	65.	91.	81.
55.	45.	45.	47.	51.	57.	59.	59.	59.	65.	67.	93.	83.
57.	47.	47.	49.	53.	59.	61.	61.	61.	67.	69.	95.	85.
59.	49.	49.	51.	55.	61.	63.	63.	63.	69.	71.	97.	87.
61.	51.	51.	53.	57.	63.	65.	65.	65.	71.	71.	99.	89.
63.	53.	53.	55.	59.	65.	67.	67.	67.	73.	73.	101.	91.
65.	55.	55.	57.	61.	67.	69.	69.	69.	75.	75.	103.	93.
67.	57.	57.	59.	63.	69.	71.	71.	71.	77.	77.	105.	95.
69.	59.	59.	61.	65.	71.	73.	73.	73.	79.	79.	107.	97.
71.	61.	61.	63.	67.	73.	75.	75.	75.	81.	81.	109.	99.
73.	63.	63.	65.	69.	71.	77.	77.	77.	83.	83.	111.	99.
75.	65.	65.	67.	71.	73.	77.	79.	79.	81.	85.	113.	103.
77.	67.	67.	69.	73.	75.	79.	81.	81.	83.	87.	115.	105.
79.	69.	69.	71.	75.	77.	81.	83.	83.	83.	89.	117.	105.

81.	71.	71.	73.	77.	79.	83.	85.	85.	85.	91.	119.	109.
83.	73.	73.	75.	79.	81.	85.	87.	87.	87.	93.	121.	109.
85.	75.	75.	77.	81.	83.	87.	89.	89.	89.	95.	123.	111.
87.	77.	77.	79.	83.	85.	89.	91.	91.	91.	97.	125.	113.
89.	79.	79.	81.	85.	87.	89.	93.	93.	93.	99.	127.	115.
91.	81.	81.	83.	87.	89.	91.	95.	95.	95.	101.	129.	117.
93.	83.	83.	85.	89.	91.	93.	95.	97.	97.	103.	131.	119.
95.	85.	85.	87.	91.	93.	93.	97.	99.	99.	105.	133.	121.
97.	87.	87.	89.	93.	95.	95.	99.	101.	101.	107.	135.	123.
99.	89.	89.	91.	95.	97.	97.	101.	103.	103.	109.	137.	125.
101.	91.	91.	93.	97.	99.	99.	103.	103.	105.	111.	139.	127.
103.	93.	93.	95.	99.	99.	101.	105.	105.	107.	113.	141.	131.
105.	95.	95.	95.	101.	101.	103.	107.	107.	109.	115.	143.	131.
107.	97.	97.	97.	101.	103.	105.	109.	109.	111.	117.	145.	133.
109.	99.	99.	99.	101.	103.	107.	109.	111.	111.	119.	147.	135.
111.	101.	101.	101.	103.	105.	109.	111.	113.	113.	121.	149.	137.
113.	103.	103.	103.	105.	109.	111.	111.	115.	115.	123.	151.	139.
115.	105.	105.	105.	107.	111.	111.	113.	115.	115.	125.	153.	141.
117.	107.	107.	107.	109.	109.	113.	115.	117.	115.	127.	153.	143.
119.	109.	109.	109.	111.	111.	115.	115.	119.	115.	129.	153.	145.
121.	111.	111.	111.	113.	113.	117.	117.	119.	117.	131.	153.	147.
123.	113.	113.	113.	115.	115.	119.	119.	119.	119.	133.	153.	149.
125.	115.	115.	115.	117.	117.	121.	121.	121.	121.	135.	153.	151.
127.	117.	117.	117.	119.	119.	123.	123.	123.	123.	137.	153.	153.
129.	119.	119.	119.	121.	121.	125.	125.	125.	125.	139.	153.	153.
131.	121.	121.	121.	123.	123.	125.	127.	127.	127.	141.	153.	153.
133.	123.	123.	123.	125.	125.	125.	125.	127.	129.	143.	153.	145.
135.	125.	125.	125.	125.	125.	125.	131.	131.	131.	145.	147.	147.
137.	127.	127.	127.	125.	127.	127.	133.	133.	133.	147.	149.	149.
139.	125.	125.	125.	125.	125.	131.	133.	135.	135.	149.	151.	151.
141.	125.	125.	125.	131.	131.	131.	133.	137.	137.	151.	153.	153.
143.	125.	125.	127.	131.	133.	133.	139.	139.	139.	153.	153.	153.
145.	125.	131.	131.	131.	125.	135.	141.	141.	141.	153.	153.	153.
147.	125.	131.	133.	133.	127.	139.	141.	143.	143.	153.	153.	153.
149.	131.	131.	133.	139.	139.	139.	145.	145.	145.	145.	153.	153.
151.	131.	131.	131.	141.	131.	141.	147.	147.	147.	147.	153.	153.
153.	131.	133.	133.	139.	133.	145.	149.	149.	149.	149.	149.	153.

Table 2.6.3. (Cont.)

(g) July

Previous Inflow limits	4.001	6.371	8.802	11.431	14.444	17.989	22.483	28.019	34.578	45.814	59.784	97.299
	7.1880	8.5270	10.839	13.034	15.505	18.246	20.569	24.613	29.083	36.335	43.221	
Initial	End-of-Month Target Storage											
3.	3.	3.	3.	3.	3.	7.	13.	15.	21.	29.	29.	37.
5.	3.	3.	3.	3.	5.	9.	15.	17.	23.	31.	31.	39.
7.	3.	3.	3.	5.	7.	11.	17.	19.	25.	33.	33.	41.
9.	3.	3.	5.	7.	9.	13.	19.	21.	27.	33.	35.	41.
11.	3.	5.	7.	9.	11.	15.	21.	23.	29.	35.	37.	43.
13.	3.	7.	9.	11.	13.	17.	23.	25.	31.	37.	39.	45.
15.	3.	9.	9.	13.	15.	19.	25.	27.	33.	39.	41.	47.
17.	5.	9.	11.	15.	17.	21.	27.	29.	35.	41.	43.	49.
19.	7.	9.	13.	17.	19.	23.	29.	31.	37.	43.	45.	51.
21.	9.	11.	15.	19.	21.	25.	29.	33.	39.	45.	47.	55.
23.	11.	13.	17.	21.	23.	27.	29.	35.	41.	47.	53.	55.
25.	13.	15.	19.	23.	25.	29.	31.	37.	43.	49.	51.	57.
27.	15.	17.	21.	25.	27.	31.	33.	37.	45.	51.	53.	59.
29.	17.	19.	23.	27.	29.	33.	35.	39.	47.	53.	55.	61.
31.	19.	21.	25.	29.	31.	35.	41.	41.	49.	55.	57.	63.
33.	21.	23.	27.	31.	33.	37.	39.	43.	51.	57.	59.	63.
35.	23.	25.	29.	33.	35.	39.	41.	45.	53.	59.	61.	63.
37.	25.	27.	31.	35.	35.	37.	43.	47.	55.	61.	63.	63.
39.	27.	29.	33.	35.	37.	39.	45.	49.	55.	63.	63.	61.
41.	29.	31.	35.	37.	39.	41.	47.	51.	57.	65.	65.	63.
43.	31.	33.	37.	39.	41.	43.	49.	53.	59.	67.	67.	63.
45.	33.	35.	39.	41.	43.	45.	51.	55.	61.	69.	69.	63.
47.	35.	37.	41.	43.	45.	47.	53.	57.	63.	71.	71.	65.
49.	37.	39.	43.	45.	47.	49.	55.	59.	65.	73.	73.	67.
51.	39.	41.	45.	47.	49.	51.	57.	61.	67.	75.	75.	69.
53.	41.	43.	45.	49.	51.	53.	59.	63.	69.	77.	77.	71.
55.	43.	45.	47.	51.	53.	55.	61.	65.	71.	77.	79.	73.
57.	45.	47.	47.	53.	55.	57.	63.	67.	71.	73.	81.	75.
59.	47.	47.	49.	53.	57.	59.	65.	69.	73.	75.	83.	77.
61.	49.	49.	51.	55.	59.	61.	67.	69.	73.	77.	83.	79.
63.	51.	51.	53.	57.	61.	63.	67.	69.	75.	79.	83.	81.
65.	53.	53.	55.	59.	63.	65.	69.	71.	77.	81.	85.	83.
67.	55.	55.	57.	61.	65.	67.	71.	73.	79.	83.	87.	85.
69.	57.	57.	59.	63.	67.	69.	73.	75.	81.	85.	87.	87.
71.	59.	59.	61.	65.	69.	71.	75.	77.	83.	87.	89.	89.
73.	61.	61.	63.	67.	71.	73.	77.	79.	85.	87.	89.	89.
75.	63.	63.	65.	69.	73.	75.	79.	81.	87.	87.	91.	91.
77.	65.	65.	67.	71.	75.	77.	81.	83.	89.	89.	93.	93.
79.	67.	67.	69.	73.	77.	79.	83.	85.	89.	89.	95.	95.

Table 2.6.3. (Cont.)

(g) July

Previous Inflow limits	4.001 7.1880	6.371 8.5270	8.802 10.839	11.431 13.034	14.444 15.505	17.989 18.246	22.483 20.569	28.019 24.613	34.578 29.083	45.814 36.335	59.784 43.221	97.299
Initial	End-of-Month Target Storage											
3.	3.	3.	3.	3.	3.	7.	13.	15.	21.	29.	29.	37.
5.	3.	3.	3.	3.	5.	9.	15.	17.	23.	31.	31.	39.
7.	3.	3.	3.	5.	7.	11.	17.	19.	25.	33.	33.	41.
9.	3.	3.	5.	7.	9.	13.	19.	21.	27.	33.	35.	41.
11.	3.	5.	7.	9.	11.	15.	21.	23.	29.	35.	37.	43.
13.	3.	7.	9.	11.	13.	17.	23.	25.	31.	37.	39.	45.
15.	3.	9.	9.	13.	15.	19.	25.	27.	33.	39.	41.	47.
17.	5.	9.	11.	15.	17.	21.	27.	29.	35.	41.	43.	49.
19.	7.	9.	13.	17.	19.	23.	29.	31.	37.	43.	45.	51.
21.	9.	11.	15.	19.	21.	25.	29.	33.	39.	45.	47.	55.
23.	11.	13.	17.	21.	23.	27.	29.	35.	41.	47.	53.	55.
25.	13.	15.	19.	23.	25.	29.	31.	37.	43.	49.	51.	57.
27.	15.	17.	21.	25.	27.	31.	33.	37.	45.	51.	53.	59.
29.	17.	19.	23.	27.	29.	33.	35.	39.	47.	53.	55.	61.
31.	19.	21.	25.	29.	31.	35.	41.	41.	49.	55.	57.	63.
33.	21.	23.	27.	31.	33.	37.	39.	43.	51.	57.	59.	63.
35.	23.	25.	29.	33.	35.	39.	41.	45.	53.	59.	61.	63.
37.	25.	27.	31.	35.	35.	37.	43.	47.	55.	61.	63.	63.
39.	27.	29.	33.	35.	37.	39.	45.	49.	55.	63.	63.	61.
41.	29.	31.	35.	37.	39.	41.	47.	51.	57.	65.	65.	63.
43.	31.	33.	37.	39.	41.	43.	49.	53.	59.	67.	67.	63.
45.	33.	35.	39.	41.	43.	45.	51.	55.	61.	69.	69.	63.
47.	35.	37.	41.	43.	45.	47.	53.	57.	63.	71.	71.	65.
49.	37.	39.	43.	45.	47.	49.	55.	59.	65.	73.	73.	67.
51.	39.	41.	45.	47.	49.	51.	57.	61.	67.	75.	75.	69.
53.	41.	43.	45.	49.	51.	53.	59.	63.	69.	77.	77.	71.
55.	43.	45.	47.	51.	53.	55.	61.	65.	71.	77.	79.	73.
57.	45.	47.	47.	53.	55.	57.	63.	67.	71.	73.	81.	75.
59.	47.	47.	49.	53.	57.	59.	65.	69.	73.	75.	83.	77.
61.	49.	49.	51.	55.	59.	61.	67.	69.	73.	77.	83.	79.
63.	51.	51.	53.	57.	61.	63.	67.	69.	75.	79.	83.	81.
65.	53.	53.	55.	59.	63.	65.	69.	71.	77.	81.	85.	83.
67.	55.	55.	57.	61.	65.	67.	71.	73.	79.	83.	87.	85.
69.	57.	57.	59.	63.	67.	69.	73.	75.	81.	85.	87.	87.
71.	59.	59.	61.	65.	69.	71.	75.	77.	83.	87.	89.	89.
73.	61.	61.	63.	67.	71.	73.	77.	79.	85.	87.	89.	89.
75.	63.	63.	65.	69.	73.	75.	79.	81.	87.	87.	91.	91.
77.	65.	65.	67.	71.	75.	77.	81.	83.	89.	89.	93.	93.
79.	67.	67.	69.	73.	77.	79.	83.	85.	89.	89.	95.	95.

81.	69.	69.	71.	75.	79.	81.	85.	87.	91.	89.	97.	99.
83.	71.	71.	73.	77.	79.	83.	87.	89.	93.	89.	99.	99.
85.	73.	73.	75.	79.	81.	85.	89.	89.	95.	89.	101.	101.
87.	75.	75.	77.	81.	83.	87.	91.	91.	97.	87.	103.	103.
89.	77.	77.	79.	83.	85.	89.	89.	93.	99.	89.	105.	105.
91.	79.	79.	81.	85.	87.	89.	91.	95.	99.	91.	105.	107.
93.	81.	81.	83.	87.	89.	91.	93.	97.	99.	93.	109.	109.
95.	83.	83.	85.	89.	91.	93.	95.	99.	101.	95.	109.	111.
97.	85.	85.	87.	91.	93.	95.	97.	101.	103.	97.	109.	113.
99.	87.	87.	89.	93.	93.	97.	99.	103.	105.	99.	111.	113.
101.	89.	89.	89.	95.	95.	99.	101.	101.	105.	99.	111.	115.
103.	91.	91.	91.	97.	97.	101.	103.	103.	109.	101.	119.	119.
105.	93.	93.	93.	99.	99.	103.	103.	105.	105.	103.	119.	119.
107.	95.	95.	95.	101.	101.	105.	105.	107.	107.	105.	119.	121.
109.	97.	97.	97.	103.	103.	107.	109.	109.	109.	109.	109.	123.
111.	99.	99.	99.	105.	105.	109.	109.	111.	111.	109.	111.	123.
113.	101.	101.	101.	107.	107.	109.	111.	113.	113.	111.	113.	123.
115.	103.	103.	103.	109.	109.	111.	111.	113.	113.	113.	115.	129.
117.	105.	105.	105.	111.	111.	111.	113.	113.	113.	113.	113.	129.
119.	107.	107.	107.	113.	113.	113.	113.	119.	119.	113.	119.	129.
121.	109.	109.	109.	113.	113.	113.	115.	119.	109.	109.	121.	131.
123.	111.	111.	111.	113.	113.	113.	111.	119.	111.	111.	111.	133.
125.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	133.
127.	113.	113.	115.	115.	115.	115.	115.	115.	115.	115.	115.	133.
129.	113.	113.	115.	115.	115.	117.	117.	115.	115.	117.	129.	129.
131.	113.	119.	119.	119.	119.	119.	119.	119.	119.	119.	119.	131.
133.	119.	119.	119.	121.	113.	113.	113.	121.	121.	121.	121.	133.
135.	119.	119.	119.	123.	115.	115.	115.	123.	123.	123.	123.	133.
137.	119.	119.	121.	123.	117.	117.	115.	111.	111.	125.	125.	133.
139.	119.	119.	123.	119.	119.	113.	113.	113.	119.	119.	127.	133.
141.	121.	129.	129.	129.	121.	115.	115.	115.	121.	121.	129.	129.
143.	121.	129.	129.	129.	123.	115.	115.	115.	123.	123.	131.	131.
145.	123.	129.	129.	119.	119.	119.	119.	119.	119.	125.	133.	133.
147.	129.	129.	129.	121.	121.	113.	113.	121.	121.	125.	133.	133.
149.	129.	129.	129.	129.	123.	113.	113.	123.	123.	129.	129.	133.
151.	129.	129.	131.	131.	115.	115.	115.	123.	125.	131.	131.	133.
153.	129.	131.	133.	113.	113.	113.	119.	119.	127.	133.	133.	133.

Table 2.6.3. (Cont.)

(h) August

Previous Inflow	5.785	7.915	9.674	11.845	14.233	16.714	19.446	22.400	26.659	32.556	39.482	55.894
limits		9.3300	11.663	14.840	18.018	20.707	24.803	28.122	33.263	40.871	52.939	70.433
Initial	End-of-Month Target Storage											
3.	5.	11.	11.	17.	19.	25.	33.	31.	35.	45.	65.	65.
5.	5.	13.	13.	19.	21.	27.	35.	33.	37.	47.	67.	67.
7.	7.	15.	15.	21.	23.	29.	37.	33.	39.	49.	69.	69.
9.	9.	17.	17.	23.	25.	31.	37.	35.	41.	51.	71.	71.
11.	11.	19.	19.	25.	27.	33.	37.	37.	43.	51.	73.	77.
13.	13.	21.	21.	27.	29.	35.	39.	37.	45.	53.	75.	75.
15.	15.	23.	23.	29.	31.	35.	41.	39.	47.	55.	77.	77.
17.	17.	25.	25.	31.	33.	37.	43.	41.	49.	61.	77.	79.
19.	19.	27.	27.	33.	35.	39.	45.	43.	51.	59.	79.	81.
21.	21.	29.	29.	35.	37.	41.	47.	45.	55.	61.	81.	83.
23.	23.	31.	31.	37.	39.	43.	53.	47.	55.	63.	83.	85.
25.	25.	33.	33.	39.	41.	45.	51.	49.	57.	65.	85.	87.
27.	27.	35.	35.	41.	43.	47.	53.	51.	59.	67.	87.	89.
29.	29.	35.	37.	43.	45.	49.	53.	53.	61.	69.	89.	91.
31.	31.	35.	39.	45.	47.	51.	55.	55.	63.	71.	91.	93.
33.	33.	39.	41.	45.	47.	53.	57.	57.	65.	73.	93.	95.
35.	35.	37.	43.	45.	49.	55.	59.	59.	67.	75.	95.	97.
37.	37.	39.	45.	47.	51.	57.	61.	61.	69.	77.	97.	99.
39.	39.	41.	47.	49.	53.	59.	63.	63.	71.	79.	99.	99.
41.	41.	43.	49.	51.	55.	61.	65.	65.	73.	81.	101.	101.
43.	43.	45.	51.	53.	57.	63.	67.	67.	75.	83.	103.	103.
45.	45.	47.	53.	55.	59.	65.	69.	69.	77.	85.	105.	105.
47.	47.	49.	55.	55.	61.	67.	71.	71.	79.	87.	103.	105.
49.	49.	51.	57.	57.	63.	69.	73.	73.	81.	89.	105.	105.
51.	51.	53.	59.	59.	65.	71.	75.	75.	83.	91.	107.	105.
53.	53.	55.	61.	61.	67.	73.	77.	75.	85.	93.	109.	105.
55.	55.	57.	63.	63.	69.	73.	79.	75.	87.	93.	111.	109.
57.	57.	59.	65.	65.	71.	73.	81.	75.	89.	93.	113.	109.
59.	59.	61.	63.	67.	73.	75.	83.	75.	91.	95.	113.	111.
61.	61.	63.	65.	69.	75.	77.	85.	77.	91.	95.	113.	113.
63.	63.	65.	65.	71.	77.	79.	87.	79.	93.	95.	113.	113.
65.	65.	67.	67.	73.	79.	81.	89.	81.	95.	97.	113.	113.
67.	67.	67.	69.	75.	81.	83.	91.	83.	97.	99.	113.	113.
69.	69.	69.	71.	77.	83.	85.	93.	85.	99.	101.	113.	113.
71.	71.	71.	73.	79.	85.	87.	95.	87.	101.	103.	113.	113.
73.	73.	73.	75.	81.	87.	89.	97.	89.	103.	105.	113.	113.
75.	75.	75.	77.	83.	89.	91.	99.	91.	105.	105.	113.	113.
77.	77.	77.	79.	81.	91.	93.	101.	93.	107.	109.	113.	113.

79.	79.	79.	81.	83.	93.	95.	103.	95.	109.	109.	113.	113.
81.	81.	81.	83.	85.	95.	97.	105.	97.	111.	111.	113.	113.
83.	83.	83.	85.	85.	97.	99.	107.	99.	113.	113.	113.	113.
85.	85.	85.	87.	87.	99.	101.	109.	101.	113.	113.	113.	113.
87.	87.	87.	89.	89.	101.	103.	111.	103.	113.	113.	113.	113.
89.	89.	89.	91.	91.	103.	105.	113.	105.	113.	113.	113.	113.
91.	91.	91.	93.	93.	105.	105.	113.	107.	113.	113.	113.	113.
93.	93.	93.	95.	95.	107.	107.	113.	109.	113.	113.	113.	113.
95.	95.	95.	97.	97.	109.	109.	113.	111.	113.	113.	113.	113.
97.	97.	97.	99.	99.	109.	111.	113.	113.	113.	113.	113.	113.
99.	99.	99.	101.	101.	109.	113.	113.	113.	113.	113.	113.	113.
101.	101.	101.	103.	103.	111.	113.	113.	113.	113.	113.	113.	113.
103.	103.	103.	105.	105.	113.	113.	113.	113.	113.	113.	113.	113.
105.	105.	105.	107.	107.	113.	113.	113.	113.	113.	113.	113.	113.
107.	107.	107.	109.	109.	113.	113.	113.	113.	113.	113.	113.	113.
109.	109.	109.	111.	111.	113.	113.	113.	113.	113.	113.	113.	113.
111.	111.	111.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
115.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
117.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
119.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
121.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
123.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
125.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
127.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
129.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
131.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.
133.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.	113.

Table 2.6.3. (Cont.)

(i) September

Previous Inflow limits	7.763	10.646	13.213	16.576	19.307	22.898	26.456	30.446	36.775	46.200	60.206	111.410
	8.6950	10.170	12.308	14.603	16.851	19.401	22.768	27.162	32.440	44.292	58.197	
Initial	End-of-Month Target Storage											
3.	3.	5.	5.	9.	9.	15.	21.	17.	21.	27.	45.	43.
5.	3.	7.	7.	11.	11.	17.	23.	19.	23.	29.	47.	45.
7.	5.	9.	9.	13.	13.	19.	25.	21.	25.	29.	49.	47.
9.	7.	11.	11.	15.	15.	21.	25.	23.	27.	29.	51.	49.
11.	9.	13.	13.	15.	17.	23.	29.	23.	29.	29.	53.	51.
13.	11.	15.	15.	15.	19.	25.	29.	27.	31.	31.	55.	53.
15.	13.	17.	17.	17.	21.	27.	29.	29.	33.	33.	57.	55.
17.	15.	19.	19.	19.	23.	29.	31.	29.	35.	35.	57.	57.
19.	17.	21.	21.	21.	25.	31.	33.	31.	37.	37.	59.	59.
21.	19.	23.	23.	23.	27.	33.	35.	33.	39.	39.	55.	61.
23.	21.	25.	25.	25.	29.	35.	37.	35.	41.	41.	57.	63.
25.	23.	27.	27.	27.	31.	37.	39.	37.	41.	43.	57.	65.
27.	25.	29.	29.	29.	33.	37.	39.	39.	41.	47.	59.	67.
29.	27.	31.	31.	31.	35.	37.	43.	43.	43.	47.	61.	69.
31.	29.	33.	33.	33.	37.	41.	43.	43.	45.	49.	63.	71.
33.	31.	35.	35.	35.	39.	41.	45.	45.	47.	51.	65.	73.
35.	33.	37.	37.	37.	41.	43.	47.	47.	49.	53.	67.	75.
37.	35.	39.	39.	39.	43.	45.	49.	49.	51.	55.	69.	77.
39.	35.	41.	41.	41.	45.	47.	51.	51.	53.	57.	71.	77.
41.	37.	43.	43.	43.	47.	49.	53.	53.	55.	59.	73.	77.
43.	39.	45.	45.	45.	49.	51.	55.	55.	57.	61.	75.	77.
45.	41.	47.	47.	47.	51.	53.	57.	57.	59.	63.	77.	79.
47.	43.	49.	47.	49.	53.	53.	59.	59.	61.	65.	79.	79.
49.	45.	49.	49.	49.	55.	55.	61.	61.	61.	67.	81.	81.
51.	47.	51.	51.	51.	57.	57.	63.	63.	63.	69.	83.	83.
53.	49.	53.	53.	53.	59.	59.	65.	65.	65.	71.	85.	85.
55.	51.	55.	53.	55.	61.	61.	67.	67.	67.	73.	87.	87.
57.	53.	55.	55.	55.	63.	63.	69.	67.	69.	75.	89.	89.
59.	55.	57.	57.	57.	65.	65.	71.	67.	71.	77.	91.	91.
61.	57.	59.	59.	59.	67.	67.	73.	69.	73.	79.	93.	93.
63.	59.	61.	61.	61.	69.	69.	75.	71.	75.	81.	95.	95.
65.	61.	63.	63.	63.	69.	71.	77.	73.	77.	83.	97.	97.
67.	63.	65.	65.	65.	69.	73.	79.	75.	79.	85.	99.	99.
69.	65.	67.	67.	67.	71.	75.	81.	77.	81.	87.	101.	101.
71.	67.	69.	69.	69.	73.	77.	83.	79.	83.	89.	103.	103.
73.	69.	71.	71.	71.	75.	79.	85.	81.	85.	91.	105.	105.
75.	71.	73.	73.	73.	77.	81.	87.	83.	87.	93.	107.	107.
77.	73.	75.	75.	75.	79.	83.	89.	85.	89.	93.	109.	109.

79.	75.	77.	77.	77.	81.	85.	91.	87.	91.	95.	111.	111.
81.	77.	79.	79.	79.	83.	87.	93.	89.	93.	97.	113.	113.
83.	79.	81.	81.	81.	85.	89.	95.	91.	95.	99.	115.	115.
85.	81.	83.	83.	83.	87.	91.	97.	91.	97.	101.	117.	117.
87.	83.	85.	85.	85.	89.	93.	97.	93.	99.	101.	119.	119.
89.	85.	87.	87.	87.	91.	95.	99.	95.	101.	103.	121.	117.
91.	87.	89.	89.	89.	93.	97.	99.	97.	103.	105.	123.	119.
93.	89.	91.	91.	91.	95.	99.	101.	99.	105.	107.	125.	119.
95.	91.	93.	91.	93.	97.	101.	103.	101.	107.	109.	127.	121.
97.	93.	93.	93.	93.	99.	103.	105.	103.	109.	111.	129.	121.
99.	95.	95.	95.	95.	101.	105.	107.	105.	111.	113.	131.	121.
101.	97.	97.	97.	97.	103.	107.	109.	107.	113.	115.	133.	121.
103.	99.	99.	99.	99.	105.	109.	111.	109.	115.	117.	135.	121.
105.	101.	101.	101.	101.	107.	111.	113.	111.	117.	119.	137.	123.
107.	103.	103.	103.	103.	109.	113.	115.	113.	119.	121.	137.	125.
109.	105.	105.	105.	105.	109.	115.	117.	115.	121.	123.	137.	127.
111.	107.	107.	107.	107.	111.	117.	117.	117.	123.	123.	137.	129.
113.	109.	109.	109.	109.	113.	119.	119.	119.	125.	125.	137.	131.

Table 2.6.3. (Cont.)

(j) October

Previous Inflow	7.447	9.381	11.259	13.565	15.606	18.174	21.029	24.876	29.388	37.564	50.860	86.017
limits		9.3160	10.584	12.476	13.880	15.333	16.743	18.661	21.423	24.700	30.468	36.716
Initial	End-of-Month Target Storage											
3.	5.	9.	13.	13.	13.	17.	17.	21.	21.	25.	29.	35.
5.	7.	11.	15.	15.	15.	19.	19.	23.	23.	27.	31.	37.
7.	9.	13.	15.	17.	17.	21.	21.	25.	25.	29.	31.	39.
9.	11.	15.	15.	19.	19.	23.	23.	27.	25.	31.	31.	41.
11.	13.	17.	17.	21.	21.	25.	25.	29.	29.	33.	33.	43.
13.	15.	19.	19.	23.	23.	27.	27.	31.	31.	35.	35.	45.
15.	17.	21.	21.	25.	25.	29.	29.	33.	31.	37.	37.	47.
17.	19.	23.	23.	27.	27.	31.	31.	35.	33.	37.	39.	49.
19.	21.	25.	25.	29.	29.	33.	33.	35.	33.	39.	41.	51.
21.	23.	27.	27.	31.	31.	35.	35.	37.	35.	39.	43.	55.
23.	25.	29.	29.	33.	33.	37.	37.	37.	37.	41.	45.	55.
25.	27.	31.	31.	35.	35.	39.	39.	39.	39.	43.	49.	57.
27.	29.	33.	33.	35.	37.	41.	41.	41.	41.	47.	49.	59.
29.	31.	35.	35.	35.	39.	43.	43.	43.	43.	47.	51.	61.
31.	33.	37.	37.	41.	41.	45.	43.	45.	45.	49.	53.	63.
33.	35.	39.	39.	39.	43.	45.	45.	47.	47.	51.	55.	65.
35.	37.	39.	41.	41.	45.	47.	47.	49.	49.	53.	57.	67.
37.	39.	39.	43.	43.	47.	49.	49.	51.	51.	55.	59.	69.
39.	41.	41.	45.	45.	49.	51.	49.	53.	53.	57.	61.	71.
41.	43.	43.	47.	47.	51.	51.	51.	55.	55.	59.	59.	73.
43.	45.	45.	49.	49.	53.	53.	53.	57.	57.	61.	61.	75.
45.	47.	47.	51.	51.	55.	55.	55.	59.	59.	63.	63.	77.
47.	49.	49.	53.	53.	55.	57.	57.	61.	59.	65.	65.	79.
49.	51.	51.	55.	55.	55.	59.	59.	63.	61.	67.	67.	81.
51.	53.	53.	57.	57.	57.	61.	61.	65.	63.	69.	69.	81.
53.	55.	55.	59.	59.	59.	63.	63.	67.	65.	71.	71.	83.
55.	57.	57.	61.	61.	61.	65.	65.	69.	67.	73.	73.	83.
57.	59.	59.	63.	63.	63.	67.	67.	71.	67.	75.	75.	85.
59.	61.	61.	65.	65.	65.	69.	69.	73.	69.	77.	77.	87.
61.	63.	63.	67.	67.	67.	71.	71.	75.	71.	79.	79.	89.
63.	65.	65.	69.	69.	69.	73.	73.	77.	73.	81.	81.	91.
65.	67.	67.	71.	71.	71.	75.	75.	79.	75.	83.	83.	93.
67.	69.	69.	73.	73.	73.	77.	77.	81.	77.	85.	85.	95.
69.	71.	71.	75.	75.	75.	79.	79.	83.	79.	87.	87.	97.
71.	73.	73.	77.	77.	77.	81.	81.	85.	81.	89.	89.	97.
73.	75.	75.	79.	79.	79.	83.	83.	85.	83.	91.	91.	99.
75.	77.	77.	81.	81.	81.	85.	85.	87.	85.	93.	93.	101.
77.	79.	79.	81.	83.	81.	87.	87.	89.	87.	95.	95.	103.

79.	81.	81.	83.	85.	83.	89.	89.	91.	89.	97.	97.	105.
81.	83.	83.	83.	87.	83.	91.	91.	93.	91.	99.	99.	107.
83.	85.	85.	85.	89.	85.	93.	93.	95.	93.	101.	101.	109.
85.	87.	87.	87.	91.	87.	95.	95.	97.	95.	103.	103.	111.
87.	89.	89.	89.	93.	89.	97.	97.	99.	97.	105.	105.	113.
89.	91.	91.	91.	95.	91.	99.	99.	99.	99.	107.	107.	115.
91.	93.	93.	93.	97.	93.	101.	101.	101.	101.	109.	109.	117.
93.	95.	95.	95.	99.	95.	103.	103.	103.	103.	111.	111.	119.
95.	97.	97.	97.	101.	97.	105.	105.	105.	105.	113.	113.	121.
97.	99.	99.	99.	103.	99.	107.	107.	107.	107.	115.	115.	123.
99.	101.	101.	101.	105.	101.	109.	109.	109.	109.	117.	117.	125.
101.	103.	103.	103.	105.	103.	111.	111.	111.	111.	119.	119.	127.
103.	105.	105.	105.	107.	105.	113.	113.	113.	113.	121.	121.	129.
105.	107.	107.	107.	107.	107.	115.	115.	115.	115.	123.	123.	129.
107.	109.	109.	109.	109.	109.	117.	117.	117.	117.	123.	125.	131.
109.	111.	111.	111.	111.	111.	119.	119.	119.	119.	125.	127.	133.
111.	113.	113.	113.	113.	113.	119.	121.	121.	121.	127.	129.	135.
113.	115.	115.	115.	115.	115.	121.	123.	123.	123.	129.	131.	137.
115.	117.	117.	117.	117.	117.	123.	125.	125.	125.	131.	133.	137.
117.	119.	119.	119.	119.	119.	125.	127.	127.	127.	133.	135.	139.
119.	121.	121.	121.	121.	121.	127.	129.	129.	129.	135.	135.	141.
121.	123.	123.	123.	123.	123.	127.	131.	131.	131.	137.	137.	143.
123.	125.	125.	125.	125.	125.	129.	133.	133.	133.	139.	139.	145.
125.	127.	127.	127.	127.	127.	131.	133.	135.	135.	139.	141.	145.
127.	129.	129.	129.	129.	129.	133.	135.	137.	137.	141.	143.	147.
129.	131.	131.	131.	131.	131.	135.	137.	139.	139.	143.	145.	149.
131.	133.	133.	133.	133.	133.	137.	139.	141.	139.	145.	145.	151.
133.	135.	135.	135.	135.	135.	139.	141.	143.	141.	147.	147.	153.
135.	137.	137.	137.	137.	137.	141.	143.	145.	143.	149.	149.	153.
137.	139.	139.	139.	139.	139.	143.	145.	147.	145.	151.	151.	153.

Table 2.6.3. (Cont.)

(k) November

Previous Inflow limits	8.440	10.010	11.616	13.156	14.574	16.091	17.709	19.979	22.997	27.103	33.291	47.626
	10.583	11.960	13.877	15.537	17.015	18.908	20.906	23.011	26.161	32.444	36.521	
Initial	End-of-Month Target Storage											
3.	3.	7.	9.	9.	13.	13.	13.	13.	17.	21.	21.	25.
5.	5.	9.	11.	11.	13.	15.	15.	15.	19.	23.	23.	29.
7.	7.	11.	13.	13.	15.	17.	17.	17.	21.	25.	25.	29.
9.	7.	13.	15.	13.	17.	19.	19.	19.	23.	27.	29.	31.
11.	7.	15.	17.	15.	17.	21.	21.	21.	25.	29.	29.	33.
13.	9.	17.	17.	17.	19.	21.	23.	23.	27.	31.	31.	35.
15.	11.	19.	19.	19.	21.	23.	23.	25.	29.	33.	33.	37.
17.	13.	21.	21.	21.	23.	25.	25.	27.	31.	35.	35.	39.
19.	15.	23.	23.	23.	25.	27.	29.	29.	33.	37.	37.	41.
21.	17.	23.	25.	25.	27.	29.	29.	31.	35.	39.	39.	43.
23.	19.	25.	27.	27.	29.	31.	31.	33.	35.	41.	41.	43.
25.	21.	27.	29.	29.	31.	33.	33.	35.	37.	43.	43.	49.
27.	23.	29.	31.	31.	33.	35.	35.	37.	39.	45.	47.	47.
29.	25.	31.	33.	33.	35.	35.	35.	39.	43.	47.	47.	47.
31.	27.	33.	35.	35.	35.	37.	41.	41.	41.	47.	49.	49.
33.	29.	35.	37.	37.	39.	39.	39.	43.	43.	49.	49.	51.
35.	31.	37.	39.	39.	39.	41.	41.	45.	45.	51.	51.	53.
37.	33.	39.	41.	41.	41.	43.	43.	45.	47.	53.	53.	55.
39.	35.	39.	43.	43.	43.	45.	45.	47.	49.	55.	53.	57.
41.	37.	41.	45.	45.	45.	47.	45.	49.	51.	55.	55.	59.
43.	39.	43.	47.	45.	47.	49.	47.	51.	53.	57.	57.	61.
45.	41.	45.	49.	47.	49.	51.	49.	53.	55.	59.	59.	63.
47.	43.	47.	51.	49.	51.	51.	51.	55.	57.	61.	61.	65.
49.	45.	49.	53.	51.	53.	53.	53.	57.	59.	63.	63.	67.
51.	47.	51.	53.	53.	55.	55.	55.	59.	61.	65.	65.	69.
53.	49.	53.	55.	55.	55.	57.	57.	59.	63.	67.	67.	69.
55.	51.	55.	57.	57.	57.	59.	59.	61.	65.	69.	69.	71.
57.	53.	57.	59.	59.	59.	61.	61.	63.	67.	71.	67.	73.
59.	55.	59.	61.	59.	61.	63.	63.	65.	69.	73.	69.	73.
61.	57.	61.	63.	61.	63.	65.	65.	67.	71.	71.	71.	75.
63.	59.	63.	65.	63.	63.	67.	67.	69.	71.	73.	73.	77.
65.	61.	63.	67.	65.	65.	69.	69.	71.	73.	75.	75.	79.
67.	63.	63.	67.	67.	67.	71.	71.	73.	75.	77.	77.	81.
69.	65.	65.	69.	69.	69.	73.	73.	75.	77.	79.	79.	83.
71.	67.	67.	71.	71.	71.	75.	75.	77.	79.	81.	81.	85.
73.	69.	69.	73.	73.	73.	77.	77.	79.	81.	83.	83.	87.
75.	71.	71.	75.	75.	75.	79.	79.	81.	81.	85.	85.	89.
77.	73.	73.	77.	77.	77.	81.	81.	81.	83.	87.	87.	91.
79.	75.	75.	79.	79.	79.	83.	83.	83.	85.	89.	89.	93.

81.	77.	77.	81.	81.	81.	85.	85.	85.	87.	91.	91.	95.
83.	79.	79.	83.	83.	83.	87.	87.	87.	89.	93.	93.	97.
85.	81.	81.	85.	85.	83.	89.	89.	89.	91.	95.	95.	99.
87.	83.	83.	87.	87.	85.	91.	91.	91.	93.	97.	97.	97.
89.	85.	85.	89.	89.	87.	93.	91.	93.	95.	99.	99.	99.
91.	87.	87.	91.	91.	89.	95.	93.	95.	97.	101.	101.	101.
93.	89.	89.	93.	93.	89.	97.	95.	97.	99.	103.	103.	103.
95.	91.	91.	95.	95.	91.	99.	97.	99.	101.	105.	105.	105.
97.	93.	93.	97.	97.	93.	101.	99.	101.	103.	107.	107.	107.
99.	95.	95.	99.	99.	95.	103.	101.	103.	105.	109.	109.	109.
101.	97.	97.	101.	101.	97.	105.	103.	105.	107.	111.	111.	111.
103.	99.	99.	103.	103.	99.	107.	105.	107.	107.	113.	113.	113.
105.	101.	101.	105.	105.	101.	109.	107.	109.	109.	115.	115.	115.
107.	103.	103.	107.	107.	103.	111.	109.	111.	111.	117.	117.	117.
109.	105.	105.	109.	109.	105.	113.	111.	113.	113.	119.	119.	119.
111.	107.	107.	111.	111.	107.	115.	113.	115.	115.	121.	121.	121.
113.	109.	109.	113.	113.	109.	117.	115.	117.	117.	123.	123.	123.
115.	111.	111.	115.	115.	111.	119.	117.	119.	119.	125.	125.	125.
117.	113.	113.	117.	117.	113.	121.	119.	121.	121.	125.	127.	127.
119.	115.	115.	119.	119.	115.	123.	121.	123.	123.	127.	129.	129.
121.	117.	117.	121.	119.	117.	125.	121.	125.	125.	129.	131.	131.
123.	119.	119.	123.	121.	119.	127.	123.	127.	127.	131.	133.	133.
125.	121.	121.	123.	123.	121.	129.	125.	129.	129.	133.	135.	135.
127.	123.	123.	125.	123.	123.	131.	127.	131.	131.	135.	137.	137.
129.	125.	125.	125.	125.	125.	133.	129.	133.	133.	137.	139.	139.
131.	127.	127.	127.	127.	127.	135.	131.	135.	135.	139.	141.	141.
133.	129.	129.	129.	129.	129.	137.	133.	137.	137.	139.	143.	143.
135.	129.	131.	131.	131.	131.	139.	135.	139.	139.	141.	145.	145.
137.	131.	133.	133.	133.	133.	141.	137.	141.	141.	143.	147.	147.
139.	133.	135.	135.	135.	135.	143.	139.	143.	143.	145.	149.	149.
141.	135.	137.	137.	137.	137.	145.	141.	145.	145.	145.	151.	151.
143.	137.	139.	139.	139.	139.	145.	143.	147.	147.	147.	151.	153.
145.	139.	141.	141.	141.	141.	143.	145.	149.	149.	149.	153.	153.
147.	141.	143.	143.	143.	143.	145.	147.	149.	151.	151.	153.	153.
149.	143.	145.	145.	145.	145.	147.	149.	151.	153.	153.	153.	153.
151.	145.	147.	147.	147.	147.	147.	151.	153.	153.	153.	153.	153.
153.	147.	149.	149.	149.	149.	149.	153.	153.	153.	153.	153.	153.

Table 2.6.3. (Cont.)

(l) December

Previous Inflow limits	9.423	11.310	12.869	14.762	16.259	17.935	19.885	21.879	24.449	29.050	34.409	46.006
	6.5980	8.3080	11.245	13.809	16.002	18.742	22.079	26.356	32.026	42.556	50.928	
Initial	End-of-Month Target Storage											
3.	3.	5.	5.	11.	11.	13.	17.	17.	19.	17.	33.	53.
5.	5.	5.	7.	11.	13.	15.	19.	19.	21.	19.	35.	53.
7.	5.	7.	9.	11.	15.	17.	19.	21.	23.	21.	37.	53.
9.	5.	9.	11.	11.	17.	17.	19.	23.	25.	23.	39.	53.
11.	7.	11.	13.	13.	17.	19.	21.	25.	27.	25.	41.	53.
13.	9.	13.	15.	15.	17.	21.	23.	27.	29.	27.	43.	55.
15.	11.	13.	17.	17.	17.	23.	25.	29.	31.	29.	45.	65.
17.	13.	13.	19.	19.	19.	25.	27.	31.	33.	31.	45.	61.
19.	15.	15.	19.	21.	21.	27.	29.	33.	33.	33.	47.	59.
21.	17.	17.	21.	23.	23.	29.	31.	35.	35.	35.	55.	61.
23.	19.	19.	23.	25.	25.	31.	33.	35.	37.	37.	53.	63.
25.	19.	21.	25.	27.	27.	33.	35.	35.	39.	39.	49.	65.
27.	21.	23.	27.	29.	29.	35.	37.	37.	41.	41.	49.	67.
29.	23.	25.	29.	31.	31.	35.	39.	43.	43.	43.	51.	69.
31.	23.	27.	29.	33.	33.	35.	41.	41.	45.	45.	53.	71.
33.	23.	29.	29.	35.	35.	39.	41.	43.	45.	47.	55.	73.
35.	25.	31.	31.	37.	37.	37.	43.	45.	45.	49.	57.	75.
37.	27.	33.	35.	37.	39.	39.	45.	47.	47.	51.	59.	77.
39.	29.	35.	35.	39.	41.	41.	47.	49.	49.	53.	61.	79.
41.	31.	35.	37.	41.	43.	43.	49.	51.	51.	55.	63.	81.
43.	33.	37.	39.	43.	45.	45.	51.	53.	53.	57.	65.	83.
45.	35.	39.	41.	45.	47.	47.	53.	55.	55.	59.	67.	85.
47.	37.	41.	43.	47.	47.	49.	55.	57.	57.	61.	69.	87.
49.	39.	43.	45.	49.	49.	51.	57.	57.	59.	63.	71.	89.
51.	41.	43.	47.	51.	51.	53.	59.	59.	61.	63.	73.	91.
53.	43.	43.	47.	53.	53.	55.	61.	61.	63.	65.	73.	93.
55.	45.	45.	49.	55.	55.	57.	63.	63.	65.	67.	75.	95.
57.	47.	47.	51.	57.	57.	59.	65.	65.	67.	69.	77.	97.
59.	47.	49.	53.	59.	59.	61.	67.	67.	69.	71.	79.	99.
61.	49.	51.	55.	59.	61.	63.	69.	69.	71.	73.	81.	101.
63.	51.	53.	57.	59.	63.	65.	71.	71.	71.	75.	83.	103.
65.	53.	55.	59.	61.	65.	67.	73.	73.	73.	77.	83.	105.
67.	55.	57.	59.	63.	67.	69.	75.	75.	75.	79.	83.	107.
69.	57.	59.	59.	65.	69.	71.	77.	77.	77.	81.	85.	109.
71.	59.	61.	61.	67.	71.	71.	79.	79.	79.	83.	87.	111.
73.	61.	63.	63.	69.	73.	73.	81.	81.	81.	85.	89.	113.
75.	63.	65.	65.	71.	75.	75.	83.	83.	83.	87.	91.	115.
77.	65.	67.	67.	73.	77.	77.	83.	85.	85.	89.	93.	117.
79.	67.	69.	69.	75.	79.	79.	85.	87.	87.	91.	95.	119.

81.	69.	69.	71.	77.	81.	81.	87.	89.	89.	93.	97.	121.
83.	71.	71.	73.	79.	83.	83.	89.	91.	91.	95.	99.	123.
85.	73.	73.	75.	81.	85.	85.	89.	93.	93.	97.	101.	125.
87.	75.	75.	77.	83.	87.	87.	89.	95.	95.	99.	103.	127.
89.	77.	77.	79.	85.	89.	89.	91.	97.	97.	101.	105.	129.
91.	79.	79.	81.	87.	91.	91.	93.	99.	99.	103.	107.	131.
93.	81.	81.	83.	89.	93.	93.	95.	101.	101.	105.	109.	133.
95.	83.	83.	85.	91.	95.	95.	97.	103.	103.	107.	111.	135.
97.	85.	85.	87.	93.	97.	97.	99.	105.	105.	109.	113.	137.
99.	87.	87.	89.	95.	99.	99.	101.	107.	107.	111.	115.	139.
101.	89.	89.	91.	97.	101.	101.	103.	109.	109.	113.	117.	141.
103.	91.	91.	91.	99.	103.	103.	105.	111.	111.	115.	119.	143.
105.	93.	93.	93.	101.	105.	105.	107.	113.	113.	117.	119.	145.
107.	95.	95.	95.	103.	105.	107.	109.	115.	115.	119.	121.	145.
109.	97.	97.	97.	105.	105.	109.	111.	117.	117.	119.	123.	147.
111.	99.	99.	99.	107.	107.	111.	113.	119.	119.	121.	125.	149.
113.	101.	101.	101.	109.	109.	113.	115.	121.	121.	123.	127.	151.
115.	103.	103.	103.	111.	111.	115.	117.	123.	123.	125.	129.	153.
117.	105.	105.	105.	111.	113.	117.	119.	125.	125.	127.	131.	153.
119.	107.	107.	107.	113.	115.	119.	121.	125.	127.	129.	133.	153.
121.	109.	109.	109.	115.	117.	121.	123.	127.	129.	131.	135.	153.
123.	111.	111.	111.	117.	119.	123.	123.	129.	131.	133.	137.	153.
125.	113.	113.	113.	119.	121.	125.	125.	131.	133.	133.	139.	153.
127.	115.	115.	115.	121.	123.	127.	127.	133.	135.	135.	141.	153.
129.	117.	117.	117.	123.	125.	129.	129.	133.	137.	137.	143.	153.
131.	119.	119.	119.	125.	127.	131.	131.	133.	139.	139.	145.	153.
133.	121.	121.	121.	127.	129.	133.	133.	135.	141.	141.	147.	153.
135.	123.	123.	123.	129.	131.	135.	135.	137.	143.	143.	149.	153.
137.	125.	125.	125.	131.	133.	137.	137.	139.	143.	145.	151.	153.
139.	127.	127.	127.	133.	135.	139.	139.	141.	145.	147.	153.	153.
141.	129.	129.	129.	135.	137.	141.	141.	143.	145.	147.	153.	153.
143.	131.	131.	131.	137.	139.	143.	143.	145.	145.	151.	153.	153.
145.	133.	133.	133.	139.	141.	145.	145.	147.	147.	151.	153.	153.
147.	135.	135.	135.	141.	143.	147.	147.	149.	149.	151.	153.	153.
149.	137.	137.	137.	143.	145.	149.	149.	151.	151.	151.	153.	153.
151.	139.	139.	139.	145.	145.	151.	151.	151.	151.	151.	153.	153.
153.	141.	141.	141.	147.	147.	151.	153.	153.	153.	151.	153.	153.

2.7 References

Doorenbos, J. and W. O. Pruitt, Crop Water Requirements, Irrigation and Drainage paper No. 24, FAO, Rome, 1975.

Hargreaves, G. H., World Water for Agriculture, Utah State University, January 1977.

Hydrologic Engineering Center, "Simulation of Flood Control and Conservation Systems: HEC 5 User's Manual," U.S. Army Corps of Engineers, Davis, California, 1979.

Kincaid, D. C. and D. F. Heerman, "Scheduling Irrigtions Using a Programmable Calculator," Agricultural Research Service, ARS-NC-12, U.S. Department of Agriculture, Fort Collins, Colorado, 1974.

Labadie, J., ed., "Application of Dynamic Programming to Water Resources Management," Notes for Short Course, Colorado State University, Fort Collins, Colorado, 1980.

Lenton, R. and K. M. Strzepeck, "Theoretical and Practical Characteristics of the MIT River Basin Simulation Model," Ralph M. Parsons Laboratory, Report No. 225, Massachusetts Institute of Technology, Cambridge, Massachusetts, August 1977.

Reyna E. and M. Paulet, Requerimientos de Agua para agricultura segun el clima de la Republica Dominicana, Secretaria de Estado de Agricultura, Dominican Republic, 1979.

Restrepo J. I. and H. J. Morel-Seytoux, Subroutine Rain, Department of Civil Engineering, Colorado State University, Fort Collins, Colorado 80523, June 1985.

Secretaria de Estado de Agricultura, Exigencias ecologicas de las plantas cultivadas y algunas con potencial economico para la Republica Dominicana, SEA, Dominican Republic, 1980.

Sheer, D. P. and D. D. Meredith, "Improve Operation of Build New Projects," Journal of Water Resources Planning and Management, ASCE, Vol. 110, No. 3, pp. 351-355, July 1984.

U.S. Army Corps of Engineers, "Program Description and User Manual for SSARR Model - Streamflow Synthesis and Reservoir Regulation," North Pacific Division, Program 724-KS-G0010, September 1972.

Yakowitz, S., "Dynamic Programming Applications in Water Resources," Water Resources Research, Vol. 18, No. 4, pp. 673-696, August 1982.

APPENDIX 2.A:

PROGRAM CSUDP OPERATING MANUAL

Manual De Operacion del programa CSUDP

****

CSUDP

PROGRAMA DE PROGRAMACION DINAMICA DE PROPOSITOS MULTIPLES

****

CODIFICADO POR J.W. LABADIE, J.M. SHAFER Y D.G. FONTANE

DEPARTAMENTO DE INGENIERIA CIVIL, UNIVERSIDAD DEL ESTADO DE COLORADO.

****

DESCRIPCION DEL PROGRAMA

****

El programa CSUDP resuelve los siguientes problemas de programacion dinamica:

1. uni y multidimensionales
2. hacia atras y hacia adelante
3. deterministicos y estocasticos
4. con ecuacion de estado invertible y no invertible

Si el problema es multidimensional solo es permitido formulaciones invertibles y deterministicas. Programacion dinamica incremental (o diferencial discreta) es usada en este caso. Sin embargo, CSUDP puede resolver ambos casos unidimensionales no invertibles e invertibles deterministicas o estocasticas. Problemas con funciones objetivo y/o ecuaciones de estado analiticas y/o tabulares tambien pueden ser resueltos.

Para solucionar un problema de programacion dinamica hacia adelante el usuario debe formular el problema de tal forma que la etapa se refiera al numero de etapas "remanentes" hasta el final del analisis. Por ejemplo, supongamos que tenemos un problema de programacion dinamica de cuatro etapas.. Para resolverlo debe ser formulado de tal forma que la primera etapa es definida como la cuarta; esto es, existen cuatro etapas remanentes al final del problema. La segunda etapa es definida como etapa 3, la tercera como la segunda y la final como la primera. Luego el usuario formula su ecuacion de estado e ingresa los limites variables y los datos de acuerdo a la nomenclatura de la nueva etapa.

Pueden ser resueltas las siguientes funciones objetivo:

* tipo 1 * MIN(o MAX) F(X), U(1), X(2)+ ... + F(N), U(N), X(N+1)

* tipo 2 * MIN(MAX(F(1), U(1), X(2),...,F(X(N), U(N), x(N+!))) o,

MAX(MIN(...))

* tipo 3 * MIN (o MAX) F(X(1), U(1), X(2)*...*F(X(N), U(N), X(N+1))

Sujeto a:

X(I+1) = G(X(I), U(I), X(I+1))

XMIN . LE . X(I) . LE . XMAX(I) (para I=1,...,N+1)

UMIN . LE . U(I) . LE . UMAX(I) (pata i=1,...,N)

Restricciones pueden ser incluidas indirectamente via terminos penalizadores en la funcion objetivo (sera explicado a posteriori).

Fije JTYPE = 1 para la solucion del problema tipo 1.

Fije JTYPE = 2 para la solucion del problema tipo 2.

Fije JTYPE = 3 para la solucion del problema tipo 3. (para todos F(I) .GT. 0)

Use INDEX = 1 para un problema de minimizacion

Use INDEX = 2 para un problema de maximizacion

N = numero de etapas.

ND = numero de variables de estado X(I) para la etapa I (dimension del problema). La maxima dimension es igual a 5 para este programa.

MD = numero de variables de decision U(I) para la etapa I. No puede exceder de ND.

Usar JTIE = 0 para retener el primer valor empatado para problemas sin un minimo (o maximo) para cada etapa.

Usar JTIE = 1 para retener el ultimo valor.

DELX = discretizacion del intervalo para el vector de estado X(I). El ususario debe buscar una escala para los componentes de X(I) de tal forma que el mismo DELX puede ser usado para todos los componentes. DELX no varia con las etapas.

** PRECAUCION ** Seleccione DELX cuidadosamente. Si es muy pequeño el tiempo de computadora puede ser excesivo. Si es muy grande se puede no encontrar el optimo.

DELU = intervalo de discretizacion para la variable de control U(I).

Una opcion divisoria es incluida en este programa la cual es permitada en el DELX y DELU para problemas deterministicos y solo para DELX en problemas estocasticos invertibles con probabilidades independientes. Se define opcion divisoria a la sucesiva reduccion en DELX para obtener una mayor precision. Es una buena idea empezar con un DELX grosero y usar esta opcion sucesivamente hasta reducirla.

Si ISPL = 0 no ocurre division alguna

Si ISPL = 1 ocurre division en DELX

Si ISPL = 2 ocurre division en DELU

NOTA: si ISPL = 2 no habra ahorro de memoria en el computador y el tiempo de uso se incrementara. es mejor usar la opcion 1 y fijar DELU de acuerdo al grado final de precision.

DELXI = DELX inicial

DELXF = DELX final

DELUI = DELU inicial

DELUF = DELU final

SPLICE = cantidad .GE. 1.0 por medio del cual DELX(o DELU) es reducido para cada iteracion sucesiva (DELX nuevo = DELX viejo/ SPLICE)

** NOTA ** si la funcion objetivo y/o restricciones es usada en forma de data tabular, DELXF debe ser igual a DELI.

XMULT = ancho del corredor en terminos de XMULT*DELX(o DELU) por encima y por debajo de X^*(o U^*) solamente para problemas unidimensionales. Para problemas multidimensionales XMULT es automaticamente fijado igual a 1.0

Fije INVERT = 0 si no es posible invertir la(s) funcion(es) G y expresar U(I) como una funcion explicita de X(I) y X(I+1). Esto tambien es aplicable si la data tabular con respecto a U(I) es usada en la ecuacion de estado y/o la funcion objetivo.

Fije INVERT = 1 si la funcion G es invertible.

** PRECAUCION ** Si la dimension (ND) es mayor que 1, el problema debe estar en la forma invertible.

Fije TOL = error de truncacion permitido entre X(I+1) y la funcion G. Es usado para problemas unidimensionales no invertibles. Si no nos preocupa el error de truncacion haga TOL =

0.5*DELX, de lo contrario haga TOL igual al valor deseado .LT. 0.5*DELX. El programa puede tener dificultad en encontrar la solucion optima si es considerado un valor de TOL muy bajo.

Fije ISTOCH =1 si es un problema estocastico y es ingresado variables aleatorias. De lo contrario haga ISTOCH = 0. Si ISTOCH = 1, IPRINT automaticamente se convierte en 2 ya que no es posible la busqueda hacia atras de las variables de decision optimas.

Fije RISKLO = nivel de riesgo ingresado por el usuario el cual esta asociado con la violacion de XMIN(i+1), I=1,...,N para problemas estocasticos.

Fije RISKHI = nivel de riesgo ingresado por el usuario el cual esta asociado con la violacion de XMAX(i+1), I=1,...,N para problemas estocasticos.

** NOTA ** En este programa, dada una determinada politica de decision, el riesgo se acumula con cada violacion de XMIN(I+1) y/o XMAX(I+1), ya que RIESGO = RIESGO + NIVEL DE PROBABILIDAD ASOCIADO A LA VARIABLE ALEATORIA (R). Cuando el riesgo es igual o excede los limites especificados (RISKLO y/o RISKHI) la politica correspondiente es declarada no factible. El valor alternativo (default) de RISKLO y RISKHI es cero. Si el problema es invertible, RISKLO y RISKHI con UMIN(I) y UMAX(I) aunque nuestra mayor preocupacion es la factibilidad de la variable aleatoria X(I+1). Note en la ecuacion de estado que un incremento de U redunda en un decremento de X(I+1), entonces el riesgo indirectamente representa el riesgo de violar XMAX(I+1) y viceversa para RISKHI. Por otro lado, si un incremento de U implica tambien un incremento de X(I+1) en la ecuacion de estado, el nivel del riesgo corresponde al caso no invertible. RISKLO y RISKHI son ingresados en fracciones.

Fije NTRANS = numero de matrices de transicion a ser ingresadas. Las filas corresponden a los valores de las variables aleatorias en la etapa I, las columnas a los valores de las variables aleatorias en la etapa I-1.

NTRANS = 0 si son usadas probabilidades independientes

NTRANS = 1 si el analisis es deterministico

Fije IPRINT = 1 para obtener solamente la solucion final

IPRINT = 2 para las politicas optimas completas para cada etapa y estado.

IPRINT = 3 para ambos casos arriba mencionados.

** NOTA ** si ND .GT. 1, la opcion IPRINT = 3 no es valida.

A pesar que para la mayoria de los problemas es suficiente con usar los valores alternativos de las tolerancias, es mejor especificarlos.

Fijar ITSET = 0 si son usados los valores alternativos

ITSET = 1 el usuario ingresa las tolerancias

TOL1 = numero grande que castiga la no factibilidad y fuerza al programa a tomar una solucion factible. El valor alternativo es 1.0E31.

TOL2 = 0.1*TOL1. Valor absoluto de la funcion objetivo total, mas otros terminos de penalizacion añadidos por el ususario. No debe exceder de TOL1.

FSTART = valor de funcion objetivo en la etapa N+1, FMIN(N+1).

ITMAX = numero maximo de iteraciones permitidas si el problema es multidimensional.

Para problemas con valores iniciales donde X(I)=C(dado), haga XMIN(1)=XMAX(1)=C. De lo contario, seran calculadas las soluciones optimas para todos los valores discretos X(I) entre XMIN(1) y XMAX(1). Para problemas con valores finales haga XMIN(N+1)=XMAX(N+1)=C(dado).

** PRECAUCION ** cuando se ejecutan problemas no invertibles que son de valores finales, debe incluirse algun valor adicional en XMIN(N+1) y XMAX(N+1) porque el programa puede no exactamente hallar el estado final debido a errores de redondeo y, por lo tanto, no ser capaz de encontrar una solucion factible.

Este programa esta dimensionado para un maximo de 100 etapas y 100 discretizaciones de la variable de estado X(I) en caso de problemas unidimensionales. Para casos de variables aleatorias esta dimensionado para un maximo de 15 intervalos.

** SUBRUTINA STATE (FORMULADA POR EL USUSARIO) **

El proposito de esta subrutina es de formular la(s) ecuacion(es) de estado X(I+1)=G(X(I),U(I),X(I+1)), donde:

I = etapa actual

J = valor del vector entero actual usado en la data tabular (JD=1,ND) de los valores discretos X(I,JD). Por ejemplo, J=1 corresponde a un XMIN(I,JD); J=2 corresponde a un XMIN(I,JD)+DELX, etc.

K = valor del vector entero actual usado en la data tabular (JD=1,ND) de los valores discretos X(I+1,JD). Por ejemplo, K=1 corresponde a un XMIN(I+1,JD); K=2 corresponde a un XMIN(I+1,JD)+DELX, etc.

L = valor del vector entero actual usado en la data tabular (LD=1,MD) de los valores discretos X(I,LD). Por ejemplo, L=1 corresponde a un UMIN(I,JD); L=2 corresponde a un UMIN(I,JD)+DELU, etc.

X = valor actual de X(I<JD), JD + 1, ND

X1 = valor actual de X(I+1,LD), LD = 1, MD

U = valor actual de U(I<LD), LD = 1, MD

Si INVERT = 0, entonces...

INPUT = i,j,x,l y U

OUTPUT = X1

Si INVERT = 1, entonces...

INPUT = I,J,K,X y X1

OUTPUT = U

** NOTA ** para los problemas de porgramacion dinamica hacia adelante, la etapa es definida como el numero de etapas remanentes:

$$I = N - II + 1$$

donde II es la etapa actual. Entonces el estado de entrada es ahora X(I+1) y el estado de salida es X(I). La ecuacion de estado de PD hacia adelante tiene la siguiente forma:

$$X(I) = G(X(I+1),U(I),X(I))$$

** SUBRUTINA OBJECT (FORMULADA POR EL USUARIO) **

El proposito de esta subrutina es la de formular la funcion objetivo F(X(I), U(I), X(I+1)). Tambien estan disponibles valores discretos de J, K y L. F = valor actual de la funcion objetivo en la etapa I, el cual es el resultado de esta subrutina.

Esta subrutina es llamada inmediatamente despues de STATE si U (para problemas invertibles) o X1 (para no invertibles) son factibles. Estos valores pasan a traves de la subrutina OBJECT para el calculo de funcion objetivo.

** NOTA ** para problemas no invertibles, es ejecutada una interpolacion lineal simple en la funcion optima (si es requerida). En este caso el programa hace una busqueda hacia adelante a traves de las diversas etapas, llamando a la subrutina OBJECT en cada etapa y calculando el valor exacto de la funcion objetivo. Estos valores interpolados son printeados con motivos de chequeo.

** SUBRUTINA READIN (FORMULADA POR EL USUSARIO) **

Se usa si la data es leida etapa por etapa, recordando que el CSUDP resuelve el problema hacia atras. La data para la etapa final debe aparecer primero y asi sucesivamente, debiendo cada usuario especificar el formato respectivo. Estos datos leidos pueden ser pasados a traves de OBJECT y STATE por COMMON BLOCKS. Los datos leidos con la instruccion READ deben ser almacenados en algun arreglo (array) o vector para las siguientes situaciones:

(1) INVERT = 0

(2) ISPL =1

(3) ND .GT. 1

En este caso los arreglos o vectores deben ser funcion de la etapa I. Si no existiera data alguna se debera incluir de todas maneras esta subrutina sin instrucciones ejecutables:

```
SUBROUTINE READIN
RETURN
END
```

** NOTA ** si se necesita mas de una iteracion (si ND .GT. 1 o ISPL = 1) la subrutina READIN es automaticamente obviada (despues de haberse realizado un paso hacia atras a traves de las etapas) para prevenir ingreso repetitivo de data.

Note que el ingreso de I,J,K, y L en STATE y OBJECT permite el uso de data tabular. El usuario puede alternativamenmte usar la instruccion DATA en STATE y OBJECT evitando hacerlo en READIN.

** COMMON BLOCKS EN SUBRUTINAS STATE, OBJECT Y READIN (INSERTADOS POR EL USUARIO) **

** NOTA ** si la dimension (ND) es igual a 1 se usara:

COMMON / ONEDM / X,X1,U,F,I,J,K,L,R,PNALTY

y debera aparecer inmediatamente despues de la instruccion SUBROUTINE.

Si la dimension (ND) es mayor que 1, se usara:

COMMON / MULTDM / X(5),X1(5),U(5),F,I,J(5),K(5),L(5),PNALTY

y, como la anterior, debera estar despues de la instruccion SUBROUTINE.

Note que para problemas unidimensionales, cualquier variable aleatoria que aparece en STATE o OBJECT son ingresadas a traves de R via COMMON / ONEDM /.

Si existen algunas restricciones adicionales de la forma H(X(I),U(I),X(I+1)) .LE. OR .EQ. OR .GE. 0.0 pueden ser indirectamente consideradas a traves de un termino penalizador en OBJECT si uno o mas de ellos es violado. En este caso es definido como PNALTY, el cual es automaticamente transferido al programa principal a traves de COMMON / ONEDM / (problemas unidimensionales) y COMMON / MULTDM / (porblemas multidimensionales). es eventualmente eliminado en el valor final de la funcion objetivo, peo es usado en la optimizacion al influir en la seleccion de las decisiones optimas.

****

ENTRADA DE DATOS EN EL PROGRAMA CSUDP

****

RECORD 1 : formato 8A10

TITLE : titulo de la corrida (no exceder de 80 caracteres)

RECORD 2 : formato 6I5

INDEX = 1 para problemas de minimizacion

-1 para problemas de maximizacion

JTYPE = 1 problemas tipo 1

2 problemas tipo 2

3 problemas tipo 3

N = numero de etapas

ND = dimension del vector de estado X(I) para la etapa I

MD = dimension del vector de decision U(I) para le etapa I

JTIE = 0 para retener el primer valor empatado

1 para retener el ultimo valor empatado

Si ND = 1 solo deberan ser incluidas los records 3A y 3B.

ND .GT. 1 solo el record 3C.

RECORD 3A : formato 6I5 (solo para problemas unidmensionales)

INVERT = 0 problemas no invertibles

1 problemas invertibles

ISTOCH = 1 problemas estocasticos

0 problemas no estocasticos

NTRANS = 0 probabilidades independientes

N probabilidades transicionales

NTRANS = numero de las matrices de transicion ha ser ingresadas.

Si NTRANS = 0 las probabilidades son independientes

ISPL = 0 no division

1 division en DELX

2 division en DELU

ITSET = 0 se usa el valor alternativo para las tolerancias y valores iniciales.

1 el usuario debera ingresar las tolerancias y el valor inicial para F(N+1)

IPRINT = 1 printea solo la solucion optima

2 printea la solucion optima de cada etapa y estado

3 realizada las dos anteriores opciones

RECORD 3B : formato 8F10.4 (solo para problemas unidimensionales)

Si ISPL = 0 (record 3A) ingrese en el record 3B lo siguiente:

DELX = discretizacion en los intervalos de X(I)

DELU = discretizacion en los intervalos para U(I)

TOL = error de truncacion permitido para problemas no invertibles.

RISKLO = nivel de riesgo para XMIN(I+1) (para problemas estocasticos).

RISKHI = nivel de riesgo para XMAX(I+1) (para problemas estocasticos).

ISPL = 1 ingrese el record 3B

DELXI = DELX inicial

DELXF = DELX final (precision final requerida)

DELU

TOL

SPLICE = cantidad de DELX que es dividido con fines de reduccion.

XMULT = ancho del corredor para X(I+1), XMULT*DELX por encima y por debajo de la trayectoria previa.

RISKLO = nivel de riesgo para XMIN(I+1) (para problemas estocasticos).

RISKHI = nivel de riesgo para XMAX(I+1) (para problemas estocasticos).

ISPL = 2 ingrese en el record 3B.

DELX

DELUI = DELU inicial.

DELUF = DELU final.

TOL

SPLICE = cantidad de DELU que es dividido con fines de reduccion.

XMULT = ancho del corredor para U(I), XMULT*DELU por encima y debajo de la trayectoria previa.

Vaya al record 4

RECORD 3C : formato 4F10.0, 2I5 (solo para problemas multidimensionales)

DELXI = intervalo de discretizacion inicial para X(I,JD)

DELXF = precision final requerida para X(I,JD)

DELU = orden de precision para la variable de control U(I,LD)

SPLICE = cantidad de DELX que es dividido con fines de reduccion si la trayectoria no varia.

ITMAX = maximo numero de iteraciones permitidas

IPRINT = 1 printea solamente la solucion optima

2 printea la solucion de cada iteracion

Ingrese secuencialmente los records 4 (NVX) y 5 por cada dimension de JD=1,ND. Estos son los limites de X(I+1). Luego, para cada dimension de LD= 1,MD ingrese los records 4 (NVU) y 6. Estos son los limites de U(I).

** LIMITES DE X **

RECORD 4 : formato I5

NVX = numero de veces que cambian los limites XMIN y XMAX desde la etapa 1 hasta N+1. Por ejemplo, si todos los limites de XMIN y XMAX son los mismos, NVX seria igual a 1, lo que se interpreta como los mismos limites XMIN y XMAX para cada etapa.

RECORD 5 : formato I5, 2F10.4

NX = etapa inicial para el grupo con limites en X(I).

XMN = limite inferior de X(I) al inicio de la etapa NX.

XMX = limite superior de X(I) al inicio de la etapa NX.

Existen un numero NVX de records en el grupo 5.

** LIMITES DE U **

GRUPO DE RECORDS 4 : formato I5, 2F10.4

NU = inIcio de la etapa para el grupo con limites en U(I).

UMN = limite inferior de U(I) al inicio de la etapa NU.

UMX = limite superior de U(I) al inicio de la etapa NU.

Existen un numero de NVU records en el grupo 6.

Si ND=1, continue con los grupos de records 7B, 8, 9 y 10 si es necesario. Si ND .GT. 1 el grupo de records 7A es el ultimo en ingresar.

GRUPO DE RECORDS 7B : formato 3F10.4

** NOTA ** omita este record si ITSET = 0 (record 3A).

TOL1 = numero grande; valor opcional (default) = 1.0E10.

TOL2 = 0.1*TOL1; valor opcional = 1.0E09.

FSTART = F(N+1); valor opcional (JTYPE = 1) = 0.0

(JTYPE = 2) = -1.0E10.

(JTYPE = 3) = INDEX

** NOTA ** ingrese el grupo de records siguientes si ISTOCH = 1 (record 3A), de lo contrario omitalo.

GRUPO DE RECORDS 8 : formato I10.

NP(I) = numero de valores de la variable aleatoria que deben ser ingresados en la etapa I.

MAX. = 15.

GRUPO DE RECORDS 9 : formato 8F10.4

R(I,J) = valores discretos aleatorios para la etapa I para J=1,NP(I).

GRUPO DE RECORDS 10 : formato 16F5.3

P(I,J) = probabilidades asociadas con los valores aleatorios discretos para la etapa I, para J= 1,NP(I).

** NOTA ** repita el grupo de records 8, 9 y 10 para cada etapa I, I=1, N.

Si son usadas las las matrices de transicion entre el grupo de records 8 y 9, como se ha mencionado arriba, pero le ingreso final seran las matrices NTRANS, P(J,K), donde K va de 1 al numero de entradas NP(I) para la etapa I; J va de 1 al numero de entradas NP(I-1) para la etapa I-1. La data es leida fila por fila.

****

Nota: Ejemplos ilustrativos de datos de entrada y salidas del programa CSUDP son mostrados en la seccion 2.4.1.

APPENDIX 2.B:

MODSIM MODEL OPERATING MANUAL AND EXAMPLES

Manual de Operacion del Modelo MODSIM

Introduccion

El programa de MODSIM esta codificado en FORTRAN 77. Tiene la capacidad de desarollar un archivo completo de data de entrada sin tener que conocer ninguna instruccion FORTRAN. Esta caracteristica del modelo permite al usuario ejecutar el programa en forma iterativa y conversacional. El programa crea un archivo para luego ser ejecutado. Requerimientos de Datos

1. Descripcion fisica del sistema a ser simulado.
2. Criterio operacional,
3. Parametros de control.
4. Descargas de avenidas semanales o mensuales.
5. Demandas semanales o mensuales, y
6. Evaporacion semanal o mensual.

Es creado un archivo llamado ADATA que contiene las descargas de entrada semanales o mensuales, las demandas y la evaporacion y otro denominado ORGNZ que tiene la morfologia de la red, el criterio de la operacion, y demas parametros fisicos del sistema. El programa tiene varios registros los cuales se listan a continuacion:

Registro #1 : Opciones de control (numeros enteros).

1. Resumen de los datos de entrada.
2. Uso de unidades inglesas o metricas.
3. Opcion para el uso de intervalos mensuales o semanales.
4. Almacenamiento del embalse y demandas basadas en las condiciones hidrologicas correspondientes.
5. Opcion del listado de graficos.

Registro # 2 Titulo de la actual simulacion (entrada alfanumerica)

Registro #3 Parametros morfologicos de la red (entradas enteras)

1. Numero de nudos (menores de 70; ingresar solo los reales)
2. Numero de conexiones (menores de 70; solo las reales)
3. Numero de embalses (menores de 25)
4. Numero de secciones en el rio.
5. Numero de nudos de demanda.
6. Numero de nudos vertedores.
7. Numero de nudos de importacion.
8. Numero de años (incrementos mensuales) o periodos de 12 semanas (menores de 20).
9. Primer año calendario de la simulacion.
10. Año final de salida.
11. Calculo de la produccion firme.

Registro #4 Nodos del sistema (los nodos de almacenamiento deben preceder a los de no-almacenamiento en orden consecutivo; todos enteros o alfanumericos).

1. Nombre del nodo de almacenamiento.
2. Numero del nodo de almacenamiento.
3. Volumen maximo de almacenamiento.
4. Volumen minimo de almacenamiento.
5. Almacenamiento inicial.
6. Nombre de los nudos de no-almacenamiento.

Registro #5 Embalses con vertedores en orden de preferencia (enteros)

Registro #6 Tablas de elevacion-area-volumen (hasta 18 puntos; tasa de infiltracion como una fracion del volumen promedio de almacenamiento durante la semana o mes (enteros).

Registro #7 Nodo de demanda.

1. Numero del nodo.
2. Nodo al cual se dirije la conexion de la demanda del flujo.
3. Demanda anual (puede ser entrada por el archivo ADATA).
4. Distribucion de la demanda en periodo de tiempo.
5. Infiltracion por agua subterranea.
6. Orden de preferencias relativo o factores de peso (valores del 1 al 99; valores bajos significan altas prioridades)

Registro #8 Nodos de Importacion

1. Numero del nodo.
2. Flujo de importacion en el periodo de tiempo.
3. Fracion de distribucion durante el periodo.

Registro #9 Calculo de estado hidrologicos (opcional)

1. Numero de reservorios en el sub-sistema.
2. Numero del nodo en la red.
3. Fraccion para el limite inferior promedio y limite promedio superior.

Registro # 10 factores de Conversion (opcional)

Registro # 11 Criterio de operacion de embalse

1. Prioridad relativa para cada año o trimestre.
2. Niveles de almacenamiento deseado.

Registro # 12 Configuracion del sistema

1. Numero de las conexiones de capacidad variable.

2. Numero de conexiones en la red.

3. Nodo de origen para cada conexion.

4. Nodo de llegada para cada conexion.

5. Capacidad maxima.

6. Capacidad minima .

7. Costo unitario en la conexion (opcional).

8. Perdida por conducion (fraccion del flujo promedio).

9. Para nodos de capacidad variable ingresar su distribucion mensual o semanal.

Registro # 13 (Todos enteros)

1. Embalses en los que se desea graficos de almacenamiento.

2. Conexiones en los que se desea graficos de flujos.

Resultados

El usuario tiene la opcion de obtener diferentes formas de salidas que incluyen:

1. Listado reducido de los datos de entrada de la configuracion y datos basicos.

2. Informe detallado a nivel mensual o semanal de los nodos y conexiones:

   a. Nodos de almacenamiento:

almacenamiento inicial	area superficial
flujo irregulares de entrada	perdidas en el sistema
descargas aguas arriba	agua bombeada a un nodo
demanda	agua bombeada desde un
escasez	nodo de almacenamiento
	(actual y deseado)
perdidas por evaporacion	

volumenes vertidos aguas abajo produccion de energia hidroelectrica

b. Nodos de demanda sin almacenamiento

c. Flujos en las conexiones.

3. Energia y potencia total producida para cada semana o mes.

EJEMPLOS DE USO DEL PROGRAMA MODSIM EN LA DISTRIBUCION DE FLUJOS DE AGUAS

Ejemplo 1

Consideremos la configuracion mostrada en la Figura 2.B.1 para un cierto mes o semana (las unidades son arbitrarias en este ejemplo). Recordando que

$$c_{iD} = -[1000 - DEMR_i \times 10]$$

Supongamos ahora que $DEMR_1 = 10$ y $DEMR_2 = 20$. Por lo tanto,

$$c_{1D} = -900$$

$$c_{2D} = -800$$

A pesar que el nodo 1 tiene un mayor costo negativo (beneficios) tiene una mayor prioridad que el nodo 2.

Asumiendo que el balance de masa satisface a todos los nodos artificiales y expresando las ecuaciones (2.B.1) a (2.B.4) para los nodos 1 y 2:

$$\min -900\, q_{1D} - 800\, q_{2D} \qquad (2.B.1)$$

sujeto a:

$3000 - q_{12} - q_{1D} = 0$: balance de masa para el nodo #1

(2.B.2)

$q_{12} + 1000 - q_{2D} = 0$: balance de masa para el nodo #2

(2.B.3)

$0 \leqslant q_{1D} \leqslant 2000$: restricciones de capacidad para conexion (1,D) (2.B.4)

$0 \leqslant q_{2D} \leqslant 3000$: restricciones de capacidad para

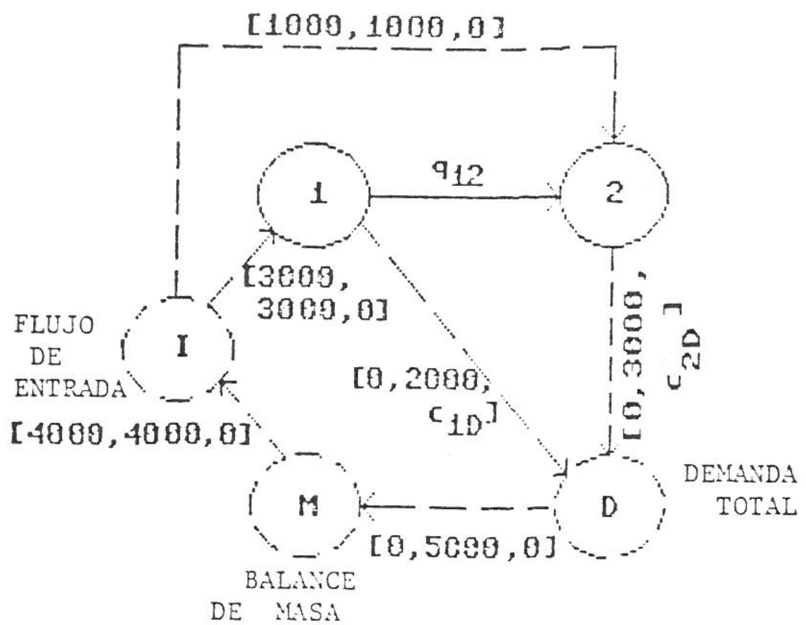


Figura 2.B.1 : Diagrama de nodos para el ejemplo 1.

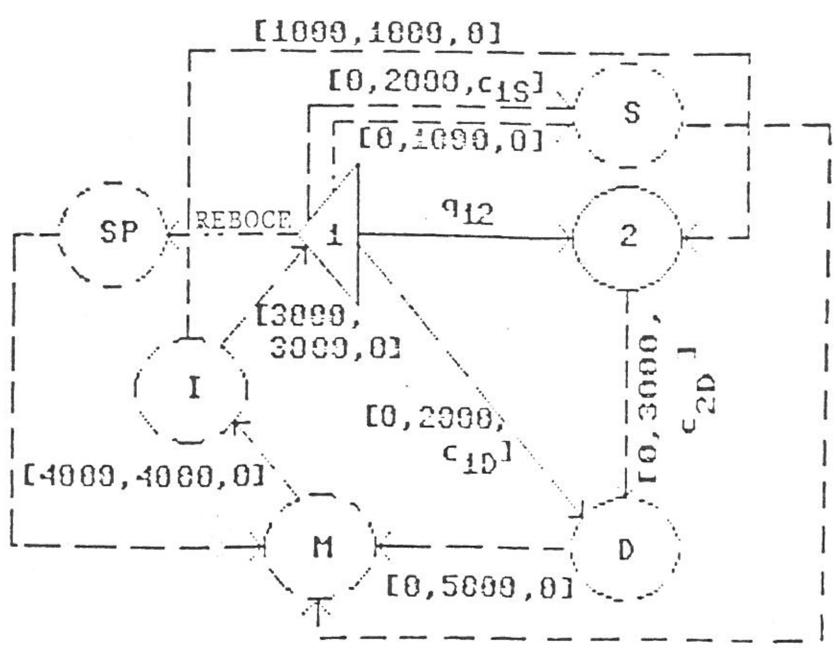


Figura 2.B.2 : Diagrama de nodos para el ejemplo 2.

la conexion (2,D) (2.B.5)

$0 \leqslant q_{12} \leqslant 4000$: restricciones de capacidad para la conexion (1,2) (2.B.6)

MODSIM resuelve este problema mediante el metodo de OUT-OF-KILTER, sin embargo, porque este metodo es algo complicado y el presente ejercicio es bastante simple, un procedimiento menos dificil podria ser usado dando la misma solucion que el mecionado

Note que:

$$q_{1D} = 3000 - q_{12} \qquad (2.B.7)$$

$$q_{2D} = 1000 + q_{12} \qquad (2.B.8)$$

Substuyendo en la funcion objetivo (2.B.1) se obtiene:

$$\min -99\ (3000-q_{12})-800(1000+q_{12}) \qquad (2.B.9)$$

o

$$\min 900\ q_{12} - 800\ q_{12} = 100\ q_{12} \qquad (2.B.10)$$

sujeto a

$$0 \leqslant (3000 - q_{12}) \leqslant 2000 \qquad (2.B.11)$$

$$0 \leqslant (1000 + q_{12}) \leqslant 3000 \qquad (2.B.12)$$

$$0 \leqslant q_{12} \leqslant 4000 \qquad (2.B.13)$$

que pueden combinarse en la expresion siguiente:

$$1000 \leqslant q_{12} \leqslant 2000 \qquad (2.B.14)$$

seleccionando el limite superior mas bajo y el limite inferior mas alto en las ecuaciones (2.B.4) a (2.B.10).

Ya que se desea minimizer $100q_{12}$, la respuesta es obviamente

$$q^*_{12} = 1000$$

Mediante el balance de masa, las descargas en las otras conexiones son

$$q^*_{1D} = 2000 \qquad q^*_{DM} = 4000$$

$$q^*_{2D} = 2000 \qquad q^*_{MI} = 4000$$

Entonces, el nodo 1 recibe completa dotacion, mientras el nodo 2 es disminuido en 1000.

Ahora supongamos que las prioridades son invertidas. Esto es

$$DEMR_1 = 20$$

$$DEMR = 10$$

Siguiendo el procedimiento anterior, la funcion objectivo es

$$\min -100\ q_{12}$$

sujeto a la restriccion (13). La repuesta es obviamente

$$q^*_{12} = 2000$$

con

$$q^*_{1D} = 1000 \qquad q^*_{DM} = 4000$$

$$q^*_{2D} = 3000 \qquad q^*_{MI} = 4000$$

<u>Ejemplo 2</u>

El siguiente ejemplo tiene un mayor grado de complejidad. Aqui, el nodo 1 es ahora considerado como de capacidad. Existe tambien una demanda directa para este nodo. Las perdidas en lo canales y por evaporacion no son consideradas. Notar que el volumen objetivo para el embalse 1 es 2000, pero el almacenamiento total es 3000. La conexion de descargas de entrada al embalse 1 es fijada en

[3000,3000,0]. Esto puede representar un flujo de entrada de 1000 y un volumen acumulado de 2000 del periodo anterior.

Ahora, se asume

$$DEMR_1 = 10$$

$$OPRP_1 = 20$$

$$DEMR_2 = 30$$

Notar que a la demanda del nodo 1 se le ha dado una mayor prioridad, seguido por la del embalse, y finalmente por la del nodo 2. Asumiendo la satisfaccion del balance de masa en todos los nodos artificiales, el ejercicio queda como sigue:

$$\min -900q_{1D} - 800q_{1S} - 700q_{2D}$$

sujeto a:

$$3000 - q_{12} - q_{1S} - q_{1D} = 0$$

$$q_{12} + 1000 - q_{2D} = 0$$

$$0 \leqslant q_{1D} \leqslant 2000$$

$$0 \leqslant q_{2D} \leqslant 3000$$

$$0 \leqslant q_{1S} \leqslant 2000$$

$$0 \leqslant q_{12} \leqslant 4000$$

Resolviendo para q_{1D} y q_{2D}:

$$q_{1D} = 3000 - q_{12} - q_{1S}$$

$$q_{2D} = 1000 + q_{12}$$

sustituyendo esto en la funcion objectivo:

$$\min - 900(3000 - q_{12} - q_{1S})$$
$$- 800q_{1S}$$
$$- 700(1000 + q_{12}).$$

o

$$\min 200q_{12} + 100q_{1S}$$

sujeto a:

$$0 \leqslant (3000 - q_{12} - q_{1S}) \leqslant 2000$$
$$0 \leqslant (1000 + q_{12}) \leqslant 3000$$
$$0 \leqslant q_{1S} \leqslant 2000$$
$$0 \leqslant q_{12} \leqslant 4000$$

Las unicas variables que subsisten son q_{12} y q_{1S}. Estas restricciones pueden ser escritas como:

$$q_{12} + q_{1S} \leqslant 3000$$
$$q_{12} + q_{1S} \geqslant 1000$$
$$q_{12} \leqslant 2000$$
$$q_{1S} \leqslant 2000$$
$$q_{12}, q_{1S} \geqslant 0$$

La region factible definida para los rangos de q_{12} y q_{1S} que satisfacen todas las restricciones arriba mencionadas son mostradas graficamente en la Figura 2.B.3.

La funcion objetivo es:

$$\min z = 200 q_{12} + 100 q_{1S}$$

o

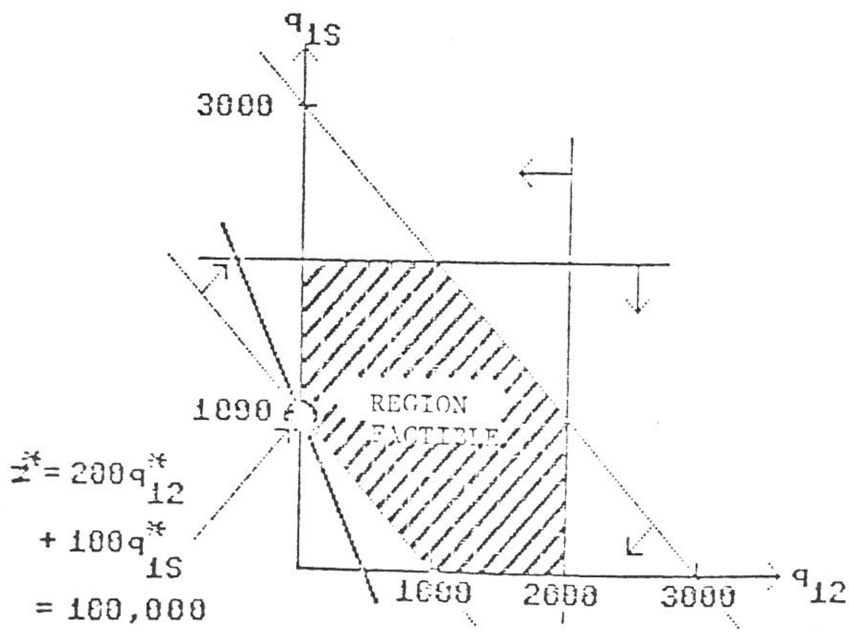


Figura 2.B.3 : Region factible de flujos para el ejemplo 2

$$q_{1S} = -\frac{200}{100} q_{12} + \frac{z}{100}$$

Para cualquier valor de z, la pendiente de la funcion objetivo es -2.

Optimizar el valor de z significa transladar una linea de pendiente -2 a la izquierda tan lejos como sea posible, pero teniendo al menos un punto factible en la linea. Este punto debe ser optimo,

$$q^*_{12} = 0 \qquad q^*_{1S} = 1000$$

para este ejemplo.

Mediante el balance de masa,

$$q^*_{1D} = 2000 \qquad q^*_{2D} = 1000$$

Por lo tanto, el nodo de demanda 1 recibe completa dotacion. Al final del periodo el volumen en el embalse 1 es deficitario en 1000 y no recibe flujo alguno la demanda del nodo 2. El volumen final de 1000 es añadido a las descargas de entrada del proximo periodo. Asi se continua para siguientes periodos simulacion. Intercambiando estas prioridades se obtendria, por supuesto, una diferente distribucion de flujos.

Comentarios Adicionales

Perdidas en los canales y evaporacion no han sido considerados en este ejemplo. Su inclusion significaria un ajuste en las condiciones de borde. Esto significa que la lineas en la Figura 2.B.3 deberian ser rearregladas de tal manera, que se obtendria una solucion differente.

Algunas variaciones seran ahora consideradas. Supongamos que $OPRP_1$ = 30 en vez de 20. Entonces

$$z = 200\, q_{12} + 200\, q_{1S}$$

la pendiente de la funcion objetivo del grafico mostrado es -1. Esto significa que

$$q^*_{12} = 0 \qquad q^*_{1S} = 1000$$

o

$$q^*_{12} = 1000 \qquad q^*_{1S} = 0$$

son optimos. MODSIM escoje uno de ellos arbitrariamente. Estos casos de igualdad son raros en ejercicios complejos, pero sirven para mostrar que es mejor asignar distintas prioridades y preferentemente no muy proximas entre ellas.